IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

SIONYX, LLC and PRESIDENT AND FELLOWS OF HARVARD COLLEGE	)	AMENDED COMPLAINT
Plaintiffs,	)	Civil Action No. 15-cv-13488-FDS
v.	)	**FILED UNDER SEAL**
HAMAMATSU PHOTONICS K.K. HAMAMATSU CORP., OCEAN OPTICS, INC., AND DOES 1 THROUGH 10	)	**JURY TRIAL DEMANDED**
Defendants.	)	

AMENDED COMPLAINT

Plaintiffs, SiOnyx, LLC ("SiOnyx") and President and Fellows of Harvard College ("Harvard"), by and through their counsel, Pepper Hamilton LLP, for its Amended Complaint against Defendants Hamamatsu Photonics K.K. and Hamamatsu Corp. (collectively, "Hamamatsu"), Ocean Optics, Inc. ("Ocean Optics"), and John Doe Defendants 1 through 10, inclusive, (collectively, "Defendants") allege as follows:

I. THE PARTIES

1. Plaintiff SiOnyx, LLC is a Delaware limited liability corporation with its principal place of business at 100 Cummings Center, Suite 243F Beverly, MA 01915.

2. Plaintiff President and Fellows of Harvard College is an educational institution and charitable corporation organized under the laws of the Commonwealth of Massachusetts with its principal place of business at Massachusetts Hall, Cambridge, MA 02138.

3. Upon information and belief, Defendant Hamamatsu Photonics K.K. is a Japanese company with its principal place of business at 325-6 Sunayama-cho, Naka-ku, Hamamatsu City, Shizuoka Pref., 430-8587, Japan.

4. Upon information and belief, Defendant Hamamatsu Corp. is a New Jersey corporation with its principal place of business at 360 Foothill Road, Bridgewater, NJ 08807.

5. Upon information and belief, Defendant Hamamatsu Corp. also has an office at 20 Park Plaza, Suite 312, Boston, MA 02116.

6. Upon information and belief, Defendant Ocean Optics, Inc. is a Florida corporation with its principal place of business at 830 Douglas Ave., Dunedin, FL 34698.

7. The names and capacities, whether individual, corporate, associate, or otherwise of John Doe Defendants 1 through 10 are unknown to Plaintiffs, who therefore sue using fictitious names. Plaintiffs will seek leave of this Court to amend this Complaint to include their proper names and capacities when they have been ascertained. Upon information and belief, the fictitiously named Defendants are customers of the Hamamatsu Defendants and thereby are liable for acts of infringement described in this Complaint and the damage resulting therefrom.

II. OTHER RELEVANT PERSONS

8. Stephen Saylor is an individual residing in Massachusetts. Mr. Saylor is the President and CEO of SiOnyx and has been employed by the company since 2006. Mr. Saylor's career spans over twenty years of working with emerging technology development and commercialization. Prior to joining SiOnyx as President and CEO, Mr. Saylor held a variety of technology management, marketing and engineering roles with Adobe, Apple, Polaroid, and Technicare Corporation. Mr. Saylor holds a bachelor of science in electrical engineering from Northeastern University.

9. Professor Eric Mazur is an individual residing in Massachusetts. Prof. Mazur is the Balkanski Professor of Physics and Applied Physics and is the Area Dean in Physics for the Harvard Jon A. Paulson School of Engineering and Applied Sciences. Prof. Mazur obtained his Ph.D. at the University of Leiden in the Netherlands in 1981 and began working at Harvard in 1982. Since 1984, he and his research group at Harvard have made important contributions to spectroscopy, light scattering, the interaction of ultra-short laser pulses with materials, and nanophotonics. Prof. Mazur co-founded SiOnyx in 2006 and is the chairman of its Scientific Advisory Board. Prof. Mazur is a named inventor on United States Patent Numbers 7,884,446 ("the '446 Patent") and 8,080,467 ("the '467 Patent"). Exs. 1-2. Prof. Mazur also is currently the Vice-President of The Optical Society ("OSA"). Founded in 1916, the OSA is the leading professional association in optics and photonics, home to accomplished science, engineering, and business leaders from all over the world.

10. Dr. Mengyan Shen is an individual residing in Massachusetts. Dr. Shen received his Ph.D. from the University of Science and Technology of China. Dr. Shen served as a visiting professor at Harvard from 2001-2006 and is currently a professor at the University of Massachusetts at Lowell. Dr. Shen is a named inventor on the '446 Patent. Ex. 1.

11. Dr. James Carey is an individual residing in Michigan. Dr. Carey is an expert in optical physics and the interaction of materials with ultrashort laser pulses. Dr. Carey played a key role in the discovery of the unique optoelectric properties of microstructured silicon, the study of which formed the basis for his Ph.D. in Applied Physics from Harvard, which he received in 2004. Dr. Carey has presented at numerous international conferences, is the author of more than twenty papers and conference proceedings, and a named inventor on twelve United States and international patents. In 2006, Dr. Carey co-founded SiOnyx with Prof. Mazur and

currently serves as SiOnyx's principal scientist. Dr. Carey is a named inventor on the '467 Patent. Ex. 2.

12. Upon information and belief, Dr. Homayoon Haddad is an individual residing in Oregon. SiOnyx employed Dr. Haddad as Vice President of Device Engineering from November of 2008 until May of 2014. Dr. Haddad is a named inventor on United States Patent No. 8,680,591 ("the '591 Patent"). Ex. 3.

13. Upon information and belief, Mr. Jutao Jiang is an individual residing in Oregon. SiOnyx employed Mr. Jiang as Senior Characterization Engineering from November of 2008 to present. He currently serves as SiOnyx's Test and Characterization Manager. Mr. Jiang is a named inventor on the '591 Patent. Ex. 3.

14. Upon information and belief, Mr. Jeffrey McKee is an individual residing in California. SiOnyx employed Mr. McKee as Principal Engineer/Program Manager for Advanced Modules from January of 2009 to May of 2014. Mr. McKee is a named inventor on the '591 Patent. Ex. 3.

15. Upon information and belief, Dr. Drake Miller is an individual residing in Oregon. SiOnyx employed Dr. Miller as a Device Engineer from March of 2009 until February of 2012. Dr. Miller is a named inventor on the '591 Patent. Ex. 3.

16. Upon information and belief, Dr. Leonard Forbes is an individual residing in Oregon. SiOnyx employed Dr. Forbes as a consultant from January 2009 to November of 2009. Dr. Forbes is a named inventor on the '591 Patent. Ex. 3.

17. Upon information and belief, Dr. Chintamani Palsule is an individual residing in India. Dr. Palsule is currently employed by SiOnyx as a Foundry Program Manager. He was hired in December of 2008. Dr. Palsule is a named inventor on the '591 Patent. Ex. 3.

18. Harvard owns the ’446 Patent and the ’467 Patent by virtue of assignments from the inventors, which patents collectively are referred to herein as the “Harvard Patents.” Harvard exclusively licensed the Harvard Patents to SiOnyx in February 2006. Exs. 4 & 4A.

19. SiOnyx owns the ’591 Patent by virtue of assignments from the inventors, which is referred to herein as the “SiOnyx Patent.” Ex. 3. The Harvard and SiOnyx Patents may be collectively referred to herein as “the Asserted Patents.”

20. Upon information and belief, Akira Sakamoto is an individual residing in Japan. Upon further information and belief, Mr. Sakamoto was employed in the Product Development Department at Hamamatsu Photonics K.K. at least in 2007. Mr. Sakamoto is a named inventor on United States Patent Numbers 8,564,087 (“the ’087 Patent”), 8,742,528 (“the ’528 Patent”), 8,916,945 (“the ’945 Patent”), 8,629,485 (“the ’485 Patent”), 8,994,135 (“the ’135 Patent”) and 9,190,551 (“the ’551 Patent”). Exs. 5 – 8, 34, & 44.

21. Upon information and belief, Terumasa Nagano is an individual residing in Japan. Upon further information and belief, Mr. Nagano was employed in the MEMS (microelectrical mechanical systems) Product Development Department at Hamamatsu Photonics K.K. at least in 2007. Mr. Nagano is a named inventor on the ’087, ’528,’945,’485, ’135, and ’551 Patents. Exs. 5 – 8, 34, & 44.

22. Upon information and belief, Koei Yamamoto is an individual residing in Japan. Upon further information and belief, Mr. Yamamoto was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Yamamoto is a named inventor on the ’945 Patent. Ex. 7.

23. Upon information and belief, Yasuhito Miyazaki is an individual residing in Japan. Upon further information and belief, Mr. Miyazaki was employed by Hamamatsu

Photonics K.K. at least in 2007. Mr. Miyazaki is a named inventor on the ’485 Patent and U.S. Patent No. 8,884,226 (“the ’226 Patent”). Exs. 8 – 9.

24. Upon information and belief, Yasuhito Yoneta is an individual residing in Japan. Upon further information and belief, Mr. Yoneta was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Yoneta is a named inventor on the ’226 Patent. Ex. 9.

25. Upon information and belief, Hisanori Suzuki is an individual residing in Japan. Upon further information and belief, Mr. Suzuki was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Suzuki is a named inventor on the ’485 and ’226 Patents. Exs. 8 – 9.

26. Upon information and belief, Matsaharu Muramatsu is an individual residing in Japan. Upon further information and belief, Mr. Muramatsu was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Muramatsu is a named inventor on the ’485 and ’226 Patent. Exs. 8 – 9.

27. Upon information and belief, Toshihisa Atsumi is an individual residing in Japan. Upon further information and belief, Mr. Atsumi was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Atsumi is a named inventor on the ’226 Patent. Ex. 9.

28. Upon information and belief, Kazuhisa Yamamura is an individual residing in Japan. Upon further information and belief, Mr. Yamamamura was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Yamamamura is a named inventor on the ’087, ’528, ’945, ’485, ’135, and ’551 Patents. Exs. 5 – 8, 34, & 44.

29. Upon information and belief, Toshitaka Ishikawa is an individual residing in Japan. Upon further information and belief, Mr. Isikawa was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Ishikawa is a named inventor on the ’528, ’135, and ’551 Patents. Exs. 6, 34, & 44.

30. Upon information and belief, Satoshi Kawai is an individual residing in Japan. Upon further information and belief, Mr. Kawai was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Kawai is a named inventor on the '528, '135, and '551 Patents. Exs. 6, 34, & 44.

31. Upon information and belief, Takashi Iida is an individual residing in Japan. Upon further information and belief, Mr. Iida was employed by Hamamatsu Photonics K.K. at least in 2007. Mr. Iida is a named inventor on the '945 Patent. Ex. 7.

32. Upon information and belief, Keith Kobayashi is an individual residing in Japan. Upon further information and belief, Mr. Kobayashi was employed in the International Division of Hamamatsu Photonics K.K. at least in 2007.

III. JURISDICTION AND VENUE

33. This Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331, 1338(a), 1367, and 2201.

34. This Court also has jurisdiction pursuant to 28 U.S.C. § 1332, as complete diversity among the parties exists, and the amount in controversy exceeds $75,000.

35. Venue is proper in this district pursuant to 28 U.S.C. § 1391(b) and (d).

IV. FACTUAL ALLEGATIONS

Summary

36. Prof. Mazur, Dr. Carey, and Dr. Shen have invented and patented (including the Harvard Patents) numerous improvements to optoelectronic devices using, among other things, a pioneering laser process technology that results in a material commonly described as "black silicon." The black silicon process uses short laser pulses to create unique micro- and nano-texture on a silicon surface and optionally can be used to incorporate a high amount of dopant

material into the silicon. The absorption of near-infrared light in a silicon optoelectronic device or substrate is dramatically improved by incorporating black silicon.

37. Prof. Mazur and Dr. Carey co-founded SiOnyx in 2006 to further develop, refine and commercialize this technology. As part of their development and commercialization effort, SiOnyx introduced the benefits of their improved technology to Hamamatsu, an established manufacturer of optical sensors and devices, in late 2006. Shortly thereafter, the parties entered into a joint-development project and entered into a Mutual Non-Disclosure Agreement, Ex. 10, to test the application of black silicon to Hamamatsu's products. SiOnyx worked with Hamamatsu for over a year to explain and prove out the benefits of the SiOnyx technology. SiOnyx developed experimental conditions and suggested appropriate device architectures for Hamamatsu to fabricate and test. These experiments were successful. SiOnyx demonstrated to Hamamatsu that the application of SiOnyx's proprietary technology to various photodiodes similar to those in Hamamatsu's commercial products exhibited improved sensitivity to infrared and near infrared radiation.

38. Shortly after the expiration of the Mutual Non-Disclosure Agreement, Hamamatsu terminated the relationship with SiOnyx, representing that it did not believe that Harvard and SiOnyx's patented technologies were useful and stating that it wanted to develop its own technology and techniques to improve near-infrared sensitivity. Hamamatsu, however, unbeknownst to Plaintiffs, thereafter filed patent applications on the same technology and techniques it learned from SiOnyx. Hamamatsu continues to prosecute patent applications directed toward SiOnyx's and Harvard's proprietary technology to this day. For example, United States Patent Application Numbers 14/683,524 and 13/634,249 are currently pending before the Patent and Trademark Office. SiOnyx and Harvard seek to correct the inventorship on

these patents, changing the incorrectly named Hamamatsu employees to the rightful SiOnyx and Harvard inventors.

39. In addition to naming the wrong inventors, the Hamamatsu patents publicly disclose confidential information that SiOnyx shared with Hamamatsu under the Mutual Non-Disclosure Agreement. This disclosure by Hamamatsu is in breach of the Mutual Non-Disclosure Agreement. SiOnyx seeks equitable and monetary relief for Hamamatsu's breach of contract.

40. SiOnyx and Harvard also seek equitable and monetary relief to compensate for Hamamatsu's infringement of the Asserted Patents, including treble damages for Hamamatsu's willful infringement of the '446, '467 and '591 Patents. Despite having knowledge of the Harvard Patents and SiOnyx's proprietary technology, Hamamatsu is currently making, using, offering for sale, selling, selling for importation, importing and selling after importation devices in the United States that practice one or more claims of the '446, '467, and '591 Patents or that were made using the methods claimed therein and/or indirectly infringing.

Harvard

41. Established in 1636, Harvard University is the nation's oldest institution of higher learning and is recognized as one of the world's leading academic institutions. The range of research activities at Harvard is broad and deep. Harvard scholars conduct research in almost every field of knowledge and constantly seek to expand human knowledge through analysis, innovation, and insight. Research at Harvard is supported by more than $800 million of sponsored research funds each year. Researchers include faculty members, visiting scholars, post-doctoral fellows, and graduate and undergraduate students. These Harvard researchers collaborate with colleagues across the University, at affiliated institutions, at other research institutions, and with private corporations throughout the world.

42. The Department of Physics at Harvard, through its faculty, students, postdoctoral fellows, and other research scholars, work in first-class facilities on individual investigator-led research projects and in collaboration with others on a broad spectrum of physics research.

43. In 1984, Prof. Mazur became a faculty member at Harvard and formed a research group, now known as the Mazur Group, to study the dynamics of molecules, chemical reactions, and condensed matter on very short timescales – down to femtoseconds (millionths of billionths of a second). The only way to study physics in this ultrafast regime is through use of light, specifically using short laser pulses. The intensity of these laser pulses is comparable to the intensity one would obtain by focusing all the sunlight that strikes the earth on an area the size of a fingernail. This high intensity creates conditions that approach those found in stars and allows researchers to study a host of new phenomena. The Mazur Group's projects are of both fundamental scientific interest and technological relevance, crossing traditional disciplinary boundaries between physics, chemistry, materials science, and optics.

44. Prof. Mazur and his research group have investigated the effect of irradiating the surface of various materials with high intensity laser pulses to determine what kinds of chemistry can occur when lasers shine on metals, like platinum. When the Mazur Group decided to irradiate silicon, a semimetal, it made an interesting discovery. After more than 500 high-intensity laser pulses, each pulse lasting less than 100 millionths of a billionth of a second, the surface of the silicon turned black. At first, the team thought that the black color was a result of the surface of the silicon being burned by the laser. Upon inspection with an electron microscope, however, Prof. Mazur and his group discovered that the surface of the silicon had become covered with micrometer-sized, needlelike spires.

45. Having created black silicon, Dr. Mazur's Group went on to investigate its properties. The spires on the surface of the black silicon enable enhanced radiation-absorbing properties. Normal silicon is silver/gray, and relatively ineffective at detection of radiation with longer wavelengths, such as near infrared radiation. Electromagnetic radiation incident on black silicon, however, is reflected back and forth between the spires in such a way that most of the light is not reflected back, thus, the silicon looks black. Additionally, the Mazur Group learned that the spires allow radiation to enter the silicon at an angle ("non-normal incidence"), increasing the optical path length of the radiation inside the silicon and hence increasing the probability of absorption.

46. Black silicon on a surface opposite the light-incident surface is also highly effective at enhancing near infrared absorption. In this architecture, the black silicon serves as a highly effective mirror, reflecting light back into the silicon through total internal reflection. Radiation can be reflected at large angles to the silicon surface, increasing the optical path length, and thus increasing the probability of absorption. Black silicon is thus much more effective in detecting near infrared radiation than normal silicon.

47. After discovery of black silicon and its potential benefits over normal silicon, Prof. Mazur and his group began to research the effects that different laser processing conditions have on the spire structures and the effects different spire structures have on the performance of the black silicon. Dr. Shen, a visiting professor at Harvard from 2001-2006, worked with the Mazur Group on varying the conditions under which the silicon is irradiated in order to produce smaller spires. Prof. Mazur and Dr. Shen disclosed and then assigned the inventions to Harvard pursuant to Harvard's Intellectual Property policy and Harvard filed a number of patents, including United States Patent Number 7,884,446 ("the '446 Patent"), entitled "Femtosecond

Laser-Induced Formation of Submicrometer Spikes on a Semiconductor Substrate." Ex. 1. The '446 Patent teaches semiconductor substrates with submicron-sized spikes on the surface layer having particular characteristics. *Id.* Harvard exclusively licensed the'446 Patent to SiOnyx on February 10, 2006. Exs. 4 & 4A.

48. From 2001-2006, Dr. Carey worked with Prof. Mazur at Harvard on investigating the effects of laser processing the silicon in the presence of other materials, such that the materials are added to the silicon. Prof. Mazur and Dr. Carey disclosed and then assigned the invention to Harvard pursuant to Harvard's Intellectual Property policy and then Harvard filed a number of patents including United States Patent Number 8,080,467 ("the '467 Patent"), entitled "Silicon-Based Visible and Near-Infrared Optoelectric Devices." Ex. 2. The '467 Patent teaches methods of fabricating semiconductor wafers by irradiating at least a portion of the wafer while it is exposed to a substance then annealing in order to generate inclusions in the surface layer. *Id.* Harvard also exclusively licensed the '467 Patent to SiOnyx on February 10, 2006. Exs. 4 & 4A.

49. In addition to researching the physical properties of black silicon, Dr. Carey worked with Prof. Mazur on developing commercial applications for black silicon. For example, because devices treated with black silicon are better able to absorb near-infrared radiation, Prof. Mazur and Dr. Carey realized black silicon could be used to improve the spectral range of photodiodes that are used in many products or product components such as image sensors.

SiOnyx

50. To pursue commercialization of black silicon, Prof. Mazur and Dr. Carey co-founded SiOnyx in 2006. Since its founding, SiOnyx has continued Prof. Mazur and Dr. Carey's work, employing world-class scientists to help develop processes and devices that use black silicon to dramatically enhance the infrared sensitivity of commercial silicon-based photonics.

The significant advantages of black silicon allow for smaller, lower cost, higher performance photonic devices, which can be used in a variety of applications. For example, in the security and surveillance industry, SiOnyx's black silicon CMOS (complementary metal oxide semiconductor) image sensors enable new capabilities for night vision and significantly enhance the performance of infrared illuminated systems. Many industrial processes that use light to inspect products also benefit from the improvements SiOnyx's black silicon delivers. In the medical imaging field, the significantly higher near-infrared sensitivity of SiOnyx's black silicon technology provides for new levels of speed, sensitivity, and accuracy. Black silicon may also be useful in the automotive industry. The next frontier of automotive safety includes driver awareness monitoring, active collision avoidance and high performance night vision systems. SiOnyx is working on applications to achieve these critical safety initiatives, which depend on the high performance infrared imaging found in SiOnyx's image sensors.

51. SiOnyx is also partnering with select defense customers on a number of next generation imaging solutions that will ensure the safety and continued superiority of our national defense. SiOnyx has received over $11.5 million in contracts from various government agencies, including the Defense Advanced Research Projects Agency (DARPA), to investigate black silicon in applications including solar power.

52. SiOnyx's work has led to numerous valuable inventions that SiOnyx has sought to commercialize and protect through patents in the United States and abroad. Dr. Haddad, Mr. Jiang, Mr. McKee, Dr. Miller, Dr. Forbes, and Dr. Palsule disclosed and then assigned the inventions to SiOnyx pursuant to their employment agreements and then SiOnyx filed a number of patents including United States Patent Number 8,680,591 ("the '591 Patent"), entitled

"Photosensitive Imaging Devices and Associated Methods." Ex. 3. The '591 Patent teaches photosensitive devices that include a textured region and methods for making the same.

Hamamatsu

53. In November of 2006, shortly after founding SiOnyx, Prof. Mazur contacted Hamamatsu to explore the possibility of a joint-development partnership. SiOnyx believed its black silicon technology could improve the performance of Hamamatsu's photodiode devices.

54. Hamamatsu Photonics K.K. is a Japanese manufacturer of optical devices, including photodiodes. Hamamatsu describes itself as a world leader in photoelectron conversion technologies. Akira Hiruma, *President's Message*, HAMAMATSU, http://www.hamamatsu.com/us/en/hamamatsu/overview/message/index.html (last visited June 8, 2015). Last year, Hamamatsu reported ¥112,092 million in net sales of such devices. *Corporate Profile*, HAMAMATSU, http://www.hamamatsu.com/us/en/hamamatsu/overview/profile /index.html (last visited June 8, 2015).

55. Hamamatsu develops, manufactures, and sells devices including silicon photodiodes, avalanche photodiodes, spectroscopy devices, and image sensors – charged coupled devices ("CCD"), complementary metal oxide semiconductor ("CMOS"), and n-type metal oxide semiconductor ("NMOS") – for use in a variety of applications. According to Hamamatsu's website, each of these product lines are developed and produced by Hamamatsu's Solid State Division. *Products*, HAMAMATSU, http://www.hamamatsu.com/us/en/hamamatsu/overview/bsd/ solid_state_division/product.html (last visited June 10, 2015).

56. The "President's Message" on Hamamatsu's webpage attributes Hamamatsu's industry success to its investments in research. The President's Message further explains that collaboration with others is critical to Hamamatsu's research and development:

> We realize that pursuing the knowledge of photonics technologies alone, by ourselves, is like reaching for the stars with a ladder. Thus we will work together with colleagues around the world, be they researchers, customers or stockholders, who share our passion and the belief that understanding photonic technologies will lead to broader applications and also generate new industries for the advancement of humankind.

President's Message, HAMAMATSU, http://www.hamamatsu.com/us/en/hamamatsu/overview /message/index.html (last visited June 8, 2015).

The Relationship between SiOnyx and Hamamatsu

57. Hamamatsu purported to enter into a collaborative relationship with SiOnyx to explore the benefits and feasibility of adding SiOnyx's black silicon technology into Hamamatsu's commercial photodiode products. The parties' relationship, which lasted over a year, resulted in successful production of test substrates by SiOnyx and the inclusion of those substrates into devices similar to those in Hamamatsu's commercial products, but with improved near-infrared sensitivity due to SiOnyx's black silicon technology. Despite the success, Hamamatsu told SiOnyx that it was not convinced that black silicon would contribute to its products. Ex. 11 (2008-01-15 Email from K. Kobayashi to S. Saylor re Photoconductor pattern). Hamamatsu stated that, instead, it would develop its own methods for improving infrared and near-infrared sensitivity. *Id.* A few years later, however, Hamamatsu began selling photodiodes that include the black silicon technology learned from SiOnyx. Further, in 2010 Hamamatsu filed patents on the technology it learned from SiOnyx that incorrectly identify the Hamamatsu employees that worked with SiOnyx as inventors, instead of the rightful SiOnyx inventors.

58. SiOnyx, through Prof. Mazur, initiated the relationship with Hamamatsu on October 16, 2006, by sending a letter requesting a meeting to discuss black silicon. Teruo Hiruma, Chairman of the Board and Chief Executive Officer of Hamamatsu, responded and the parties set up a meeting for November 15, 2006. Representatives from SiOnyx, including Prof.

Mazur, Dr. Carey, and Mr. Stephen Saylor, President and Chief Executive Officer of SiOnyx, met with representatives from Hamamatsu, including Mr. Keith Kobayashi of Hamamatsu's International Division and Mr. Koei Yamamoto, Senior Executive Managing Director of Hamamatsu and General Manager of the Company's Solid State Division.

59. During the November 15, 2006 meeting, the parties discussed the benefits and practical applications of black silicon and Hamamatsu expressed an interest in experimenting with the addition of SiOnyx's black silicon to its photodiode devices. After the meeting, the parties entered into a Mutual Non-Disclosure Agreement, which SiOnyx signed on December 15, 2006 and Hamamatsu Photonics K.K. signed on January 11, 2007. Ex. 10 at 2. The Agreement provides:

> "Each party proposes to disclose certain of such information to the other party, to be used by the other party solely for the limited purpose of EVALUATING APPLICATIONS AND JOINTS [*SIC*] DEVELOPMENT OPPORTUNITIES OF PULSED LASER PROCESS DOPED PHOTONIC DEVICES and for no other purposes whatsoever (the "Permitted Purpose").
>
> . . . .
>
> The Receiving Party acknowledges that the Disclosing Party (or any third party entrusting its own confidential information to the Disclosing Party) claims ownership of the Confidential Information disclosed by the Disclosing Party and all patent, copyright, trademark, trade secret, and other intellectual property rights in, or arising from, such Confidential Information. No option, license, or conveyance of such rights to the Receiving Party is granted or implied under this Agreement. If any such rights are to be granted to the Receiving Party, such grant shall be expressly set forth in a separate written instrument.

Id. at 1-2 (emphasis original).

60. The Mutual Non-Disclosure Agreement expired twelve months after its January 11, 2007 execution. *Id.* at 2. Any new or additional confidential information shared after this date would not be subject to the Agreement. *Id.* at 2. The parties' confidentiality obligations

regarding information shared during the twelve-month term of the Agreement, however, remained in effect for seven years after the termination of the Agreement, until January 11, 2014. *Id.*

61. On January 16, 2007, with the Non-Disclosure Agreement in place, Hamamatsu began soliciting SiOnyx for suggestions regarding experimental device architecture. The following day, SiOnyx sent schematics of device architectures to Mr. Kobayashi. Ex. 12 (Preferred Device Architecture and Process Flow). SiOnyx's suggestions included both photovoltaic and photoconductive photodiodes. *Id.* There are different possible definitions of photovoltaic and photoconductive. As used by the parties in their interactions leading to the filing of this action, a photovoltaic photodiode refers to photodiodes with pn or PIN junctions. An example of the photovoltaic photodiode architecture proposed by SiOnyx, along with Dr. Carey's description of the architecture, is reproduced below:

> Alternative #1) We can also attempt an architecture more similar to the typical Hamamatsu PIN diode. This device would have p-type up and the laser processed layer as the backside contact. This may work for increased long wavelength response and operate well for short-wavelength sensitivity. Laser processing can be performed on the entire wafer in this architecture.

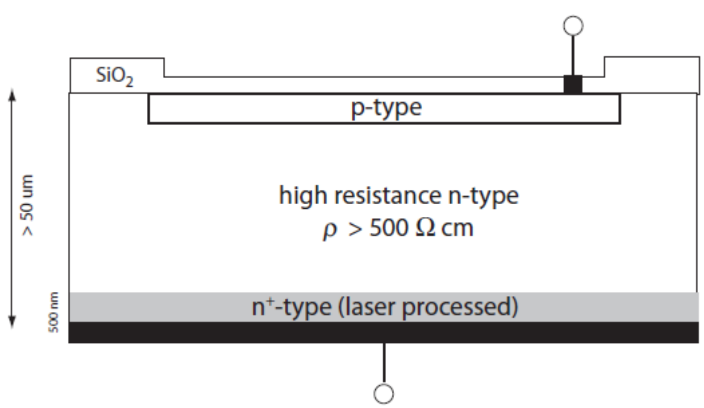


Fig. 1: Suggested Architecture for Photovoltaic Photodiode Sent to Hamamatsu by SiOnyx January 17, 2007. Ex. 12 (Preferred Device Architecture and Process Flow).

62. Photoconductive photodiodes, as defined by the parties, refers to architectures that do not have a pn or PIN junction. An example of the photoconductive photodiode architecture proposed by SiOnyx, along with Dr. Carey's description of the architecture, is reproduced below:

> Alternative #2) Because of the high photoconductive gain, an interesting alternative device architecture may be a phototransistor. Laser processing can also be preformed on the entire wafer in this architecture.

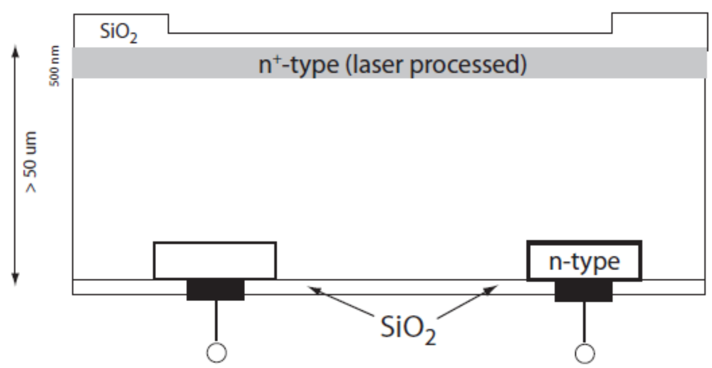


Fig. 2: Suggested Architecture for Photoconductive Photodiode Sent to Hamamatsu by SiOnyx January 17, 2007. Ex. 12 (Preferred Device Architecture and Process Flow).

63. As shown in Figure 2, this device has [redacted]

64. The photoconductive architecture was proposed as an academic experiment to test theories in an article published by Dr. Carey. *See* Ex. 13 (2007-10-12 Attachment to Email from T. Nagano to N. McCaffrey re Laser Condition). As part of the SiOnyx-Hamamatsu collaboration, Dr. Carey suggested that these photovoltaic photodiodes be tested for their commercial applicability. For example, "Alternative #1)," reproduced in Figure 1, above, shows SiOnyx's proposed modification to add black silicon to devices similar to Hamamatsu's

commercial photovoltaic photodiodes. *See* Ex. 14 (2007-01-17 Email from J. Carey to K. Kobayashi re 1st Device Diagram) ("The suggested device architecture was selected based on our past experiments and what we believe is compatible with current Hamamatsu photodetectors.")

65. In February and March of 2007, SiOnyx worked with Hamamatsu to develop an experiment plan to fabricate photoconductive and photovoltaic samples. During these discussions, instead of providing its own parameters, Hamamatsu consistently requested that SiOnyx provide the parameters for the experimental devices. One of SiOnyx's suggestions was to explore the use of black silicon in backside-thinned photovoltaic CCDs. Ex. 15 (2007-02-22 Email from S. Saylor to K. Yamamoto re SiOnyx Update); Ex. 16 (2007-03-01 Email from K. Yamamoto to S. Saylor re Backside thinned CCDs). Mr. Yamamoto responded affirmatively, telling SiOnyx that the main reason Hamamatsu was interested in exploring black silicon was to improve the infrared sensitivity of its backside-thinned CCDs. Ex. 16 (2007-03-01 Email from K. Yamamoto to S. Saylor re Backside thinned CCDs).

66. Ultimately, the experiment consisted of four architecture types, three photovoltaic and one photoconductive. Type 2 incorporated SiOnyx's suggestion of using a backside-thinned architecture. Ex. 17 (2007-04-04 Black Silicon Presentation). Hamamatsu fabricated the experimental semiconductor substrates, per the agreed upon architectures, then sent the substrates to SiOnyx to be laser processed, thereby adding black silicon. After processing, SiOnyx returned the black silicon device to Hamamatsu. Hamamatsu annealed the devices, according to SiOnyx's instructions, and then packaged them to enable testing.

67. Hamamatsu tested the black silicon devices in November of 2007. The tests consisted of measuring characteristics of the devices in response to light incident on the side of

the semiconductor substrate opposite to the black silicon. *See, e.g.,* Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary)). The academic-based photoconductive photodiode was not as successful as the parties had hoped. But, as Hamamatsu acknowledged, this was not the main purpose of the experiment. Ex. 13 (2007-10-12 Attachment to Email from T. Nagano to S. Saylor re Laser Condition). The photovoltaic photodiode experiments, however, were successful. As promised by SiOnyx, black silicon significantly improved the near-infrared sensitivity of the photovoltaic photodiodes. Ex. 18 at 15.

68. The chart below, generated by Hamamatsu from test data of the three photovoltaic photodiode experimental wafers, which were subjected to SiOnyx proprietary process, show improved sensitivity to near-infrared radiation ("NIR up") as compared to a reference diode (light green) that was not subjected to SiOnyx's proprietary laser treatment and annealing process.

[redacted]

Fig. 3: Photosensitivity of Photovoltaic Photodiode Experimental Substrates. Ex. 18 at 14 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary).

69. Based on these successful experiments, SiOnyx sought to initiate discussions regarding transitioning the parties' experimental development relationship into a business

relationship. Hamamatsu declined to engage in such discussions, informing SiOnyx that it was only interested in continuing near-term technical evaluation of photovoltaic type photodiodes. Ex. 19 (2008-01-08 Email from S. Saylor to K. Kobayashi re Photoconductor pattern). Based on the success of the photovoltaic photodiode wafers, SiOnyx responded that it did not believe Hamamatsu needed additional tests in order to decide whether it wished to license SiOnyx's technology for use in its commercial products. Ex. 19 (2008-01-11 Email from S. Saylor to K. Kobayashi re Photoconductor pattern).

70. Hamamatsu, however, terminated the relationship with SiOnyx on January 15, 2008, explaining: "[W]e are not confident that black silicon technology will greatly contribute. We would rather like to stick with our own technique/technology for that purpose because we would like to keep our own pace of development and accumulate our own know-hows." Ex. 11 (2008-01-15 Email from K. Kobayashi to S. Saylor re Photoconductor pattern).

71. SiOnyx did not hear from Hamamatsu again regarding black silicon until February of 2009, when Mr. Saylor and Prof. Mazur received an email from Mr. Kobayashi, informing Mr. Saylor and Prof. Mazur that Hamamatsu planned to demonstrate photovoltaic photodiodes that include a "black silicon surface fabricated by laser in the [*sic*] inert gas atmosphere." Ex. 20 (2009-02-09 Email from K. Kobayashi to S. Saylor & E. Mazur re Hamamatsu Photonics PHOTON FAIR). The email included an attachment showing a drawing of Hamamatsu's new product, an "NIR ['near-infrared'] High sensitivity photodiode / Cross Section." Mr. Kobayashi's email further expressed a belief that Hamamatsu developed the technology in this new product on its own, without SiOnyx's input, and that Hamamatsu did not believe it was infringing any of SiOnyx's intellectual property or breaching any confidentiality obligations under the Mutual Non-Disclosure Agreement.

72. Although similar to what SiOnyx taught Hamamatsu under the Mutual Non-Disclosure Agreement, the drawing alone was insufficient for SiOnyx to determine whether Hamamatsu was using SiOnyx's proprietary technology disclosed to Hamamatsu under the Mutual Non-Disclosure Agreement. Likewise, the drawing was insufficient to allow SiOnyx to determine whether Hamamatsu was infringing the Harvard Patents licensed to SiOnyx. Thus, Mr. Saylor responded to Mr. Kobayashi's email, seeking assurances that Hamamatsu was respecting its confidentiality obligations under the Mutual Non-Disclosure Agreement and not infringing SiOnyx or Harvard's intellectual property. Ex. 21 (2009-02-19 Email from S. Saylor to K. Kobayashi re Hamamatsu Photonics PHOTON FAIR). Mr. Saylor's email also requested that Hamamatsu send further device specifications to allow SiOnyx and Harvard to determine whether Hamamatsu was infringing or violating the Mutual Non-Disclosure Agreement. *Id.*

73. Hamamatsu never provided additional specifications as requested. On March 11, 2009 Mr. Kobayashi sent another email to Mr. Saylor, again claiming that Hamamatsu was not using the proprietary information learned from SiOnyx in its photovoltaic photodiodes. Ex. 22 (2009-03-11 Email from K. Kobayashi to S. Saylor re Hamamatsu Photonics PHOTON FAIR). Before SiOnyx had the opportunity to respond, Mr. Kobayashi sent another email to Mr. Saylor, alleging SiOnyx had somehow agreed that Hamamatsu's new product did not infringe SiOnyx's intellectual property. Ex. 22 (2009-04-15 Email from K. Kobayashi to S. Saylor re Hamamatsu Photonics PHOTON FAIR).

74. SiOnyx never agreed that products represented by Hamamatsu's drawing did not breach Hamamatsu's confidentiality obligation under the Mutual Non-Disclosure Agreement or infringe SiOnyx and Harvard's intellectual property. Instead, when Hamamatsu began selling infrared-enhanced devices around 2010, SiOnyx took steps to investigate whether these devices

used SiOnyx and Harvard's proprietary technology. For example, SiOnyx looked at the spectral response of Hamamatsu's commercial photodiodes to determine whether they might be using the technology disclosed to Hamamatsu under the Mutual Non-Disclosure Agreement. Below is a graph of the spectral response of the Hamamatsu S11499 series of commercial photodiodes next to the spectral response from the SiOnyx-Hamamatsu test photodiodes.

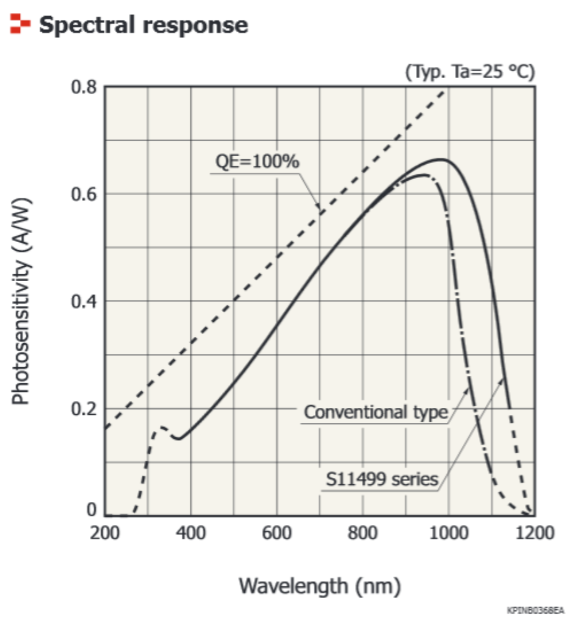


Fig. 6: Spectral Response of Hamamatsu S11499 Series, Showing Improved Spectral Response for Near-Infrared Radiation. Ex. 23 at 2, (Datasheet for IR-Enhanced Si PIN Photodiodes, S11499 Series, Hamamatsu Photonics K.K., http://www.hamamatsu.com/resources/pdf/ssd/s11499_series_kpin1082e.pdf (last visited June 15, 2015))

[redacted]

Fig. 7: Photosensitivity of Photovoltaic Photodiode Experimental Substrates. Ex. 18 at 14 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary).

75. As shown in Figures 6 and 7, above, the improvement in near-infrared sensitivity of the Hamamatsu S11499 series photodiodes is nearly identical to the improved performance of the photodiodes with black silicon fabricated under the Mutual Non-Disclosure Agreement. The peak photosensitivity of both the Hamamatsu S11499 series and the test photodiodes is between 600 and 700 A/W. Further, as shown in Figure 8, below, Hamamatsu's website explains that Hamamatsu uses "laser processing technology" to improve the near-infrared sensitivity of its photodiodes.

Enhanced IR sensitivity

These sensors have MEMS structures fabricated by our own unique laser processing technology. These sensors have achieved very high sensitivity in the near infrared region at wavelengths longer than 800 nm. Utilizing high sensitivity characteristic in the near infrared region, these sensors should find applications in Raman spectroscopy.

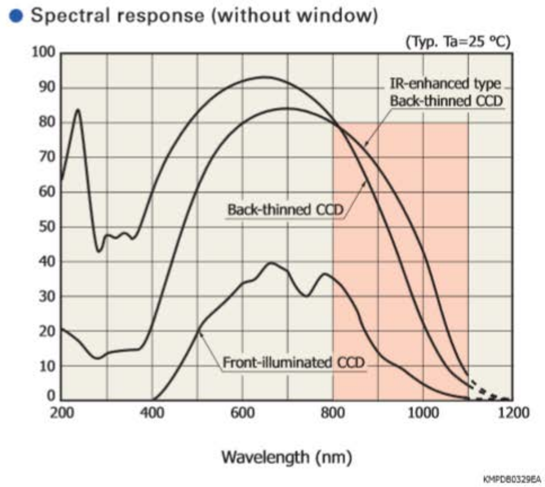


Fig. 8: Hamamatsu's Explanation of Improved Performance of Photodiodes using Laser Processing. Ex. 24 Image Sensors, Selection Guide (Sept. 2014), Hamamatsu Photonics K.K., http://www.hamamatsu.com/resources/pdf/ssd/image_sensor_kmpd0002e.pdf, (last visited June 15, 2015)

76. In addition to incorporating SiOnyx and Harvard's proprietary technology into its devices, Hamamatsu filed Japanese patent applications in 2010 claiming the black silicon technology for use in photovoltaic photodiodes that Hamamatsu learned from SiOnyx. The named inventors on these patent applications are Hamamatsu employees, including Mr. Nagano, Mr. Sakamoto, and Mr. Yamamoto, who worked on the joint-development project with SiOnyx, under the Mutual Non-Disclosure Agreement. Hamamatsu also filed versions of these applications with the United States Patent and Trademark Office. A side-by-side comparison of the architecture suggested by SiOnyx with the devices taught in Hamamatsu's patents demonstrates the similarity. For example, Figure 9 shows the architecture suggested by SiOnyx, wherein the black squares represent black silicon and the light blue box along the bottom represents an accumulation layer. Figure 10, on the right, shows a figure from Hamamatsu's 8,916,945 Patent that has had color and annotations added. Ex. 7.

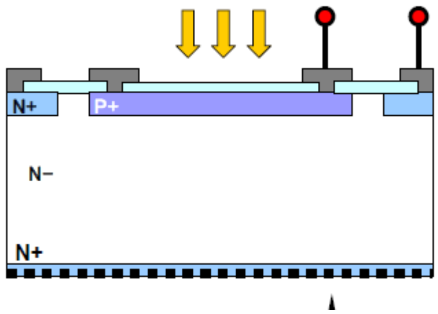


Fig. 9: Schematic of Photodiode Architecture Suggested to Hamamatsu by SiOnyx. Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary))

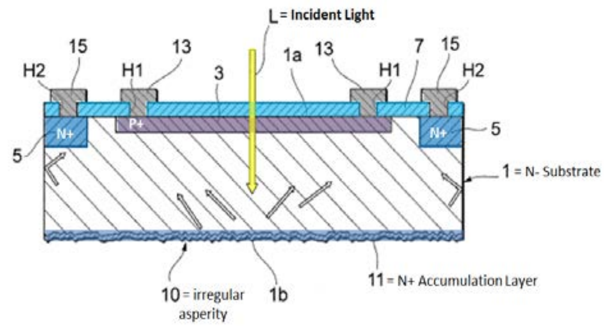


Fig. 10: Annotated Version of Fig. 11 from '945 Patent, Ex. 7 (Color and Text Labels not Original).

77. Figures 9 and 10 show that Hamamatsu filed patents on technology developed by SiOnyx and Harvard. SiOnyx and Harvard seek to correct inventorship of the Hamamatsu patents that incorrectly join and/or fail to join Prof. Mazur and Dr. Carey as inventors.

<u>The Hamamatsu Patents</u>

United States Patent No. 8,564,087

78. On February 15, 2010, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/148,091, entitled "Photodiode Manufacturing Method and Photodiodes." United States Patent Number 8,564,087 ("the '087 Patent") issued from this application on October 22, 2013. Ex. 5. The '087 Patent teaches Prof. Mazur and Dr. Carey's inventions, but does not name them as inventors. Instead, Hamamatsu Photonics K.K. employees, including Mr. Nagano and Mr. Sakamoto, who worked on the joint development project with SiOnyx, are named as inventors. *Id.* The '087 Patent is assigned to Hamamatsu Photonics K.K. *Id.* SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

79. The ’087 Patent teaches a backside-thinned photovoltaic photodiode with a black silicon surface and methods for manufacturing said photodiode. *Id.* Claims 1 and 5 are the only independent claims. Claim 1 is reproduced below:

> A photodiode manufacturing method comprising:
>
> > a step of preparing a silicon substrate having a semiconductor substrate having a first principal surface and a second principal surface opposed to each other, an insulating layer provided on the second principal surface of the semiconductor substrate, a first impurity region of a first conductivity type provided on the insulating layer, and a low-concentration impurity region of the first conductivity type provided on the first impurity region and having a lower impurity concentration than the first impurity region;
> >
> > a step of forming a photosensitive region including an impurity region of a second conductivity type, in the low-concentration impurity region;
> >
> > a step of shaping the first impurity region and the low-concentration impurity region into a mesa shape to form a semiconductor mesa portion including the photosensitive region;
> >
> > a step of forming a second impurity region of the first conductivity type having a higher impurity concentration than the low-concentration impurity region, on a surface of the semiconductor mesa portion and forming a third impurity region of the first conductivity type having a higher impurity concentration than the low-concentration impurity region, on a side face of the semiconductor mesa portion, to electrically connect the first impurity region, the second impurity region, and the third impurity region;
> >
> > a step of thinning a portion in the semiconductor substrate corresponding to the photosensitive region, from the first principal surface side, while leaving a surrounding region around the thinned portion;
> >
> > a step of irradiating the thinned portion of the silicon substrate with a pulsed laser beam from the first principal surface side to form an irregular asperity;

> a step of subjecting the silicon substrate to a thermal treatment, after the step of forming the irregular asperity; and
>
> a step of, after the step of subjecting the silicon substrate to the thermal treatment, forming a first electrode on the semiconductor mesa portion so as to be electrically connected to the impurity region of the photosensitive region and forming a second electrode on the semiconductor mesa portion so as to be electrically connected to the second impurity region.

80. In allowing the claims of the ’087 Patent, the patent examiner identified only the last three steps as the point of novelty. Ex. 25 at 7 (U.S. Patent App. No. 13/148,091 2013-06-26 Notice of Allowance and Fees Due). SiOnyx, and specifically Dr. Carey, taught all three of these elements to the Hamamatsu employees named as inventors on the ’087 Patent. For example, the experimental architecture shown in Figure 11 below, which SiOnyx proposed to Hamamatsu, shows a backside-thinned portion of a silicon substrate, wherein black silicon has been created on the thinned portion.

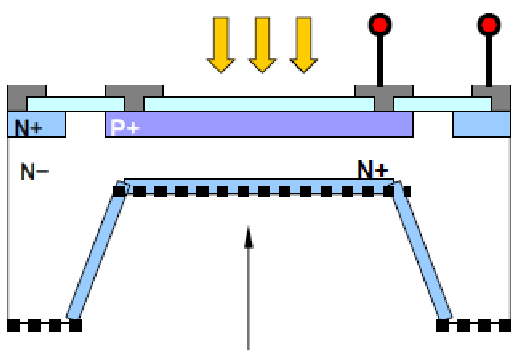


Fig. 11: Architecture of Backside-Thinned Photovoltaic Photodiode, Designed by SiOnyx, Fabricated and Tested under Mutual Non-Disclosure Agreement. Ex. 18 at 2 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary)).

81. The surface structures in black silicon, represented in Figure 11 above by black squares, comprise an “irregular asperity,” as claimed in the ’087 Patent. The specification of the ’087 Patent explains that the irregular asperity is created by exposure of the silicon to a pulsed

laser beam, just as SiOnyx taught Hamamatsu. *See* Ex. 5 at col. 9:41-44. SiOnyx also taught Hamamatsu to subject the substrate to a thermal treatment after forming the black silicon. *See, e.g.,* Ex. 26 (2007-02-28 Email from J. Carey to K. Yamamoto re Proposed project plan Feb 2007). Finally, Figure 11, above, also shows that SiOnyx taught Hamamatsu to connect a first electrode to the photosensitive region and a second electrode to a second impurity region, as claimed.

82. As with claim 1, the examiner allowed claim 5 of the '087 Patent because of elements that SiOnyx taught to Hamamatsu. *See* Ex. 25 at 7 (U.S. Patent App. No. 13/148,091 Notice of Allowance and Fees Due). Claim 5 is reproduced below:

> A photodiode comprising:
>
> > a silicon substrate portion having a semiconductor substrate having a first principal surface and a second principal surface opposed to each other, an insulating layer provided on the second principal surface of the semiconductor substrate, and a semiconductor mesa portion provided on the insulating layer and having a principal surface formed opposite to a joint surface to the insulating layer; and
> >
> > a first electrode and a second electrode provided on the principal surface of the semiconductor mesa portion,
> >
> > wherein the semiconductor mesa portion comprises:
> >
> > a first impurity region of a first conductivity type provided on the joint surface to the insulating layer;
> >
> > a low-concentration impurity region of the first conductivity type provided on the first impurity region and having a lower impurity concentration than the first impurity region;
> >
> > a photosensitive region provided in the low-concentration impurity region and including an impurity region of a second conductivity type;
> >
> > a second impurity region of the first conductivity type provided on the principal surface of the semiconductor

> mesa portion in the low-concentration impurity region and having a higher impurity concentration than the low-concentration impurity region; and
>
> a third impurity region of the first conductivity type provided on a side face of the semiconductor mesa portion in the low-concentration impurity region and having a higher impurity concentration than the low-concentration impurity region,
>
> wherein in the silicon substrate portion, a portion corresponding to the photosensitive region is thinned from the semiconductor substrate side while leaving a surrounding region around the thinned portion,
>
> wherein an irregular asperity is formed in a surface opposed to the principal surface of the semiconductor mesa portion in the thinned portion of the silicon substrate portion and the surface is optically exposed,
>
> wherein the third impurity region is electrically connected to the first impurity region and the second impurity region, and
>
> wherein the first electrode is electrically connected to the impurity region of the photosensitive region and the second electrode is electrically connected to the second impurity region.

83. The examiner found that the prior art of record fails to disclose or suggest "wherein an irregular asperity is formed in a surface opposed to the principal surface of the semiconductor mesa portion in the thinned portion of the silicon substrate portion and the surface is optically exposed . . . ." Ex. 25 at 7 (U.S. Patent App. No. 13/148,091 2013-06-26 Notice of Allowance and Fees Due). SiOnyx taught Hamamatsu to create black silicon – *i.e.,* an "irregular asperity" – on the surface opposed to the surface on which light is incident. This is shown, for example, in Figure 11, above. The black squares represent the placement of black silicon and the yellow arrows show the direction of light incident on the photodiode. Ex. 18 at 2 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary)). Hamamatsu therefore learned all

inventive aspects of the claims of the ’087 Patent from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the ’087 Patent.

84. The ’087 Patent cites United States Patent No. 7,442,629 (“the ’629 Patent”), which is assigned to Harvard, as prior art. Exs. 5, 27. Prof. Mazur and Dr. Shen are the named inventors on the ’629 Patent. *Id.* The ’087 Patent also cites United States Patent Publication Number 20120146172, a now abandoned application, naming Dr. Carey as an inventor. Exs. 5, 28.

United States Patent No. 8,742,528

85. On February 15, 2010, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/147,884, entitled “Photodiode and Photodiode Array.” United States Patent Number 8,742,528 (“the ’528 Patent”) issued from this application on June 3, 2014. Ex. 6. The ’528 Patent teaches Prof. Mazur and Dr. Carey’s inventions, but does not name them as inventors. Instead, Hamamatsu Photonics K.K. employees, including Mr. Nagano and Mr. Sakamoto, who worked on the joint-development project with SiOnyx, are named as inventors. *Id.* The ’528 Patent is assigned to Hamamatsu Photonics K.K. *Id.* SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

86. The ’528 Patent claims an array of avalanching photovoltaic photodiodes with a black silicon layer on a surface opposed to the surface where light is incident. *Id.* Claim 1 is the only independent claim and is reproduced below:

> A front-illuminated type photodiode array in which a plurality of photodetecting channels configured for detection target light to enter thereinto are formed on a silicon substrate having a semiconductor layer of a first conductivity type, the photodiode array comprising:
>
> > an epitaxial semiconductor layer of a second conductivity type formed on the semiconductor layer of the first conductivity type, forming pn junctions at an interface of

> the semiconductor layer, and having a plurality of multiplication regions for avalanche multiplication of carriers generated with incidence of said detection target light, so that the multiplication regions correspond to the respective photodetecting channels; and
>
> a plurality of resistors each having two end portions, provided for the respective photodetecting channels, and each electrically connected through one of the end portions to the epitaxial semiconductor layer and connected through the other of the end portions to a signal conducting wire,
>
> wherein an irregular asperity is formed in at least a surface corresponding to the photodetecting channels in the semiconductor layer of the first conductivity type,
>
> wherein at least the surface corresponding to the photodetecting channels in the semiconductor layer of the first conductivity type is optically exposed, and
>
> wherein a surface opposed to the surface with the irregular asperity formed therein constitutes a light incident surface, light incident from the light incident surface travels in the silicon substrate.

87. In allowing the claims of the ’528 Patent, the patent examiner identified only the “irregular asperity” and the placement of the irregular asperity on a surface opposed to the surface on which light is incident as novel. Ex. 29 at 6-7 (U.S. Patent App. No. 13/147,884 2014-01-27 Notice of Allowance and Fees Due). SiOnyx taught these elements to the Hamamatsu employees named as inventors on the ’528 Patent. For example, the experimental architecture shown in Figure 12 below, which SiOnyx proposed to Hamamatsu, shows the formation of an irregular asperity – *i.e.,* black silicon – on a surface opposed to the surface on which light is incident. The black squares shown in Figure 12 represent black silicon and the yellow arrows represent incident light.

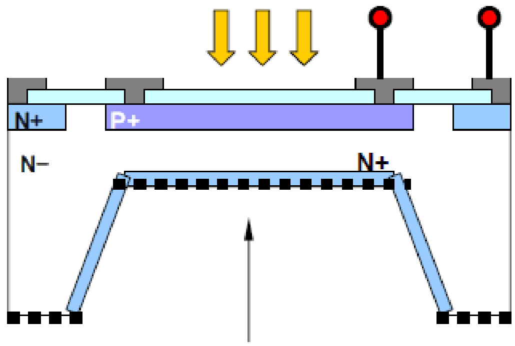


Fig. 12: Architecture of Backside-Thinned Photovoltaic Photodiode, Designed by SiOnyx, Fabricated and Tested under Mutual Non-Disclosure Agreement. Ex. 18 at 3 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary)).

As shown in Figure 12, above, Hamamatsu learned all inventive aspects of the claims of the ’528 Patent from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the ’528 Patent.

88. The ’528 Patent cites United States Patent No. 7, 057,256 (the ’256 Patent”), assigned to Harvard, as prior art. Exs. 6, 30. Prof. Mazur and Dr. Carey are the named inventors on the ’256 Patent. *Id.*

United States Patent No. 8,916,945

89. On February 15, 2010, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/147,871, entitled “Semiconductor Light-Detecting Element.” United States Patent Number 8,916,945 (“the ’945 Patent”) issued from this application on December 23, 2014. Ex. 7. The ’945 Patent teaches Prof. Mazur and Dr. Carey’s inventions, but does not name them as inventors. *Id.* Instead, Hamamatsu Photonics K.K. employees, including Mr. Nagano, Mr. Sakamoto, and Mr. Yamamoto, who worked on the joint-development project with SiOnyx, are named as inventors. *Id.* The ’945 Patent is assigned to Hamamatsu Photonics K.K. SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

90. The ’945 Patent claims a semiconductor photodiode having black silicon on a surface opposed to the surface on which light is incident. *Id.* Claim 1 is the only independent claim and is reproduced below:

> A semiconductor light-detecting element comprising:
>
> > a silicon substrate having a principle surface and having a pn junction comprised of a semiconductor region of a first conductivity type and a semiconductor region of a second conductivity type,
> >
> > wherein on the silicon substrate, an accumulation layer of the first conductivity type is formed on a principal surface side of the silicon substrate and an irregular asperity is formed in at least a region opposed to the pn junction in the principal surface,
> >
> > wherein the region opposed to the pn junction in the principal surface of the silicon substrate is optically exposed, and
> >
> > wherein a surface opposed to the principal surface where the irregular asperity is formed constitutes a light incident surface, light incident from the light incident surface travels in the silicon substrate, the semiconductor light-detecting element being a front-illuminated type.

91. Figure 11 from the ’945 Patent embodies the elements of claim 1.

Fig.11

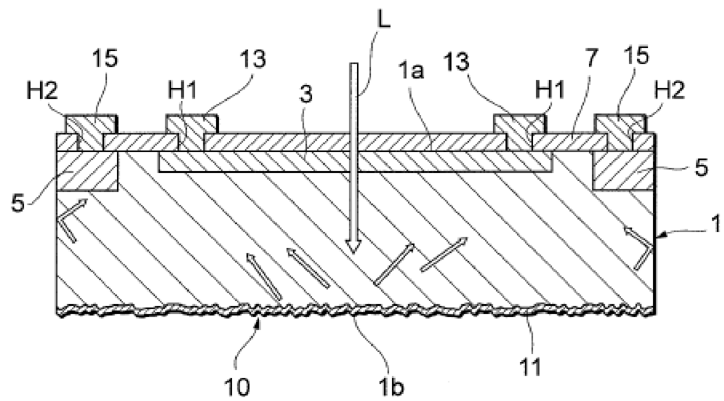


Fig. 13: Figure 11 from '945 Patent. Ex. 7.

Label 1 refers to an n^--type semiconductor substrate. *Id.* at col. 4:45. Label 3 refers to a p^+-type semiconductor region. *Id.* at col. 4:46. Label 5 refers to an n^+-type semiconductor region. *Id.* at col. 4:43-44. Label 10 refers to an "irregular asperity." *Id.* at col. 5:40-43. Label 11 refers to an n^+-type accumulation layer. *Id.* at col. 5:56-63. Labels 13 and 15 refer to electrodes. *Id.* at col. 6:16-20. Label "L" refers to light incident on the first principal surface 1a. *Id.* at col. 6:51-52.

92. Below is a side-by-side comparison of Figure 11 from the '945 Patent, on the left, with one of the experimental architectures suggested to Hamamatsu by SiOnyx, on the right.

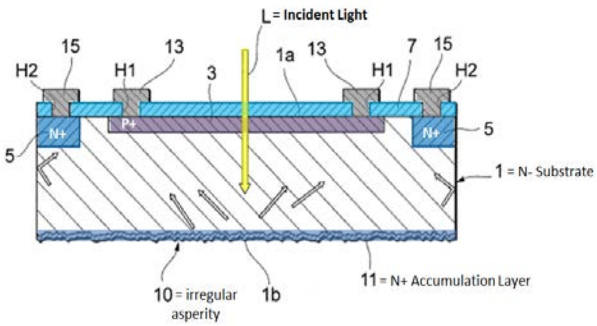


Fig. 14: Annotated Version of Fig. 11 from '945 Patent (Color and Text Labels not Original). Ex. 7.

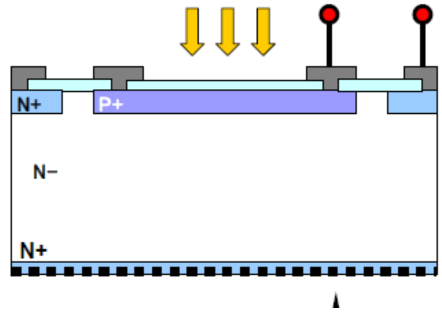


Fig. 15: Schematic of Photodiode Architecture Suggested to Hamamatsu by SiOnyx. Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary))

93. As shown by Figures 14 and 15, above, Hamamatsu learned all inventive aspects of the claims of the '945 Patent from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the '945 Patent.

94. The '945 Patent cites United States Patent No. 7, 057,256 (the '256 Patent"), assigned to Harvard, as prior art. Exs. 7, 30. Prof. Mazur and Dr. Carey are the named inventors on the '256 Patent. Ex. 30.

United States Patent Number 8,629,485

95. On February 9, 2010, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/143,765, entitled "Semiconductor Photodetection Element." United States Patent Number 8,629,485 ("the '485 Patent") issued from this application on January 14, 2014. Ex. 8. The '485 Patent teaches Prof. Mazur and Dr. Carey's inventions, but does not name them as inventors. *Id.* Instead, Hamamatsu Photonics K.K. employees, including Mr. Nagano and Mr. Sakamoto, who worked on the joint-development project with SiOnyx, are named as inventors. *Id.* The '485 Patent is assigned to Hamamatsu Photonics K.K. *Id.* SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

96. The scope of the claims of the ’485 Patent are substantially the same as the scope of the claims that issued in the ’945 Patent. *Compare* Ex. 8 at 17:45-18:53 *with* Ex. 7 at 29:4-30:17. According to the patent examiner, the only difference between the two is that the ’485 Patent specifically claims a “transfer electrode part” which is provided on the first principal surface of the silicon substrate. Ex. 31 at 4 (U.S. Patent App. No. 13/143,765, 2012-08-07 Non-Final Rejection). The examiner continued that the transfer electrodes claimed were obvious to those of skill in the art. *Id.* The applicants agreed with the examiner’s assessment by filing a terminal disclaimer to overcome the rejection. Ex. 32 (U.S. Patent App. No. 13/143,765, 2013-02-05 Terminal Disclaimer to Obviate a Provisional Double Patenting Rejection of a Pending “Reference” Application”).

97. The ’485 Patent has two independent claims, 1 and 6. Claim 1 is reproduced below:

> A semiconductor photodetection element comprising:
>
> > a silicon substrate which is comprised of a semiconductor of a first conductivity type, which has a first principal surface and a second principal surface opposed to each other, and which has a semiconductor region of a second conductivity type formed on the first principal surface side; and
> >
> > a transfer electrode part which is provided on the first principal surface of the silicon substrate and which transfers generated charge,
> >
> > wherein in the silicon substrate, an accumulation layer of the first conductivity type having a higher impurity concentration than the silicon substrate is formed on the second principal surface side and an irregular asperity is formed in a region opposed to at least the semiconductor region of the second conductivity type, in the second principal surface, and

> wherein the region where the irregular asperity is formed in the second principal surface of the silicon substrate is optically exposed.

98. Claim 6 is reproduced below:

A photodiode comprising:

> a silicon substrate which is comprised of a semiconductor of a first conductivity type, which has a first principal surface and a second principal surface opposed to each other, and which has a semiconductor region of a second conductivity type formed on the first principal surface side,
>
> wherein in the silicon substrate, an accumulation layer of the first conductivity type having a higher impurity concentration than the silicon substrate is formed on the second principal surface side and an irregular asperity is formed in a region opposed to at least the semiconductor region of the second conductivity type, in the second principal surface, and
>
> wherein the region opposed to the semiconductor region of the second conductivity type, in the second principal surface of the silicon substrate is optically exposed.

99. For at least the reasons discussed above with respect to the ’945 Patent, in paragraphs 89 - 94, which are incorporated herein by reference, Prof. Mazur and Dr. Carey should be the named inventors on the ’485 Patent.

100. The ’485 Patent cites United States Patent No. 7, 057,256 (the ’256 Patent”), assigned to Harvard, as prior art. Exs. 8, 30. Prof. Mazur and Dr. Carey are the named inventors on the ’256 Patent. *Id.*

United States Patent Number 8,884,226

101. On January 19, 2011, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/522,103, entitled “OCT Device.” United States Patent Number 8,884,226 (“the ’226 Patent”) issued from this application on November 11, 2014. Ex. 9. The ’226 Patent teaches Prof. Mazur and Dr. Carey’s inventions, but does not name them as inventors. Instead,

Hamamatsu Photonics K.K. employees are named as inventors. *Id.* The '226 Patent is assigned to Hamamatsu Photonics K.K. *Id.* SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

102. The '226 Patent teaches an optical coherence tomography device comprising a photo detector comprised of a silicon substrate with black silicon on a surface opposed to the surface on which light is incident. Claim 1 is the only independent claim and is reproduced below:

> An OCT device comprising:
>
> > a light source outputting light;
> >
> > a splitting unit outputting first split light and second split light by splitting the light output from the light source;
> >
> > a probe unit irradiating a measurement target object with the first split light output from the splitting unit and inputting and guiding light from the measurement target object;
> >
> > a coupling unit inputting light guided by the probe unit and reached as sample light, inputting the second split light output from the splitting unit and reached as reference light, and multiplexing the input reference light and the input sample light, and outputting an interference light caused by multiplexing; and
> >
> > a photodetector detecting an intensity of the interference light output from the coupling unit,
> >
> > wherein the photo detector comprises:
> >
> > a silicon substrate comprised of a semiconductor of a first conductivity type, having a first principal surface and a second principal surface opposed to each other, and having a semiconductor region of a second conductivity type formed on the first principal surface side; and
> >
> > a transfer electrode part provided on the first principal surface of the silicon substrate and transferring a generated charge,

> wherein in the silicon substrate, an accumulation layer of the first conductivity type having a higher impurity concentration than the silicon substrate is formed on the second principal surface side and an irregular asperity is formed in a region opposed to at least the semiconductor region of the second conductivity type, in the second principal surface, and
>
> wherein the region in which the irregular asperity is formed in the second principal surface of the silicon substrate is optically exposed.

103. Optical coherence tomography devices were known in the art before the filing of the ’226 Patent. In allowing the claims, the examiner found only the last two elements to be novel. Ex. 33 at 6 (U.S. Patent App. No. 13/522,103, 2014-07-17 Notice of Allowance and Fees Due). SiOnyx taught these elements to Hamamatsu.

104. In particular, the ’226 Patent describes the photodetector of the claims as “a back incident type solid-state imaging device and a BT-CCD (Charge Coupled Device) obtained by thinning the back side of a semiconductor substrate SS by etching with a KOH aqueous solution or the like.” Ex. 9 at col. 5:22-26. In an email dated March 2, 2007, Mr. Saylor suggested using black silicon with backside thinned, “backside illuminated CCD’s[.]” Ex. 16 (2007-03-02 Email from S. Saylor to K. Yamamoto re Backside thinned CCDs). Mr. Yamamoto of Hamamatsu Photonics K.K. responded, “The main reason why I [*sic*] interested in your technology was [*sic*] how to improve our BT-CCD [backside-thinned charged coupled device].” Ex. 16 (2007-03-02 Email from K. Yamamoto to S. Saylor re Backside thinned CCDs).

105. In addition to suggesting the use of black silicon in backside-thinned, backside-illuminated CCDs, SiOnyx suggested the other claim elements of the ’226 Patent related to the semiconductor substrate. For example, the below experimental architecture, suggested to Hamamatsu by SiOnyx, shows these elements.

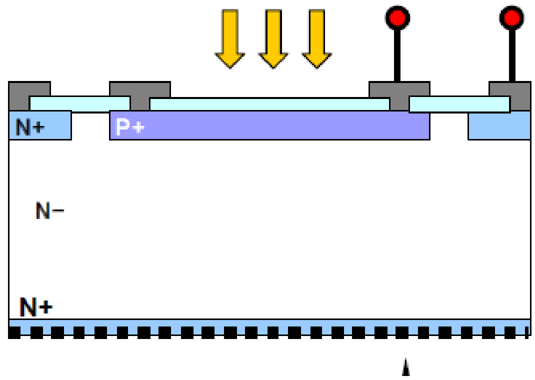


Fig. 16: Schematic of Photodiode Architecture Suggested to Hamamatsu by SiOnyx. Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary))

106. As shown in Figure 16, above, the silicon substrate is comprised of a first conductivity type, n-type. The silicon substrate has a first principal surface at the top of the schematic and a second principal surface at the bottom, opposed to one another. A region of a second conductivity type, p-type, is formed on the first principal surface side. As shown by the blue box along the bottom of the schematic, an accumulation layer of the first conductivity type, n-type, having a higher impurity concentration than the silicon substrate, as indicated by the "N+" label, is formed on the second principal surface side. The black squares along the bottom of the schematic indicate black silicon, which comprises an "irregular asperity." Hamamatsu therefore learned all inventive aspects of the claims of the '226 Patent from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the '226 Patent.

United States Patent Number 8,994,135

107. On December 23, 2013, Hamamatsu Photonics K.K. filed United States Patent Application No. 14/138,950, entitled "Photodiode and Photodiode Array." United States Patent Number 8,994,135 ("the '135 Patent") issued from this application on March 31, 2015. Ex. 44. The '135 Patent teaches Prof. Mazur and Dr. Carey's inventions, but does not name them as inventors. Instead, Hamamatsu Photonics K.K. employees are named as inventors. *Id.* The '135

Patent is assigned to Hamamatsu Photonics K.K.. *Id.* SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

108. The '135 Patent claims a photodiode array having black silicon on a light-incident surface. *Id.* Claims 1 and 7 are the only independent claims. Claim 1 is reproduced below:

> A back-illuminated type photodiode array in which a plurality of photodetecting channels configured for detection target light to enter thereinto are formed on a silicon substrate having a semiconductor layer of a first conductivity type, the photodiode array comprising:
>
>> an epitaxial semiconductor layer of a second conductivity type formed on the semiconductor layer of the first conductivity type, forming pn junctions at an interface of the semiconductor layer, and having a plurality of multiplication regions for avalanche multiplication of carriers generated with incidence of the detection target light, so that the multiplication regions correspond to the respective photodetecting channels; and
>>
>> a plurality of resistors each having two end portions, provided for the respective photodetecting channels, and each electrically connected through one of the end portions to the epitaxial semiconductor layer and connected through the other of the end portions to a signal conducting wire,
>>
>> wherein an irregular asperity is formed in at least a surface corresponding to the photodetecting channels in the semiconductor layer of the first conductivity type,
>>
>> wherein at least the surface corresponding to the photodetecting channels in the semiconductor layer of the first conductivity type is optically exposed, and
>>
>> wherein the surface where the irregular asperity is formed constitutes a light incident surface, light incident from the surface travels in the silicon substrate.

109. Claim 7 is reproduced below:

> A back-illuminated type photodiode array in which a plurality of photodetecting channels configured for detection target light to enter thereinto are formed on a silicon substrate having a

> semiconductor layer of a first conductivity type, the photodiode array comprising:
>
> > an epitaxial semiconductor layer of the first conductivity type formed on the semiconductor layer of the first conductivity type, and having a plurality of multiplication regions for avalanche multiplication of carriers generated with incidence of the detection target light, so that the multiplication regions correspond to the respective photodetecting channels;
> >
> > a semiconductor region of a second conductivity type formed in the epitaxial semiconductor layer of the first conductivity type and forming pn junctions at an interface of the epitaxial semiconductor layer; and
> >
> > a plurality of resistors each having two end portions, provided for the respective photodetecting channels, and each electrically connected through one of the end portions to the semiconductor region of the second conductivity type in the epitaxial semiconductor layer and connected through the other of the end portions to a signal conducting wire,
> >
> > wherein an irregular asperity is formed in at least a surface corresponding to the photodetecting channels in the semiconductor layer of the first conductivity type,
> >
> > wherein at least the surface corresponding to the photodetecting channels in the semiconductor layer of the first conductivity type is optically exposed, and
>
> wherein the surface where the irregular asperity is formed constitutes a light incident surface, light incident from the surface travels in the silicon substrate.

110. Avalanching photodiode arrays were known in the art. Thus, in allowing claims 1 and 7 of the ’135 Patent, the patent examiner identified only the “irregular asperity” and the placement of the irregular asperity on a light-incident surface of a back-illuminated photodiode array as novel. Ex. 45 at 11 (U.S. Patent App. No. 14/138,950 2014-11-21 Notice of Allowance and Fees Due). SiOnyx taught these elements to the Hamamatsu employees named as inventors on the ’135 Patent. For example, SiOnyx taught Hamamatsu to place black silicon on a light

incident surface. For example, in Figure 17 below, the black boxes represent black silicon and the yellow arrows represent incident light.

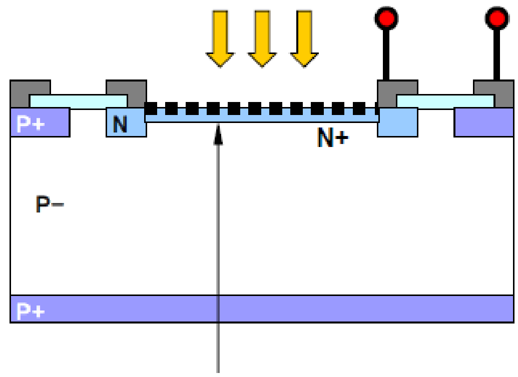


Fig. 17: Schematic of Photodiode Architecture Suggested to Hamamatsu by SiOnyx. Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary))

111. Further, SiOnyx suggested back-illuminated designs. *See, e.g.,* Ex. 16 (2007-03-02 Email from S. Saylor re Backside thinned CCDs). Hamamatsu therefore learned all inventive aspects of the claims of the ’135 Patent from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the ’135 Patent.

112. The ’135 Patent cites United States Patent No. 7,057,256 (“the ’256 Patent”), which is assigned to Harvard, as prior art. Exs. 30 & 44. Prof. Mazur and Dr. Carey are the named inventors on the ’256 Patent. *Id.* The ’135 Patent also cites United States Patent Publication Number 20120127401, which identifies Prof. Mazur as the named inventor.

United States Patent Number 9,190,551

113. On August 18, 2011, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/202,224, entitled “Photodiode and Photodiode Array.” United States Patent Number 9,190,551 (“the ’551 Patent”) issued from this application on November 17, 2015. Ex. 34. The ’551 Patent teaches Prof. Mazur and Dr. Carey’s inventions, but does not name them as inventors. Instead, Hamamatsu Photonics K.K. employees are named as inventors. *Id.* The ’551

Patent is assigned to Hamamatsu Photonics K.K. *Id.* SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application or patent until 2015.

114. The ’551 Patent claims an avalanche semiconductor photodiode having black silicon on a surface opposed to the surface on which light is incident. *Id.* Claim 1 is the only independent claim and is reproduced below:

> A photodiode comprising:
>
> > a silicon substrate comprised of a semiconductor of a first conductivity type and having a first principal surface and a second principal surface opposed to each other,
> >
> > wherein an avalanche photodiode composed of a pn junction between a semiconductor region of the first conductivity type having a higher impurity concentration than the silicon substrate and a semiconductor region of a second conductivity type is arranged on a first principal surface side of the silicon substrate,
> >
> > wherein on a second principal surface side of the silicon substrate, an accumulation layer of the first conductivity type having a higher impurity concentration than the silicon substrate is formed and an irregular asperity is formed in at least a region opposed to the avalanche photodiode,
> >
> > wherein the region opposed to the avalanche photodiode in the second principal surface of the silicon substrate is optically exposed, and
> >
> > wherein the first principal surface constitutes a light incident surface, light incident from the first principal surface ravels in the silicon substrate, the photodiode being a front-illuminated type.

115. Avalanche photodiodes were known in the art before the filing of the ’551 Patent. In allowing the claims of the ’551 Patent, the patent examiner identified only the element claiming “wherein the first principal surface constitutes a light incident surface, light incident from the first principal surface travels in the silicon substrate, the photodiode being a front-illuminated type” as novel. Ex. 35 at 7 (U.S. Patent App. No. 13/202,244 2015-07-15 Notice of

Allowance and Fees Due). SiOnyx, and specifically Dr. Carey, taught this element to the individuals named as inventors on the ’551 Patent. For example, the experimental architecture shown in Figure 18 below, which SiOnyx proposed to Hamamatsu, shows a front-illuminated photodiode with a first principal surface that is a light incident surface and light incident from the first principal surface travels in the silicon substrate.

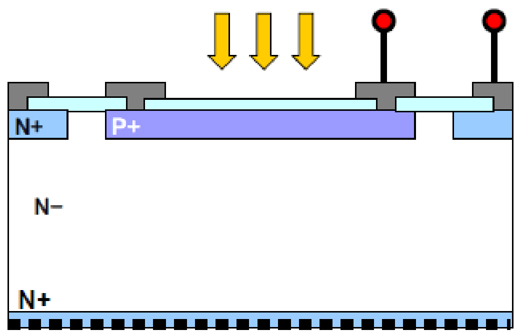


Fig. 18: Architecture of Photovoltaic Photodiode, Designed by SiOnyx, Fabricated and Tested under Mutual Non-Disclosure Agreement. Ex. 18 at 2 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary)).

116. The surface structures in black silicon, represented in Figure 18 above by black squares, comprise an “irregular asperity,” as claimed in the ’551 Patent. The specification of the ’551 Patent explains that the irregular asperity is created by exposure of the silicon to a pulsed laser beam, just as SiOnyx taught Hamamatsu. *See* Ex. 34 at col. 6:4-23. SiOnyx also taught Hamamatsu to subject the substrate to a thermal treatment after forming the black silicon. *See, e.g.,* Ex. 26 (2007-02-28 Email from J. Carey to K. Yamamoto re Proposed project plan Feb 2007).

117. Finally, below is a side-by-side comparison of Figure 11 from the ’551 Patent, which shows all elements of claim 1, on the left, with one of the experimental architectures suggested to Hamamatsu by SiOnyx, on the right.

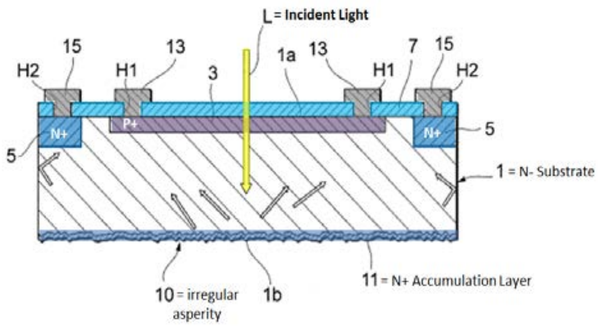


Fig. 19: Annotated Version of Fig. 11 from '551 Patent (Color and Text Labels not Original). Ex. 34

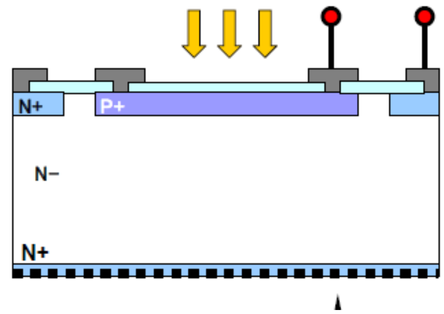


Fig. 20: Schematic of Photodiode Architecture Suggested to Hamamatsu by SiOnyx. Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary))

118. As shown by Figures 19 and 20, above, Hamamatsu learned all inventive aspects of the claims of the '551 Patent from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the '551 Patent.

United States Patent Application Number 13/634,249

119. On September 12, 2012, Hamamatsu Photonics K.K. filed United States Patent Application No. 13/634,249 ("the '249 Application"), entitled "Semiconductor Light Detecting Element Having Silicon Substrate and Conductor." The Patent and Trademark Office issued a Notice of Allowance for this Application on November 11, 2015. Ex. 46. The allowed claims of the '249 Application teach Prof. Mazur and Dr. Carey's inventions, but the application does not name them as inventors. Instead, Hamamatsu Photonics K.K. employees are named as inventors. *Id.* The '249 Application is assigned to Hamamatsu Photonics K.K. Ex. 48. SiOnyx, Harvard, Prof. Mazur, and Dr. Carey were unaware of this application until 2015.

120. The allowed claims of the '249 Application teach a semiconductor light detecting element having an irregular asperity formed on the surface opposite to the surface on which light

is incident. Ex. 46 at 9. Only one independent claim was allowed. This claim is reproduced below:

> A semiconductor light detecting element comprising:
>
> > a silicon substrate having a semiconductor layer having a first impurity concentration, and an epitaxial semiconductor layer grown on the semiconductor layer and having a second impurity concentration lower than the first impurity concentration; and
> >
> > a conductor provided on a surface of the epitaxial semiconductor layer,
> >
> > wherein a photosensitive region is formed in the epitaxial semiconductor layer,
> >
> > wherein irregular asperity is formed at least in a surface opposed to the photosensitive region in the semiconductor layer,
> >
> > wherein the irregular asperity is optically exposed,
> >
> > wherein the irregular asperity is formed by applying pulsed laser light,
> >
> > light incident into the silicon substrate is scattered, diffused, or reflected by the irregular asperity to travel in the silicon substrate, and
> >
> > the photosensitive region is configured to generate an electric charge in response to incident light.

121. In allowing the claims of the ’249 Application, the examiner cited only the last 5 elements as the point of novelty. Ex. 46 at 7. SiOnyx, and specifically Dr. Carey, taught all three of these elements to the Hamamatsu employees named as inventors on the ’249 Application. For example, SiOnyx taught Hamamatsu to create black silicon using laser pulsed laser light on a surface opposed to the photosensitive region. For example, the architecture below, suggested to Hamamatsu by SiOnyx, shows black silicon, represented by black squares,

on a surface opposite to the photosensitive region, indicated by the yellow arrows, showing the direction of incident light.

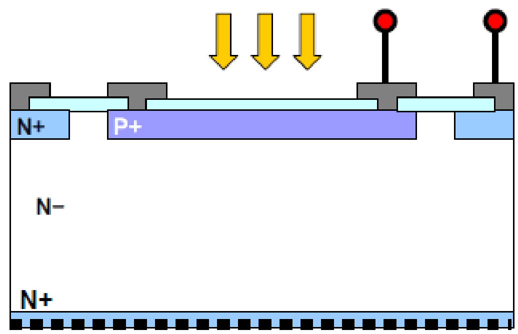


Fig. 21: Schematic of Photodiode Architecture Suggested to Hamamatsu by SiOnyx. Ex. 18 (2007-11-28 Black Silicon Photo Detector No. 1 (brief summary))

122. The black silicon in the above image is optically exposed, light incident into the silicon substrate is [redacted] Finally, the architecture suggested to Hamamatsu by SiOnyx is for a photodiode. Ex. 18 at 4. Thus, Hamamatsu learned all inventive aspects of the claims of the ’249 Application from SiOnyx. Accordingly, Prof. Mazur and Dr. Carey are the true inventors of the ’249 Application.

United States Patent Application Number 14/683,524

123. In addition to the issued Patents and Application discussed above, Hamamatsu has at least one application pending before the United States Patent and Trademark Office with a claim set currently directed to information SiOnyx disclosed to Hamamatsu under the Mutual Non-Disclosure Agreement.

124. Hamamatsu filed United States Patent Application Number 14/683,524 (“the ’524 Application”) on April 15, 2015. The ’524 Application is a continuation of Application Number 13/202,244, which issued as the ’551 Patent, discussed above. All elements of the claims currently pending in the ’524 Application were taught to Hamamatsu by SiOnyx under the

Mutual Non-Disclosure Agreement. For example, currently pending claim 8 of the ’524 Patent teaches a photodiode with “an irregular asperity” formed on a “light incident surface.” An excerpt of the file history, including the specification and currently pending claims, of the ’524 Application is attached hereto as Exhibit 47. Should a patent issue from the ’524 Application that claims Harvard’s and SiOnyx’s technology, Prof. Mazur and Dr. Carey are the rightful inventors of such claims.

V. COUNT I

Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,564,087 (Prof. Mazur and Dr. Carey as Sole Joint Inventors)
Against Hamamatsu Photonics K.K.

125. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

126. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the ’087 Patent.

127. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the ’087 Patent and the individuals currently listed as inventors on the ’087 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

VI. COUNT II

In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,564,087 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors)
Against Hamamatsu Photonics K.K.

128. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

129. Prof. Mazur and Dr. Carey are inventors of all claims of the ’087 Patent and should be added to the individuals currently named as inventors on the ’087 Patent.

130. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the ’087 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

VII. COUNT III

Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,742,528 (Prof. Mazur and Dr. Carey as the Sole Joint Inventors) Against Hamamatsu Photonics K.K.

131. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

132. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the ’528 Patent.

133. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the ’528 Patent and the individuals currently listed as inventors on the ’528 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

VIII. COUNT IV

In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,742,528 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors) Against Hamamatsu Photonics K.K.

134. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

135. Prof. Mazur and Dr. Carey are inventors of all claims of the ’528 Patent and should be added to the individuals currently named as inventors on the ’528 Patent.

136. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the ’528 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

IX. COUNT V

Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,916,945 (Prof. Mazur and Dr. Carey as Sole Joint Inventors) Against Hamamatsu Photonics K.K.

137. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

138. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the ’945 Patent.

139. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the ’945 Patent and the individuals currently listed as inventors on the ’945 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

X. COUNT VI

In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,916,945 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors) Against Hamamatsu Photonics K.K.

140. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

141. Prof. Mazur and Dr. Carey are inventors of all claims of the ’945 Patent and should be added to the individuals currently named as inventors on the ’945 Patent.

142. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the ’945 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

XI. COUNT VII

**Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,629,485 (Prof. Mazur and Dr. Carey as the Sole Joint Inventors)
Against Hamamatsu Photonics K.K.**

143. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

144. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the ’485 Patent.

145. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the ’485 Patent and the individuals currently listed as inventors on the ’485 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

XII. COUNT VIII

**In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,629,485 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors)
Against Hamamatsu Phonics K.K.**

146. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

147. Prof. Mazur and Dr. Carey are inventors of all claims of the ’485 Patent and should be added to the individuals currently named as inventors on the ’485 Patent.

148. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the ’485 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

XIII. COUNT IX

Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,884,226 (Prof. Mazur and Dr. Carey as Sole Joint Inventors)
Against Hamamatsu Photonics K.K.

149. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

150. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the ’226 Patent.

151. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the ’226 Patent and the individuals currently listed as inventors on the ’226 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

XIV. COUNT X

In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,884,226 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors)
Against Hamamatsu Photonics K.K.

152. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

153. Prof. Mazur and Dr. Carey are inventors of all claims of the ’226 Patent and should be added to the individuals currently named as inventors on the ’226 Patent.

154. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the '226 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

XV. COUNT XI

<u>Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,994,135 (Prof. Mazur and Dr. Carey as Sole Joint Inventors)</u>
<u>Against Hamamatsu Photonics K.K.</u>

155. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

156. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the '135 Patent.

157. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the '135 Patent and the individuals currently listed as inventors on the '135 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

XVI. COUNT XII

<u>In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 8,994,135 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors)</u>
<u>Against Hamamatsu Photonics K.K.</u>

158. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

159. Prof. Mazur and Dr. Carey are inventors of all claims of the '135 Patent and should be added to the individuals currently named as inventors on the '135 Patent.

160. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the ’135 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

XVII. COUNT XIII

**<u>Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 9,190,551 (Prof. Mazur and Dr. Carey as Sole Joint Inventors)
Against Hamamatsu Photonics K.K.</u>**

161. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

162. Prof. Mazur and Dr. Carey are the sole joint inventors of all claims of the ’551 Patent.

163. Through omission, inadvertence, and/or error, Prof. Mazur and Dr. Carey were not listed as inventors on the ’551 Patent and the individuals currently listed as inventors on the ’551 Patent were improperly joined. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur or Dr. Carey.

XVIII. COUNT XIV

**<u>In the Alternative: Correction of Inventorship under 35 U.S.C. § 256 on U.S. Patent No. 5,190,551 (Prof. Mazur and Dr. Carey as Joint Inventors with the Currently Named Inventors)
Against Hamamatsu Photonics K.K.</u>**

164. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

165. Prof. Mazur and Dr. Carey are inventors of all claims of the ’551 Patent and should be added to the individuals currently named as inventors on the ’551 Patent.

166. Through omission, inadvertence, and/or error Prof. Mazur and Dr. Carey were not listed on the ’551 Patent as joint inventors. The omission, inadvertence, and/or error occurred without any deceptive intent on the part of Prof. Mazur and Dr. Carey.

XIX. COUNT XV

Declaratory Judgment Under 28 U.S.C. §§ 2201 and 2202
Against Hamamatsu Photonics K.K. and Hamamatsu Corp.

167. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

168. An actual, present, and justiciable controversy has arisen concerning inventorship of the ’087, ’528,’945, ’485, ’226, ’ 135, and ’551 Patents.

169. Prof. Mazur and Dr. Carey are the sole joint inventors of the ’087, ’528,’945, ’485, ’226, ’135, and ’551 Patents or joint inventors with the inventors currently listed on those Patents.

170. Prof. Mazur and Dr. Carey are not listed as the sole inventors or joint inventors with the inventors currently listed on the ’087, ’528,’945, ’485, ’226, ’135, and ’551 Patents.

171. Plaintiffs seek declaratory judgment from this Court that Prof. Mazur and Dr. Carey are the sole inventors of the ’087, ’528,’945, ’485, ’226, ’135, and ’551 Patents and any injunctive relief necessary to enforce its rights under that declaratory judgment.

XX. COUNT XVI

Breach of Contract
against Hamamatsu Photonics K.K.

172. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

173. The Mutual Non-Disclosure Agreement constitutes a valid and enforceable contract.

174. SiOnyx entered into the Mutual Non-Disclosure Agreement with Hamamatsu Photonics K.K. on January 11, 2007. Hamamatsu Photonics K.K. agreed that information disclosed pursuant to the Mutual Non-Disclosure Agreement would be "solely for the limited purpose of EVALUATING APPLICATIONS AND JOINTS [*SIC*] DEVELOPMENT OPPORTUNITIES OF PULSED LASER PROCESS DOPED PHOTONIC DEVICES and for no other purposes whatsoever (the 'Permitted Purpose.')." Ex. 10 at 1 (emphasis original). Further, the Agreement provides:

> The Receiving Party acknowledges that the Disclosing Party (or any third party entrusting its own confidential information to the Disclosing Party) claims ownership of the Confidential Information disclosed by the Disclosing Party and all patent, copyright, trademark, trade secret, and other intellectual property rights in, or arising from, such Confidential Information. No option, license, or conveyance of such rights to the Receiving Party is granted or implied under this Agreement. *Id.* at 2.

175. SiOnyx has performed all conditions, covenants, and promises required by the Mutual Non-Disclosure Agreement.

176. Hamamatsu Photonics K.K. has breached the Mutual Non-Disclosure Agreement at least by disclosing SiOnyx's confidential and proprietary technology in filing the applications that lead to the issuance of the '087, '528,'945, '485, '226, '135, and '551 Patents.

177. In addition, Hamamatsu Photonics K.K. has breached the Mutual Non-Disclosure Agreement at least by using SiOnyx's confidential and proprietary technology in commercial products that include black silicon.

178. SiOnyx seeks damages incurred as a result of Hamamatsu Photonics K.K.'s breach of the Mutual Non-Disclosure Agreement. The damages to SiOnyx are in excess of $75,000, exclusive of interest and costs, with the specific amount subject to further evaluation and calculation.

179. In particular, SiOnyx seeks damages from the Hamamatsu Defendants in an amount sufficient to compensate for lost business opportunities caused by Hamamatsu's incorrect claims of inventorship and ownership of the '087, '528,'945, '485, '226, '135, and '551 Patents. By non-limiting example, in the summer of 2014, SiOnyx entered into a [redacted] with [redacted] for development of customized silicon sensors using Harvard's and SiOnyx's proprietary black silicon technology. Ex. 38. Upon information and belief, SiOnyx lost the contract with [redacted] because of the existence of Hamamatsu's Patents, including the '087, '528,'945, '485, '226, '135, and '551 Patents. The loss of profits to SiOnyx is a reasonably foreseeable result of Hamamatsu's breach of the Mutual Non-Disclosure Agreement, Ex. 10, by improperly filing patents on Harvard's and SiOnyx's technology.

XXI. COUNT XVII

Unjust Enrichment
Against Hamamatsu Photonics K.K. and Hamamatsu Corp.

180. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

181. Plaintiffs conferred a benefit on the Hamamatsu Defendants by providing them with valuable intellectual property through Prof. Mazur and Dr. Carey.

182. The Hamamatsu Defendants accepted and retained Plaintiffs' valuable intellectual property and used it to their own advantage at Plaintiffs' expense.

183. The Hamamatsu Defendants have been and continue to be unjustly enriched by profiting from the wrongful conduct described in this Complaint. In particular, the Hamamatsu Defendants have made wrongful use of SiOnyx and Harvard's property by asserting inventorship, refusing to name Prof. Mazur and Dr. Carey as the sole inventors or joint inventors

with the individuals currently listed as inventors on the ’087, ’528,’945, ’485, ’226, ’135, and ’551 Patents, and deriving an unjust benefit from commercially exploiting SiOnyx and Harvard’s inventions. It would be inequitable for the Hamamatsu Defendants to retain the benefits of its wrongful conduct.

184. Plaintiffs have incurred, and continue to incur detriment in the form of loss of money and property as a result of the Hamamatsu Defendants’ wrongful use of Prof. Mazur and Dr. Carey’s intellectual property rights, including the right to any patent based on their intellectual property and to any patent documents (including assignment documents), U.S. or foreign that belong to Plaintiffs.

185. The intellectual property and associated rights, including the right to any patents based on Prof. Mazur and Dr. Carey’s inventions and to any patent documents (including assignment documents), U.S. and foreign, are unique and there is no adequate remedy at law.

186. The harm to Plaintiffs is and continues to be substantial and irreparable.

XXII. COUNT XVIII

Patent Infringement under 35 U.S.C. § 271 of U.S. Patent 7,884,446 against Defendants

187. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

188. Upon information and belief, in violation of 35 U.S.C. § 271, Defendants and their subsidiaries have directly infringed and continue to directly infringe, both literally and under the doctrine of equivalents, one or more claims of the ’446 Patent, by, without limitation, making, using, importing, selling, and/or offering for sale products incorporating a silicon die that includes all of the limitations of one or more of the claims of the ’446 Patent, within the District of Massachusetts and elsewhere within the United States. For example, Hamamatsu

offers to sell and/or sells imaging devices that meet all elements of one or more claims of the '446 Patent within the United States through its website. *See, e.g.,* Exs. 23-24, 39, & 41. An element-by-element analysis showing that an exemplary Hamamatsu imaging sensor practices all elements of one or more claims of the '446 Patent is provided below. Defendants' end products that incorporate Hamamatsu's sensors also infringe.

189. Also in violation of 35 U.S.C. § 271, upon information and belief, Defendants and their subsidiaries have indirectly infringed and continue to indirectly infringe one or more claims of the '446 Patent by contributing to or inducing direct infringement, either literally or under the doctrine of equivalents, by another. Hamamatsu, for example, has had knowledge of the '446 Patent at least as of the filing date of Hamamatsu's '087, '528, '945, '485, '135, and '551 Patents, which cite Dr. Carey and Dr. Mazur's Patents as prior art. Exs. 5-8, 34, & 44. Further, Hamamatsu was aware of Harvard's and SiOnyx's intellectual property since the beginning of the relationship with SiOnyx. *See* Exs. 10 & 21. Having knowledge of Harvard's and SiOnyx's Patents, Hamamatsu induced others in the United States to use, sell, and/or offer for sale in the United States, and/or import into the United States products that include Hamamatsu's image sensors that practice all elements of one or more claims of the '446 Patent. 35 U.S.C. § 271(b). For example, the Ocean Optics Maya2000 Pro-NIR spectrometer, which is offered for sale and sold in the United States, includes a Hamamatsu S11499-01 image sensor. Exs. 40-41. As described below, the S11499-01 practices all elements of one or more claims of the '446 Patent. Upon information and belief, Hamamatsu knew and intended that use of these sensors would cause direct infringement of the '446 Patent.

190. Further, the Hamamatsu image sensors that practice all elements of one or more claims of the '446 Patent, such as the S11499-01 sensor has no substantial non-infringing uses.

35 U.S.C. § 217(c). Upon information and belief, Hamamatsu has knowingly contributed to the direct infringement of another through use, sale, and/or offers of sale in the United States and/or importation into the United States of its devices that practice one or more claims of the ’446 Patent.

191. Hamamatsu’s infringement of the ’446 Patent is willful. Hamamatsu had knowledge of the ’446 Patent at least as of the filing date of the ’087, ’528, ’945, ’485, ’135, and ’551 Patents, which cite patents in the same family the ’446 Patent as prior art, but has continued to directly and indirectly infringe. *See* Exs. 5-8, 34, & 44. In addition, Hamamatsu has had knowledge of Harvard’s and SiOnyx’s intellectual property since the beginning of the relationship between SiOnyx and Hamamatsu. *See* Exs. 10 & 21. Despite knowing of this intellectual property, Hamamatsu intentionally made, used, offered for sale, or sold in the United States or imported into the United States infrared-enhanced photodiodes that practice one or more claims of the ’446 Patent.

192. Defendant’s acts of infringement have caused damage to SiOnyx. SiOnyx is entitled to recover damages in an amount subject to proof at trial, including treble damages for Hamamatsu’s willful infringement.

193. Plaintiffs have been, and continue to be, damaged and irreparably harmed by Defendants’ infringement, which will continue unless Defendants are enjoined by this Court. *See eBay Inc. v. Mercexchange, LLC*, 547 U.S. 388 (2006). In particular, SiOnyx is a practicing entity in the business of selling sensors that practice all elements of one or more claims of the ’446 Patent. *See, e.g.,* Ex. 43 (“Sensors” page from SiOnyx’s website describing SiOnyx’s XQE sensors). Hamamatsu is a direct competitor to SiOnyx in the field of infrared-enhanced sensors. Further, the inventions of the ’446 Patent are central to SiOnyx’s business. Thus, remedies

available at law are inadequate to protect SiOnyx from Defendants' infringement and the balance of hardships favors enjoining Defendants' actions. Finally, the public interest would not be disserved by a permanent injunction preventing Defendants from selling products that infringe the '446 Patent.

194. An element-by-element comparison of the Hamamatsu S11499-01 sensor to the claims of the '446 Patent is provided below. This analysis is exemplary and not intended to limit Plaintiffs' allegations to S11499-01 sensor. Rather, Hamamatsu produces many imaging devices with improved near-infrared characteristics that meet all elements of one or more claims of the '446 Patent, including at least the following sensors: C11008MA; C11010MA; C5964-0901; C5964-1011; C8484-03; C9408MA; C9410MA; S11499; S11510-1006; S11510-1106; S12028; C9405CB; S11500-1007; S11518-10; S11518-30; S11519-10; and S11519-30. Defendants' end products that incorporate Hamamatsu's sensors also infringe.

195. Further, the claims analyzed below are exemplary only and not intended to limit Plaintiffs' allegations. The analysis is based on information available to Plaintiffs before discovery in this action. Plaintiffs preserve the right to add additional asserted claims alleged to be infringed based on discovery conducted in this action.

Claim 1

a. [Preamble] A semiconductor substrate comprising:

196. The Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode includes a semiconductor substrate. In particular, the image below is a top-view of the Hamamatsu S11499-01, showing the photon receiving area, which includes a silicon substrate.

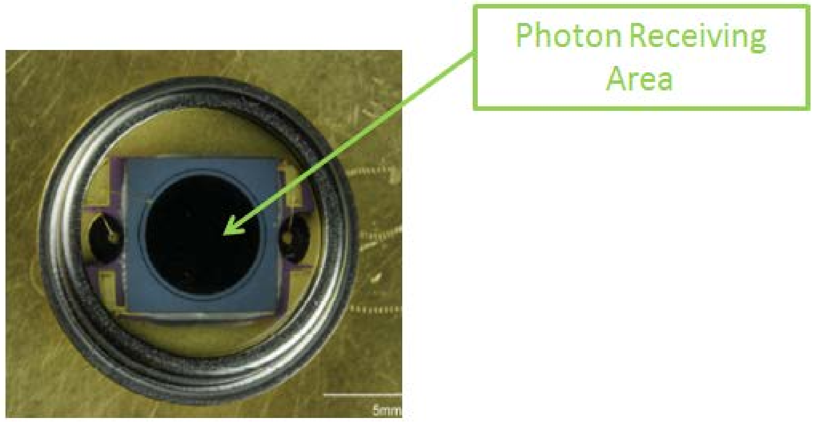


Fig. 22: Top-View Image of Hamamatsu S11499-01 Sensor

197. The following cross-section image of the Hamamatsu S11499-01, taken by Chipworks Inc., shows the silicon die included in the photon receiving area. The silicon die comprises a semiconductor substrate.

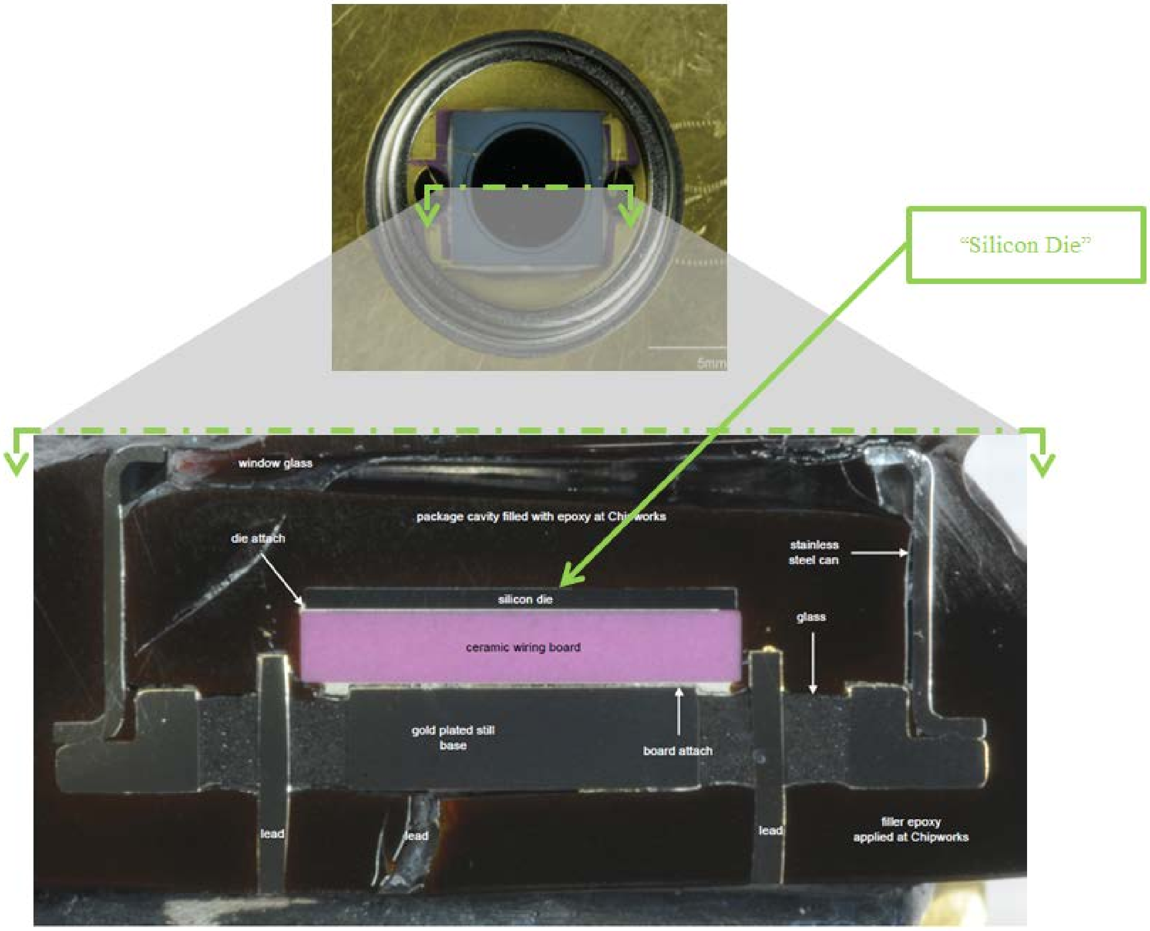


Fig. 23: Top-View and Cross-Section of Hamamatsu S11499-01 Sensor

b. [Element 1a]: a surface layer having at least a portion exhibiting an undulating topography characterized by a plurality of sub-micron sized features having an average height less than about 1 micrometer and an average width in a range of about 100 nm to about 500 nm

198. The semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode comprises a surface layer having at least a portion exhibiting an undulating topography characterized by a plurality of sub-micron sized features having an average height less than about 1 micrometer and an average width in a range of about 100 nm to about 500 nm. In particular, the image below, taken by Chipworks Inc. with a scanning electron microscope ("SEM"), is a magnified cross-section of the semiconductor substrate included in the

Hamamatsu S11499-01. This image shows the undulating topography of the surface layer of the substrate.

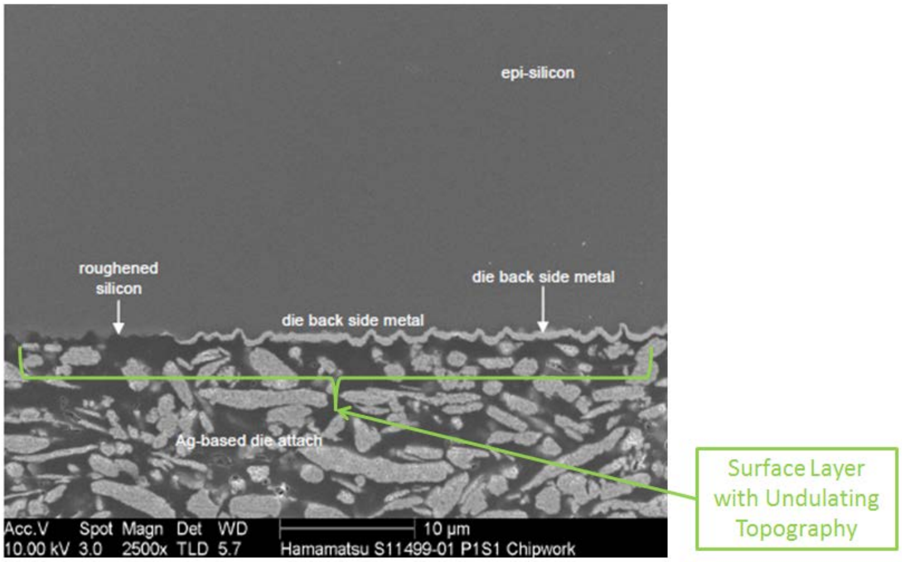


Fig. 24: SEM Image of Substrate of Hamamatsu S11499-01 Substrate

199. The undulating topography of the semiconductor substrate of the S11499-01 is characterized by a plurality of submicron sized features having an average height less than about 1 micrometer (μm). The SEM image below, taken by Chipworks, Inc., is a magnified cross section of the semiconductor substrate included in the Hamamatsu S11499-01. The scale at the bottom of the image shows a 10 μm (micrometer) length. This scale is used in subsequent images to measure the size of the features that characterize the undulating topography.

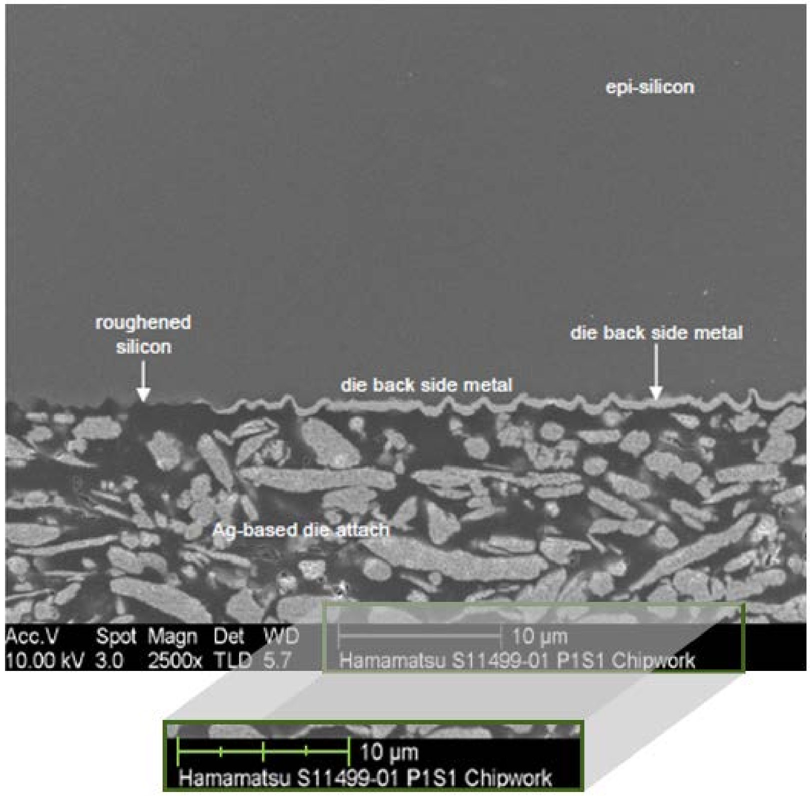


Fig. 25: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing Scale

200. As shown in the image below, measurements based on the 10 µm scale show that the plurality of submicron-sized features that characterize the undulating topography of the silicon substrate included in the Hamamatsu S11499-01 have an average height of less than about 1 micrometer.

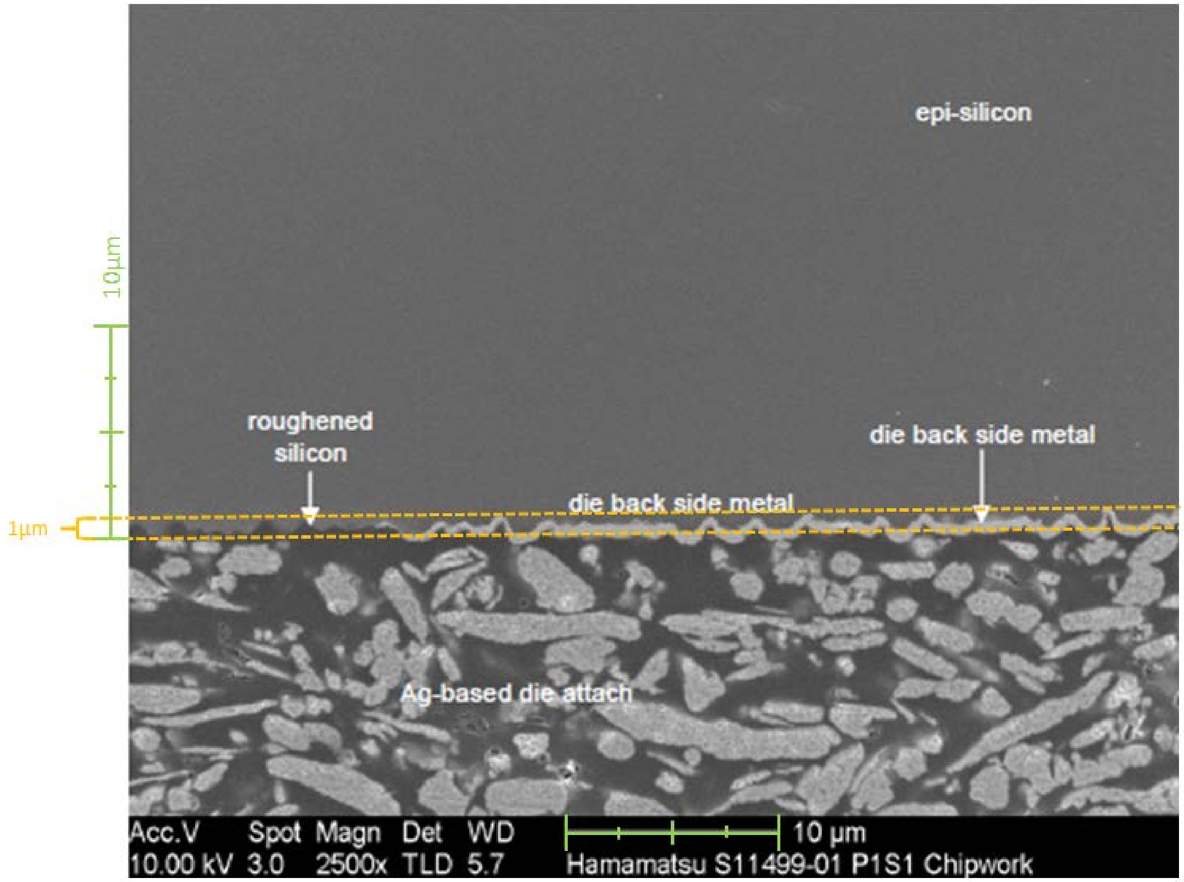


Fig. 26: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing 1 µm Measurement

201. The submicron-sized features that characterize the surface layer of the S11499-01 photodiode have an average width in a range of about 100 nanometers (0.1 µm) to about 500 nanometers (0.5 µm). In particular, the SEM image below, taken by Chipworks Inc., is a magnified cross section of the semiconductor substrate included in the Hamamatsu S11499-01. For example, below is a top-down image of the surface layer of semiconductor substrate included in the Hamamatsu S11499-01, taken by Chipworks Inc. The undulating topography of the surface layer includes submicron sized features, whose individual width is less than or about 1 µm.

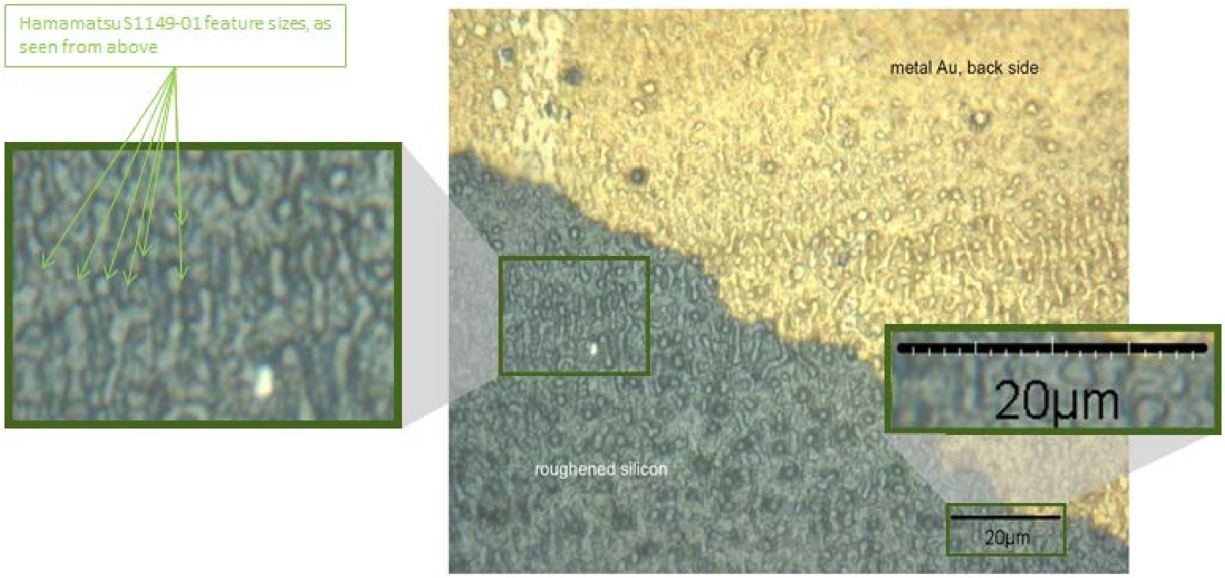


Fig. 27: Magnified Top-Down Image of the Semiconductor Substrate of the S11499-01 Showing Surface Feature Width

202. Further, the SEM image below is a cross section of the semiconductor substrate included in the Hamamatsu S11499-01, also taken by Chipworks Inc. Measurements of several features are provided, based on the 10 μm scale. The average width of these features is less than about 500 nm (0.5 μm).

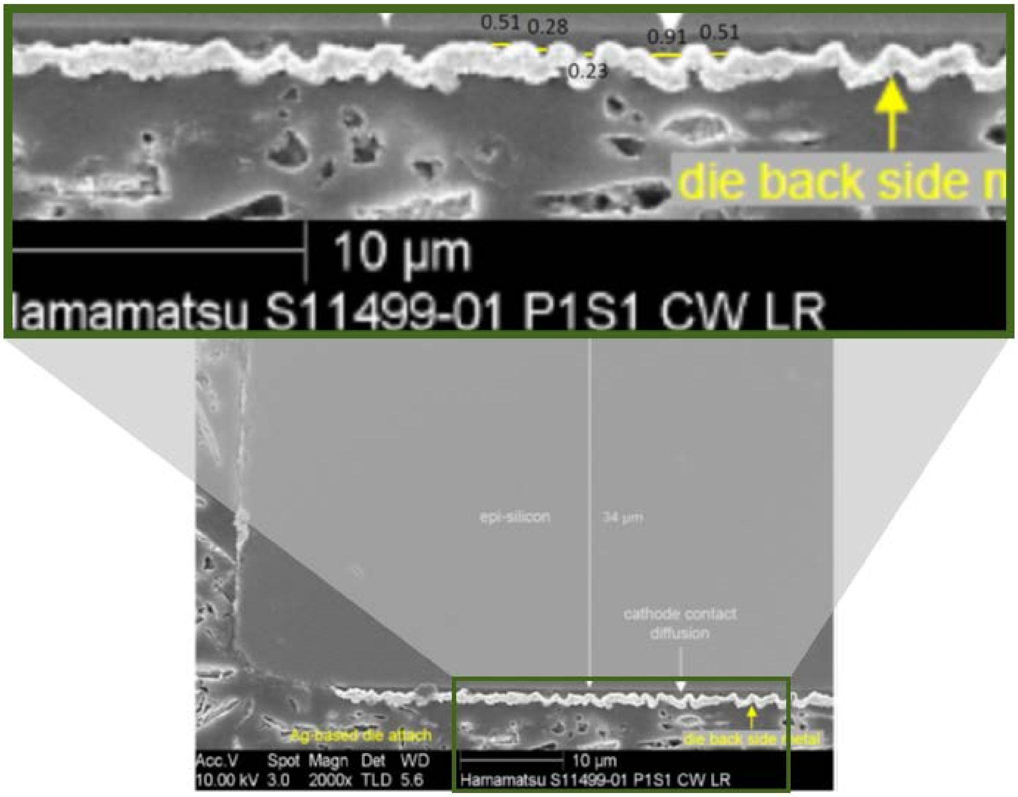


Fig. 28: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing Surface Feature Width.

203. Accordingly, the semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode meets all elements of claim 1 of the '446 Patent.

Claim 2: The semiconductor of claim 1, wherein said substrate comprises a silicon wafer.

204. The semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode comprises a silicon wafer. In particular, the following cross-section image of the Hamamatsu S11499-01, taken by Chipworks Inc., shows the silicon die included in the photon receiving area. The silicon die comprises a silicon wafer.

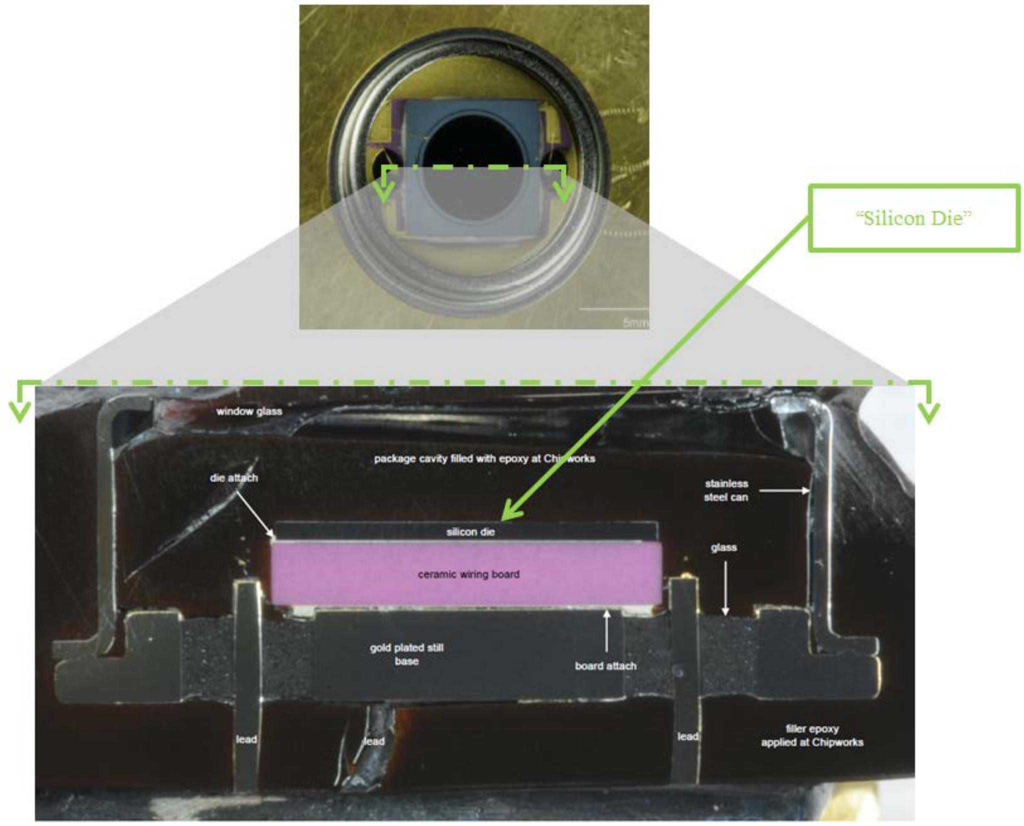


Fig. 29: Top-View and Cross-Section of Hamamatsu S11499-01 Sensor

205. Further, the below secondary ion mass spectrometry profile, prepared by Chipworks Inc., shows that the semiconductor included in the Hamamatsu S11499-01 is comprised of a silicon wafer.

Secondary Ion Mass Spectrometry Profile – Bottom Side Cathode Doping, 3 µm Deep Profile for As, F, N, P, S, and Sb (*Note: all elements are at their detection limits after they reach plateau*)

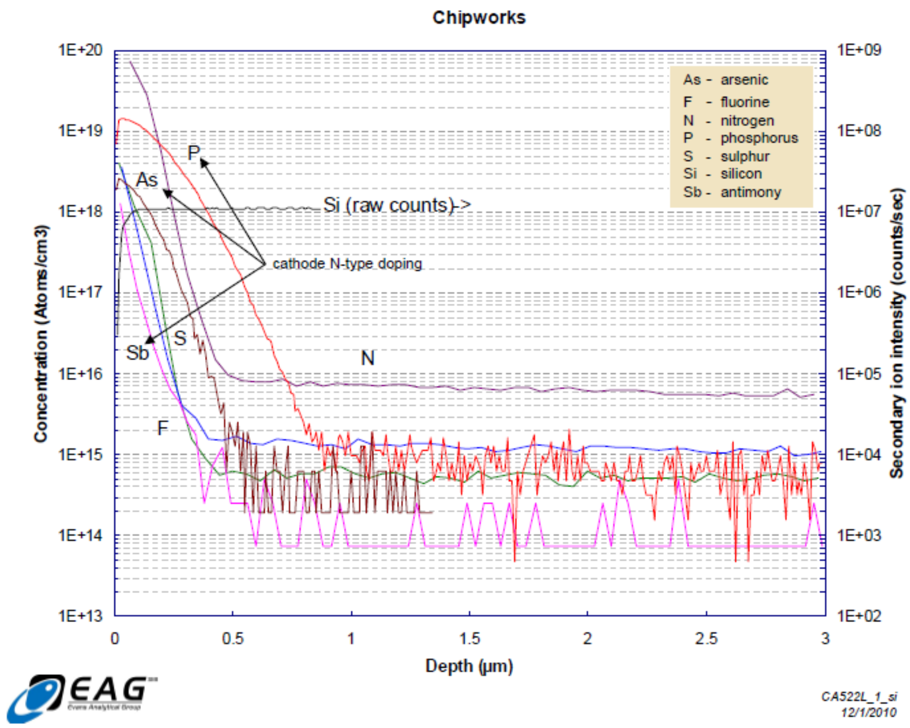


Fig. 30: Secondary Ion Mass Spectrometry Showing S11499-01 Substrate is Comprised of Silicon ("Si (raw counts)")

Claim 3: The semiconductor substrate of claim 1, wherein said substrate comprises an n-doped silicon wafer.

206. The semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode comprises an n-doped silicon wafer. In particular, the secondary ion mass spectrometry profile, prepared by Chipworks Inc., shows that the semiconductor substrate of the Hamamatsu S11499-01 includes arsenic (chemical symbol As), phosphorus (chemical symbol P), and antimony (chemical symbol Sb). Upon information and belief, one or more of these substances are used for n-type doping of the substrate. N-type doping refers to the introduction of interstitial atoms with 5 valence electrons into the crystalline lattice of intrinsic silicon. As, P, and Sb each have 5 valence electrons.

Secondary Ion Mass Spectrometry Profile – Bottom Side Cathode Doping, 3 µm Deep Profile for As, F, N, P, S, and Sb (*Note: all elements are at their detection limits after they reach plateau*)

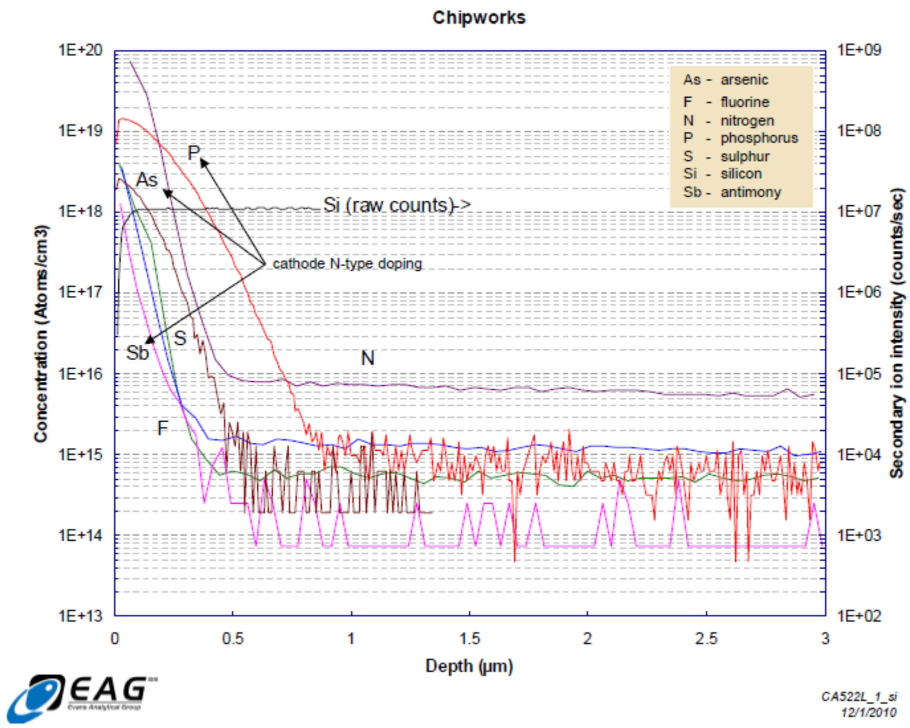


Fig. 31: Secondary Ion Mass Spectrometry Showing S11499-01 Substrate Includes N-Type Dopants ("As," "P," & "Sb")

Claim 4: The semiconductor substrate of claim 1, wherein said surface layer has a thickness in a range of about 20 nm to about 1 micrometer.

207. The surface layer of the semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode has a thickness in a range of about 20 nm to about 1 micrometer. In particular, the SEM image below, taken by Chipworks Inc., is a cross section of the semiconductor substrate included in the Hamamatsu S11499-01. The orange lines show a thickness of about 1 µm (1000 nm). The thickness of the surface layer, which exhibits an undulating topography, is between 20 nm (0.02 µm) and 1 µm.

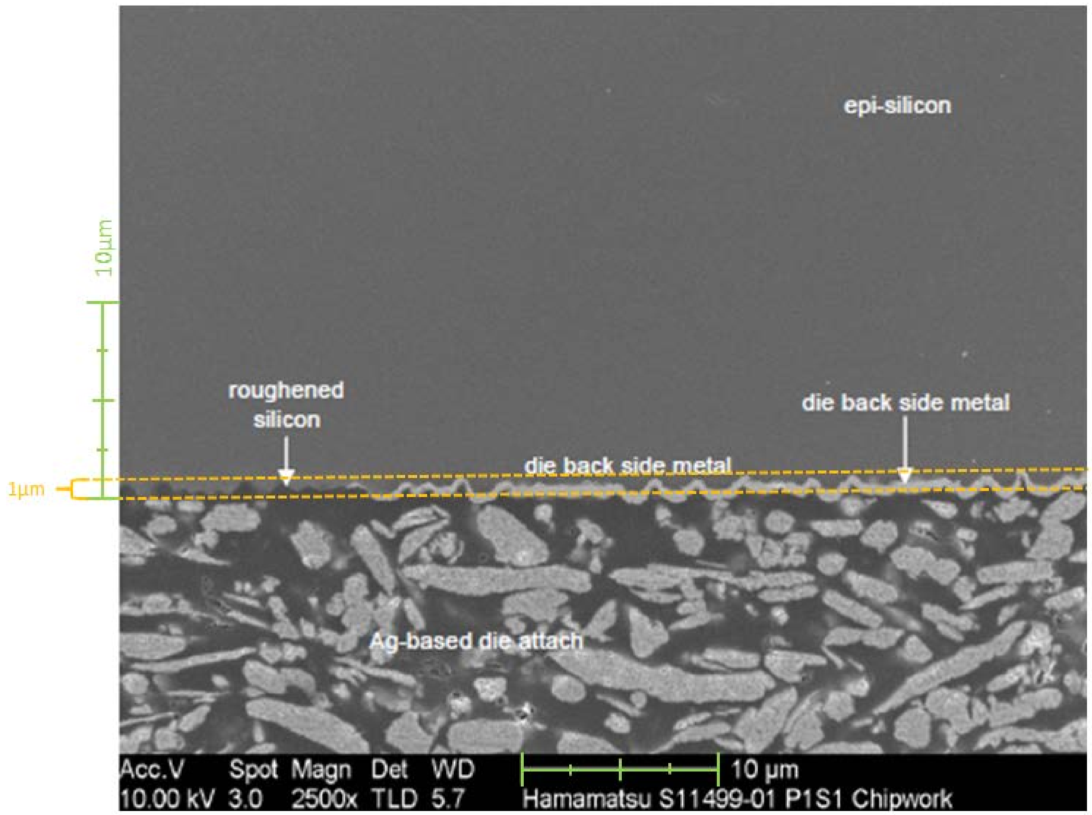


Fig. 32: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing 1 µm Measurement

Claim 5: The semiconductor substrate of claim 1, wherein said submicron-sized features comprise spikes extending from a base to a tip separated from the base by a distance of less than about 1 micrometer.

208. The submicron-sized features of the semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode comprise spikes extending from a base to a tip separated from the base by a distance less than about 1 micrometer. In particular, the SEM image below, taken by Chipworks Inc., is a cross section of the semiconductor substrate included in the Hamamatsu S11499-01. The orange lines in the image below show a distance of about 1 µm. The distance from the base to the tip of the spikes that comprise the submicron-sized features fall within these lines.

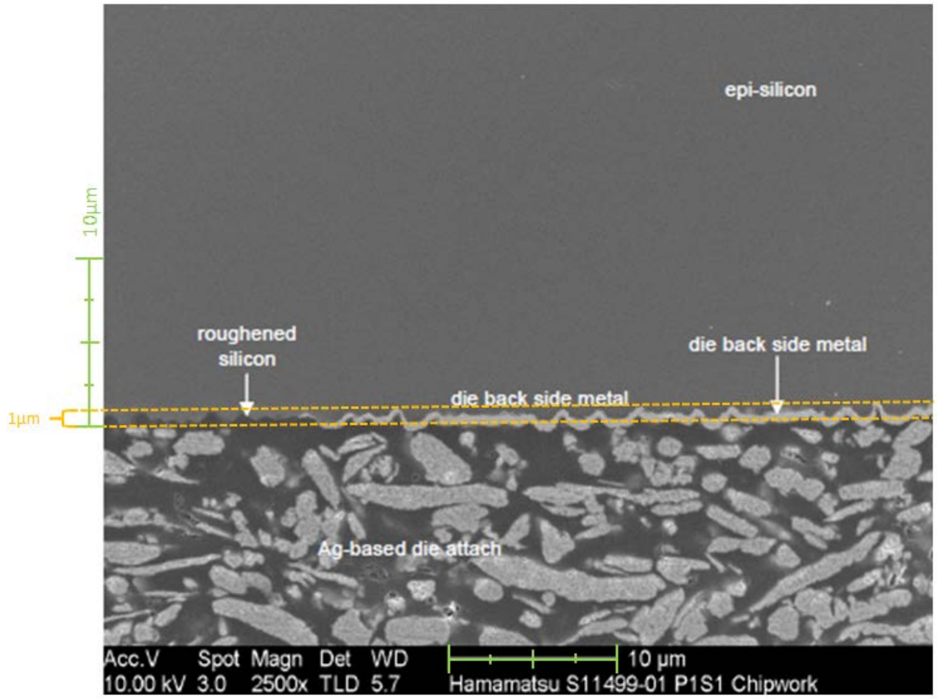
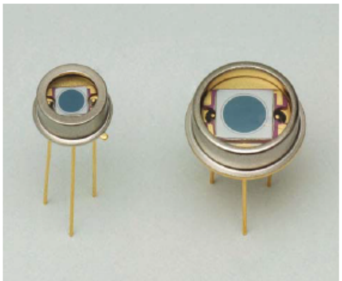


Fig. 33: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing 1 µm Measurement

Claim 7: The semiconductor substrate of claim 1, wherein said submicron-sized features are generated by irradiating a surface of the substrate with short laser pulses.

209. Upon information and belief, submicron-sized features of the semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode are generated by irradiating a surface of the substrate with short laser pulses. Hamamatsu's website explains that the S11499-01 sensor has "enhanced near-infrared sensitivity due to a MEMS ["micro-electro-mechanical system"] structure formed on the back side of the photodiode. Exs. 23 & 42 (Hamamatsu Glossary).

HAMAMATSU
PHOTON IS OUR BUSINESS



IR-enhanced Si PIN photodiodes

S11499 series

Large area, enhanced near IR sensitivity, using a MEMS technology

HAMAMATSU has developed various types of Si detectors that offer enhanced near-infrared sensitivity due to a MEMS structure formed on the back side of the photodiode. The S11499 series is a family of Si PIN photodiodes with drastically improved sensitivity in the near infrared region at wavelengths longer than 900 nm. Compared to our conventional product, the S11499 series has much higher sensitivity to YAG laser light (1.06 □m). It also offers improved temperature characteristics of sensitivity at wavelengths longer than 950 nm.

Fig. 34: Excerpt from Ex. 23 at 1 (S11499-01 Datasheet)

210. Hamamatsu's Image Sensor Selection Guide explains that the MEMS structure used to enhance infrared sensitivity is created by laser processing.

Enhanced IR sensitivity

These sensors have MEMS structures fabricated by our own unique laser processing technology. These sensors have achieved very high sensitivity in the near infrared region at wavelengths longer than 800 nm. Utilizing high sensitivity characteristic in the near infrared region, these sensors should find applications in Raman spectroscopy.

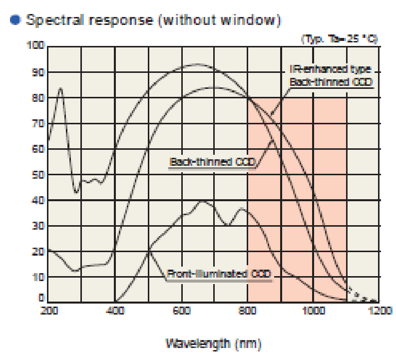


Fig. 35: Excerpt from Ex. 24 at 10 Describing MEMS Fabrication Using Laser Processing

Claim 8: The semiconductor substrate of claim 7, wherein said short laser pulses have pulse widths in a range of about 50 femtoseconds to about a few nanoseconds.

211. Upon information and belief, laser pulses used to generate the submicron-sized features of the semiconductor substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode have pulse widths in a range of about 50 femtoseconds to about a few

nanoseconds. In particular, as explained above, the MEMS structure formed on the back side of the S11499-01 is fabricated using laser processing.

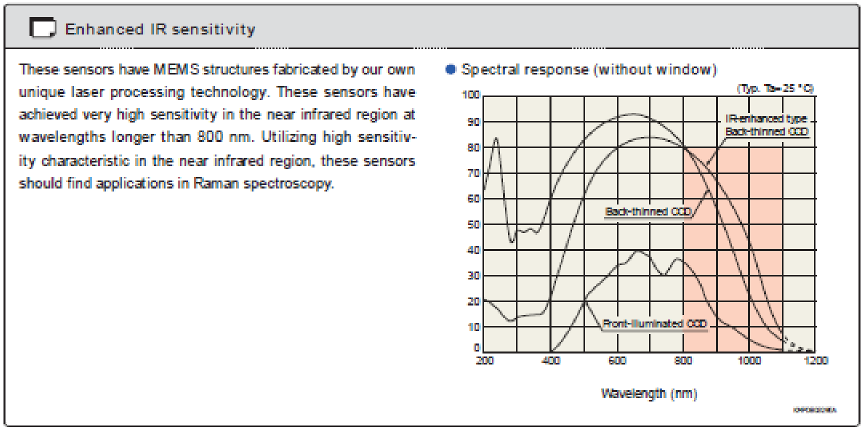


Fig. 36: Excerpt from Ex. 24 at 10 Describing MEMS Fabrication Using Laser Processing

212. Further, the image below, taken by Chipworks Inc., shows submicron-sized features of the semiconductor substrate included in the Hamamatsu S11499-01. The characteristics of the surface texture, including the size and shape of the features, indicate that the surface was irradiated with short laser pulses having pulse widths of about 50 femtoseconds to about a few nanoseconds.

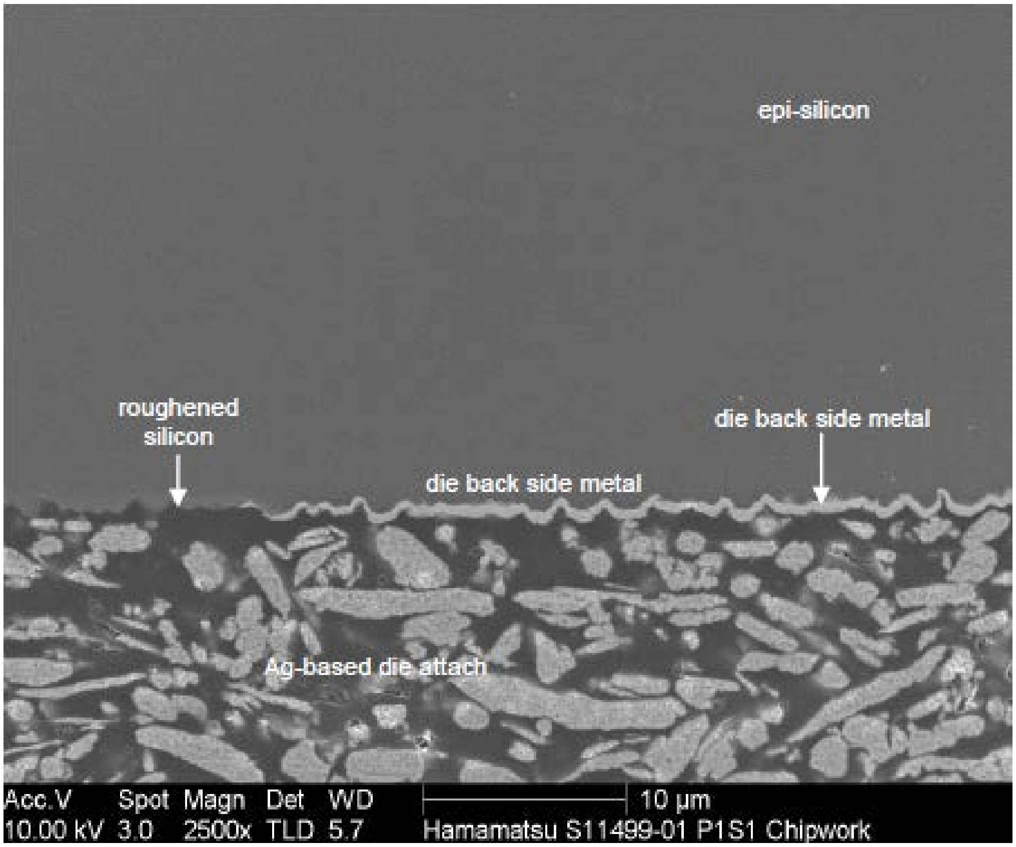


Fig. 37: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing Features Characteristic of Laser Pulses

XXIII. COUNT XIX

Patent Infringement under 35 U.S.C. § 271 of U.S. Patent No. 8,080,467 against Defendants

213. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

214. Upon information and belief, in violation of 35 U.S.C. § 271, Defendants and their subsidiaries have directly infringed and continue to directly infringe, both literally and under the doctrine of equivalents, one or more claims of the ’467 Patent, by, without limitation, making, using, importing, selling, and/or offering for sale products incorporating a silicon die that includes all of the limitations of one or more of the claims of the ’467 Patent, within the District of Massachusetts and elsewhere within the United States. For example, Hamamatsu

offers to sell and/or sells imaging devices that meet all elements of one or more claims of the ’467 Patent within the United States through its website. *See, e.g.,* Exs. 23-24, 39, & 41. An element-by-element analysis showing that an exemplary Hamamatsu imaging sensor practices all elements of one or more claims of the ’467 Patent is provided below. Defendants’ end products that incorporate Hamamatsu’s sensors also infringe.

215. Also in violation of 35 U.S.C. § 271, upon information and belief, Defendants and their subsidiaries have indirectly infringed and continue to indirectly infringe one or more claims of the ’467 Patent by contributing to or inducing direct infringement, either literally or under the doctrine of equivalents, by another. Hamamatsu, for example, has had knowledge of the ’467 Patent at least as of the filing date of Hamamatsu’s ’087, ’528, ’945, ’485, ’135, and ’551 Patents, which cite Dr. Carey and Dr. Mazur’s Patents as prior art. Exs. 5-8, 34, & 44. Further, Hamamatsu was aware of Harvard’s and SiOnyx’s intellectual property since the beginning of the relationship with SiOnyx. *See* Exs. 10 & 21. Having knowledge of Harvard’s and SiOnyx’s Patents, Hamamatsu induced others in the United States to use, sell, and/or offer for sale in the United States, and/or import into the United States products that include Hamamatsu’s image sensors that practice all elements of one or more claims of the ’467 Patent. 35 U.S.C. § 271(b). For example, the Ocean Optics Maya2000 Pro-NIR spectrometer, which is offered for sale and sold in the United States, includes a Hamamatsu S11499-01 image sensor. Exs. 40-41. As described below, the S11499-01 practices all elements of one or more claims of the ’467 Patent. Upon information and belief, Hamamatsu knew and intended that use of these sensors would cause direct infringement of the ’467 Patent.

216. Further, the Hamamatsu image sensors that practice all elements of one or more claims of the ’467 Patent, such as the S11499-01 sensor has no substantial non-infringing uses.

35 U.S.C. § 217(c). Upon information and belief, Hamamatsu has knowingly contributed to the direct infringement of another through use, sale, and/or offers of sale in the United States and/or importation into the United States of its devices that practice one or more claims of the '467 Patent.

217. Hamamatsu's infringement of the '467 Patent is willful. Hamamatsu had knowledge of the '467 Patent at least as of the filing date of the '087, '528, '945, '485, '135, and '551 Patents, which cite patents in the same family the '467 Patent as prior art, but has continued to directly and indirectly infringe. See Exs. 5-8, 34, & 44. In addition, Hamamatsu has had knowledge of Harvard's and SiOnyx's intellectual property since the beginning of the relationship between SiOnyx and Hamamatsu. *See* Exs. 10 & 21. Despite knowing of this intellectual property, Hamamatsu intentionally made, used, offered for sale, or sold in the United States or imported into the United States infrared-enhanced photodiodes that practice one or more claims of the '467 Patent.

218. Defendant's acts of infringement have caused damage to SiOnyx. SiOnyx is entitled to recover damages in an amount subject to proof at trial, including treble damages for Hamamatsu's willful infringement.

219. Plaintiffs have been, and continue to be, damaged and irreparably harmed by Defendants' infringement, which will continue unless Defendants are enjoined by this Court. *See eBay Inc. v. Mercexchange, LLC*, 547 U.S. 388 (2006). In particular, SiOnyx is a practicing entity in the business of selling sensors that practice all elements of one or more claims of the '467 Patent. *See, e.g.,* Ex. 43 ("Sensors" page from SiOnyx's website describing SiOnyx's XQE sensors). Hamamatsu is a direct competitor to SiOnyx in the field of infrared-enhanced sensors. Further, the inventions of the '467 Patent are central to SiOnyx's business. Thus, remedies

available at law are inadequate to protect SiOnyx from Defendants' infringement and the balance of hardships favors enjoining Defendants' actions. Finally, the public interest would not be disserved by a permanent injunction preventing Defendants from selling products that infringe the '467 Patent.

220. An element-by-element comparison of the Hamamatsu S11499-01 sensor to the claims of the '467 Patent is provided below. This analysis is exemplary and not intended to limit Plaintiffs' allegations to S11499-01 sensor. Rather, Hamamatsu produces many imaging devices with improved near-infrared characteristics that meet all elements of one or more claims of the '467 Patent, including at least the following sensors: C11008MA; C11010MA; C5964-0901; C5964-1011; C8484-03; C9408MA; C9410MA; S11499; S11510-1006; S11510-1106; S12028; C9405CB; S11500-1007; S11518-10; S11518-30; S11519-10; and S11519-30. Defendants' end products that incorporate Hamamatsu's sensors also infringe.

221. Further, the claims analyzed below are exemplary only and not intended to limit Plaintiffs' allegations. The analysis is based on information available to Plaintiffs before discovery in this action. Plaintiffs preserve the right to add additional asserted claims alleged to be infringed based on discovery conducted in this action.

Claim 1

a. [Preamble] A method of fabricating a semiconductor wafer, comprising:

222. The Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode is produced using a method of fabricating a semiconductor wafer according to claim 1 of the '467 Patent, as discussed below. The image below is a top-view of the Hamamatsu S11499-01, showing the photon receiving area, which includes a silicon die, cut from a semiconductor wafer.

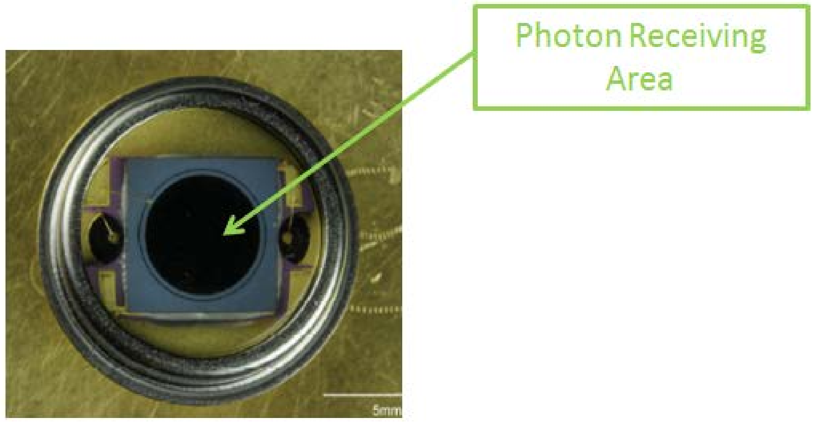


Fig. 38: Top-View Image of Hamamatsu S11499-01 Sensor

223. The following cross-section image of the Hamamatsu S11499-01, taken by Chipworks Inc., shows the silicon die included in the photon receiving area.

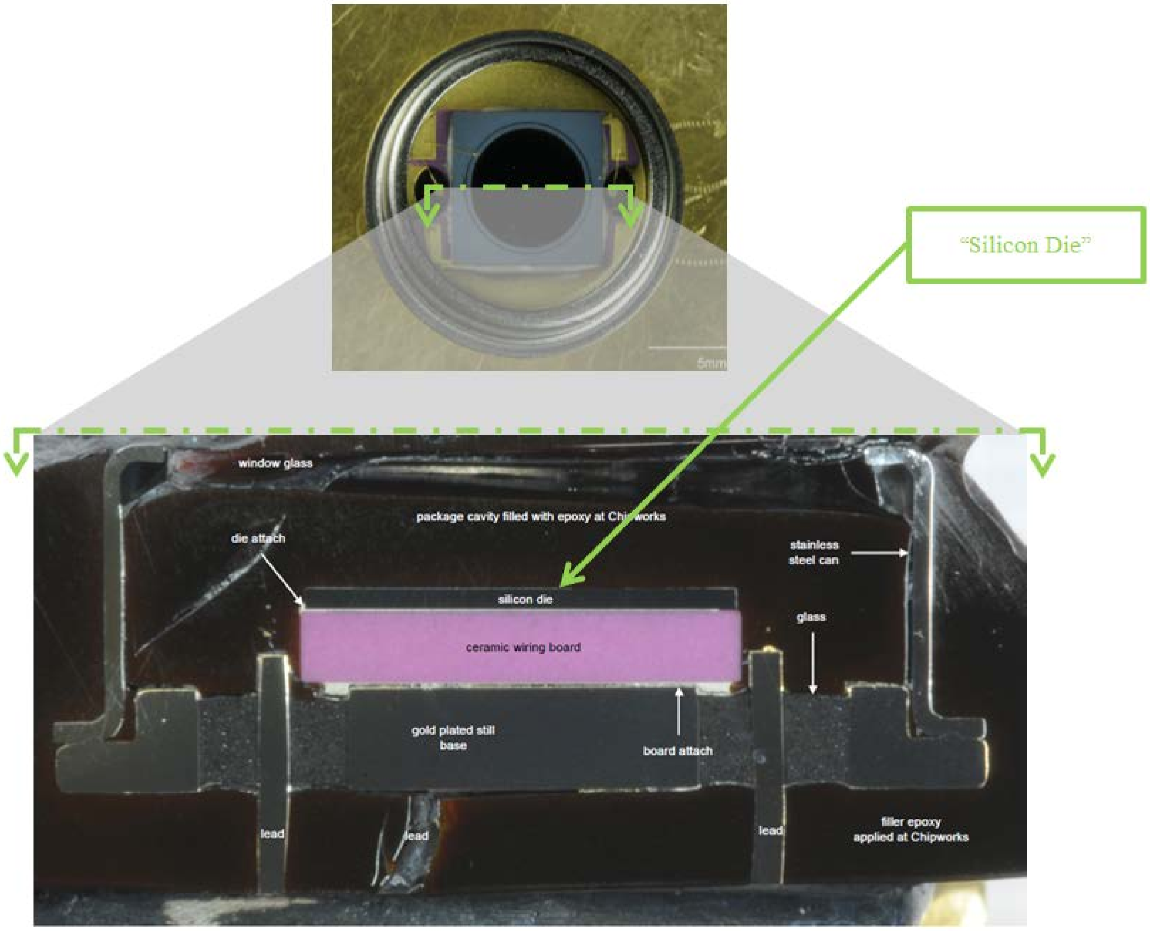
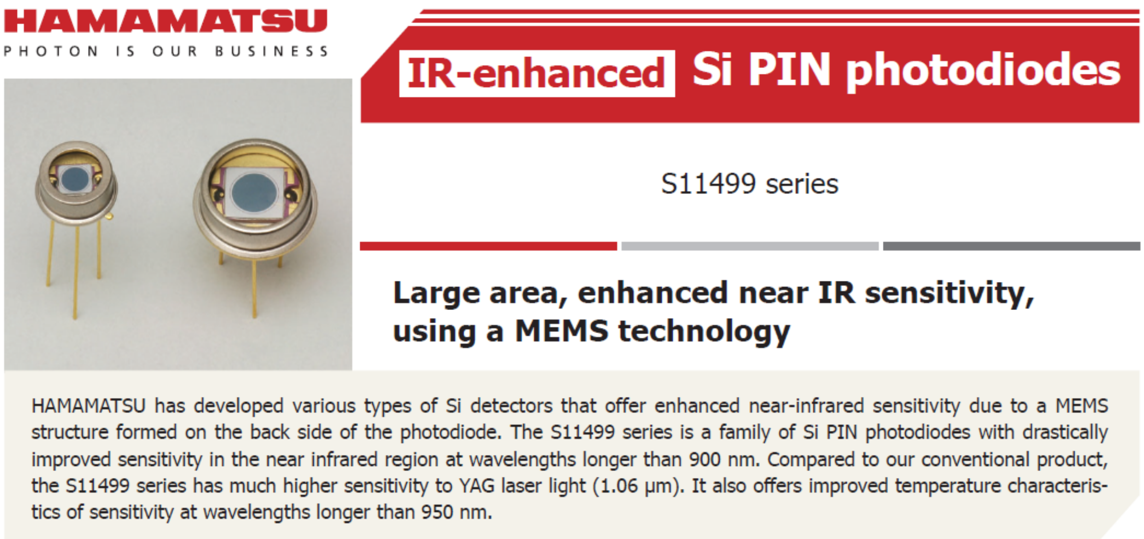


Fig. 39: Top-View and Cross-Section of Hamamatsu S11499-01 Sensor

b. [Element 1a] irradiating one or more surface locations of a silicon substrate with a plurality of temporally short laser pulses while exposing said one or more locations to a surface so as to generate a plurality of surface inclusions containing at least a constituent of said substance in a surface layer of said substrate

224. Upon information and belief, the semiconductor wafer, from which the silicon substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode is cut, is produced by irradiating one or more surface locations of a silicon substrate with a plurality of temporally short laser pulses while exposing said one or more locations to a substance so as to generate a plurality of surface inclusions containing at least a constituent of said substance in a

surface layer of said substrate. In particular, As described on Hamamatsu's website, the S11499-01 offers "enhanced near-infrared sensitivity due to a MEMS [micro-electro-mechanical systems] structure formed on the back side of the photodiode."


HAMAMATSU
PHOTON IS OUR BUSINESS

IR-enhanced Si PIN photodiodes

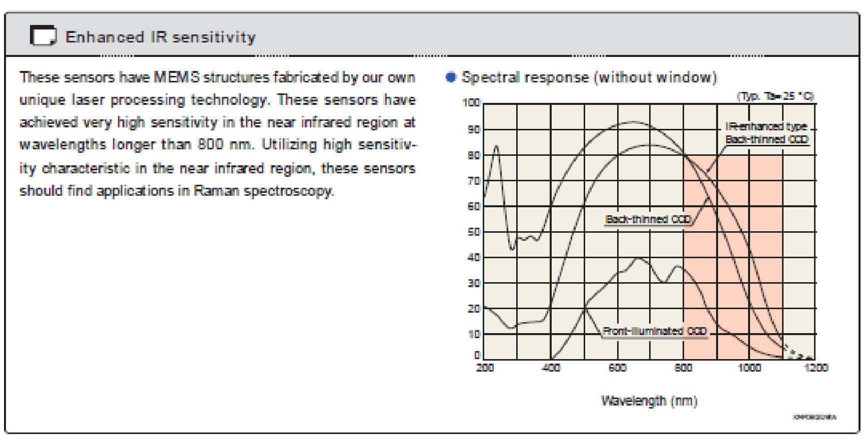
S11499 series

Large area, enhanced near IR sensitivity, using a MEMS technology

HAMAMATSU has developed various types of Si detectors that offer enhanced near-infrared sensitivity due to a MEMS structure formed on the back side of the photodiode. The S11499 series is a family of Si PIN photodiodes with drastically improved sensitivity in the near infrared region at wavelengths longer than 900 nm. Compared to our conventional product, the S11499 series has much higher sensitivity to YAG laser light (1.06 μm). It also offers improved temperature characteristics of sensitivity at wavelengths longer than 950 nm.

Fig. 40: Excerpt from Ex. 23 at 1 (S11499-01 Datasheet)

225. Hamamatsu's Image Sensor Selection Guide explains that the MEMS structure used to enhance infrared sensitivity is created by laser processing.


Enhanced IR sensitivity

These sensors have MEMS structures fabricated by our own unique laser processing technology. These sensors have achieved very high sensitivity in the near infrared region at wavelengths longer than 800 nm. Utilizing high sensitivity characteristic in the near infrared region, these sensors should find applications in Raman spectroscopy.

Fig. 41: Excerpt from Ex. 24 at 10 Describing MEMS Fabrication Using Laser Processing

226. Further upon information and belief, the "laser processing technology" used by Hamamatsu involves irradiating the silicon substrate with a plurality of temporally short laser

pulses while exposing said one or more locations to a substance so as to generate a plurality of surface inclusions containing at least a constituent of said substance in a surface layer of said substrate. For example, the graph below, prepared by Chipworks Inc., shows the concentrations of arsenic, fluorine, nitrogen, phosphorus, sulfur, and antimony to a depth of 3 µm (micrometer) into the silicon substrate included in the S11499-01.

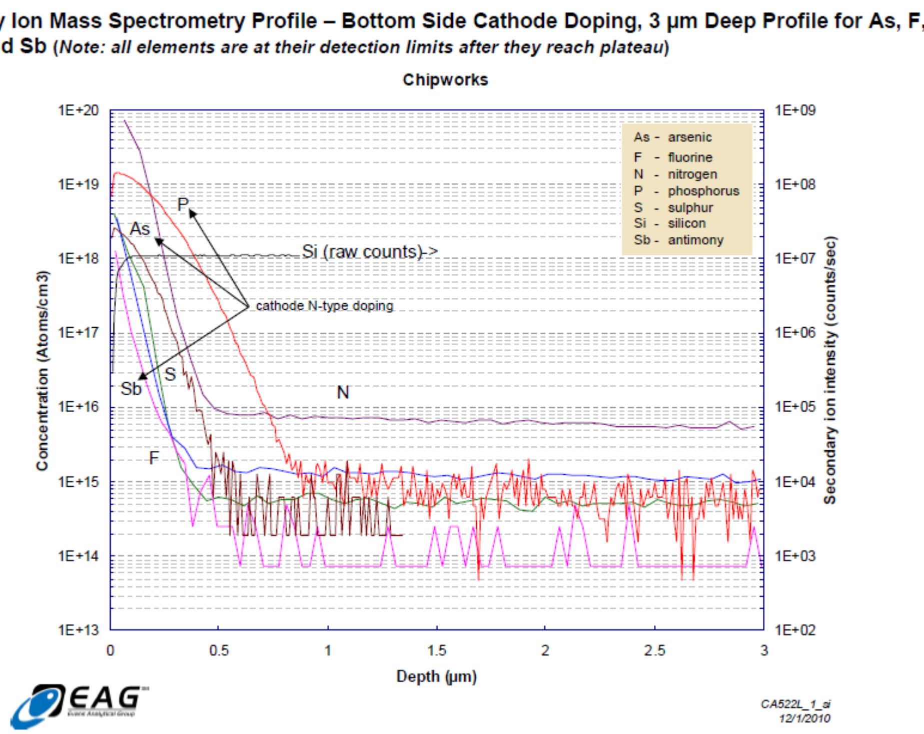


Fig. 42: Secondary Ion Mass Spectrometry of Bottom Side Cathode Doping, Showing S11499-01 Substrate Includes Arsenic, Fluorine, Nitrogen, Phosphorus, Sulphur, and Antimony Constituents

227. Further, the graph below, also prepared by Chipworks Inc. shows the concentrations of calcium and argon to a depth of 1 µm into the silicon substrate included in the S11499-01.

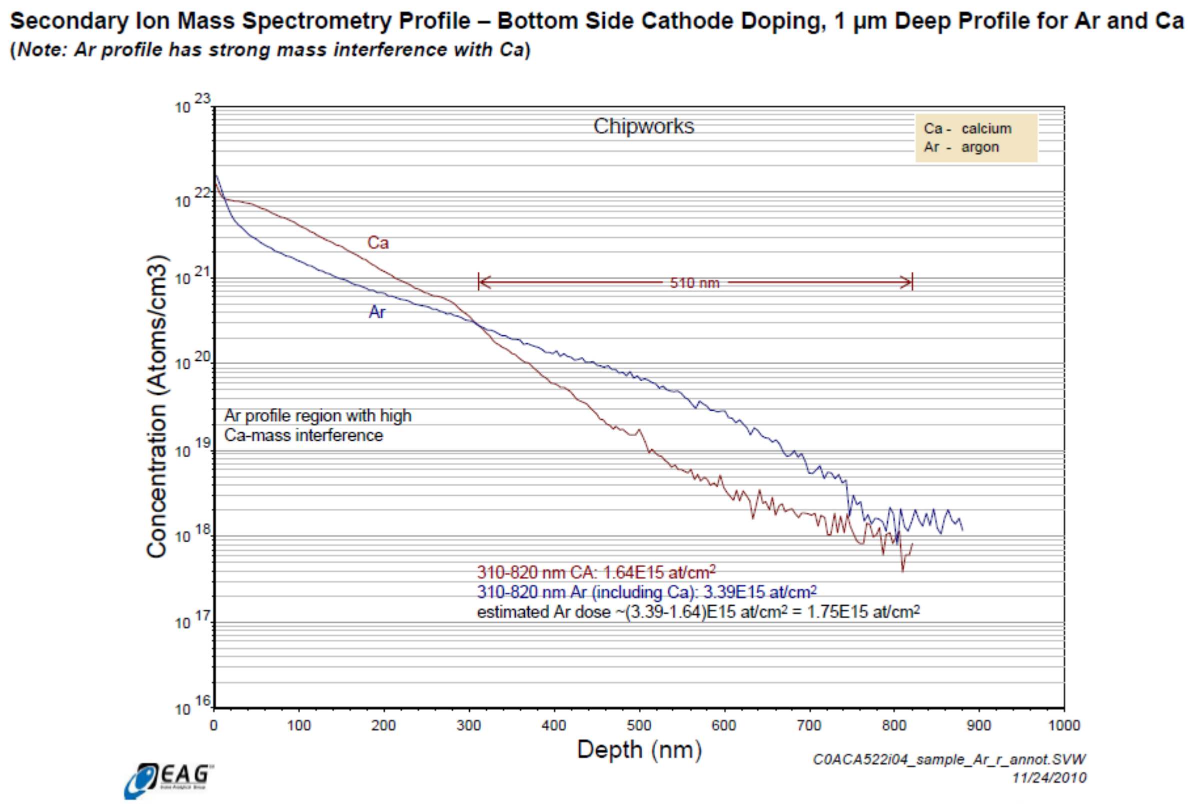


Fig. 43: Secondary Ion Mass Spectrometry of Bottom Side Cathode Doping Showing S11499-01 Substrate Includes Argon and Calcium Constituents

228. The bottom side cathode doping shown in the spectrometry profiles above can also be seen in the SEM image below. In particular, the darker gray color indicates that the cathode contact diffusion area includes constituent elements, such as arsenic, fluorine, nitrogen, phosphorus, sulfur, antimony, argon, and/or calcium.

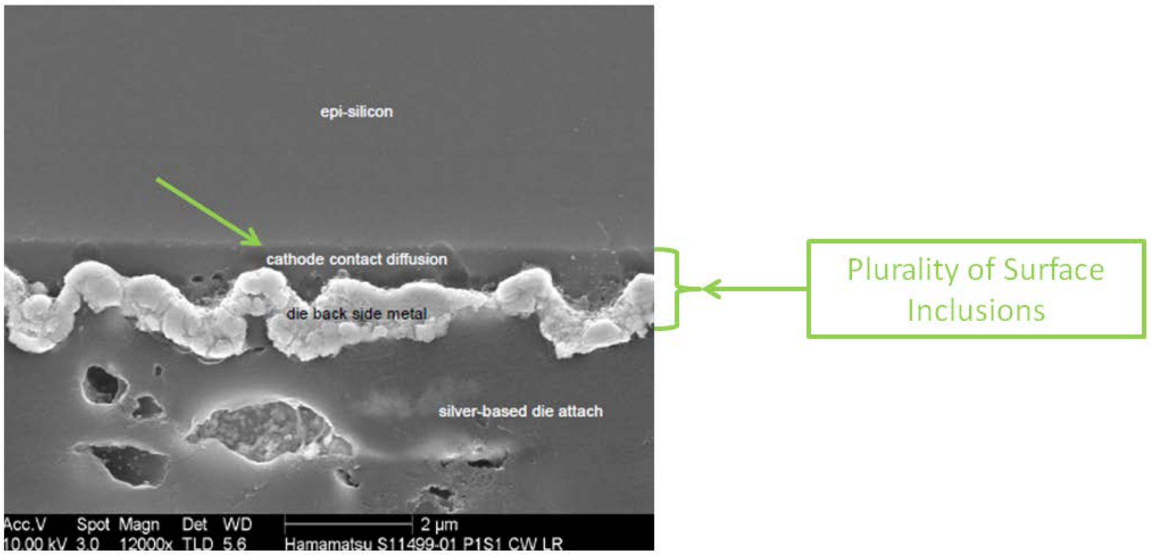


Fig. 44: SEM Image of Substrate of Hamamatsu S11499-01 Substrate Showing Cathode Contact Diffusion Includes Constituent Materials

c. [Element 1b] annealing said substrate at an elevated temperature and for a duration selected to enhance a density of charge carriers in said surface layer.

229. Upon information and belief, the semiconductor wafer, from which the silicon substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode is cut, is produced by annealing the silicon substrate at an elevated temperature and for a duration selected to enhance a density of charge carriers in said surface layer. The graph below, prepared by Chipworks Inc., shows "Cathode Doping" concentrations of the surface layer of the silicon die included in the Hamamatsu S11499-01 to a depth of 3 µm.

Secondary Ion Mass Spectrometry Profile – Bottom Side Cathode Doping, 3 µm Deep Profile for As, F, N, P, S, and Sb (*Note: all elements are at their detection limits after they reach plateau*)

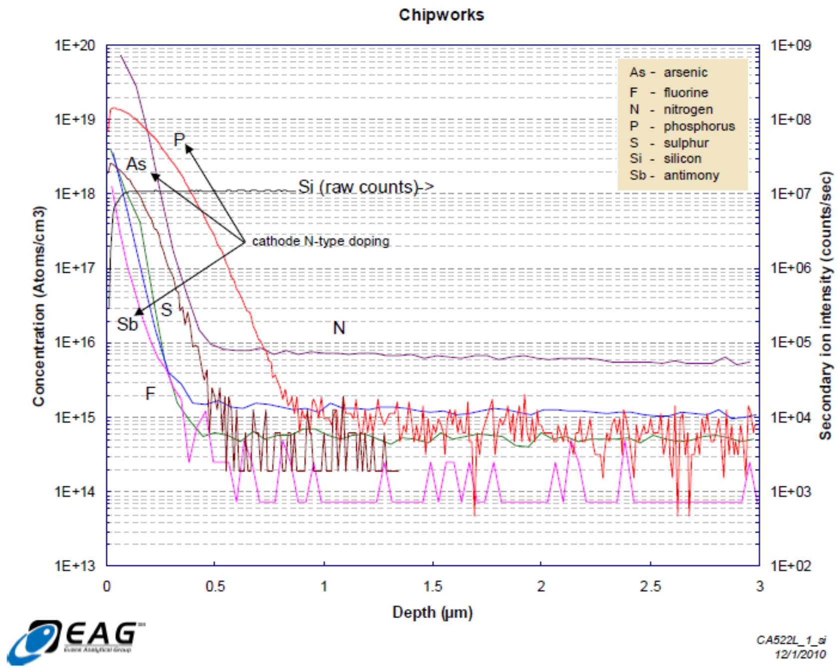


Fig. 45: Secondary Ion Mass Spectrometry of Bottom Side Cathode Doping, Showing Diffusion of Constituent Components in Surface Layer of S11499-01 Substrate

230. Further, the graph below, prepared by Chipworks Inc., shows the density of charge carriers ("Carrier Concentration (cm-3)") of the cathode diffusion of the silicon substrate included in the Hamamatsu S11499-01 to a depth of 100 µm. Accordingly, upon information and belief, the silicon substrate included in the Hamamatsu S11499-01 is annealed at an elevated temperature and for a duration selected to enhance a density of charge carriers in the surface layer.

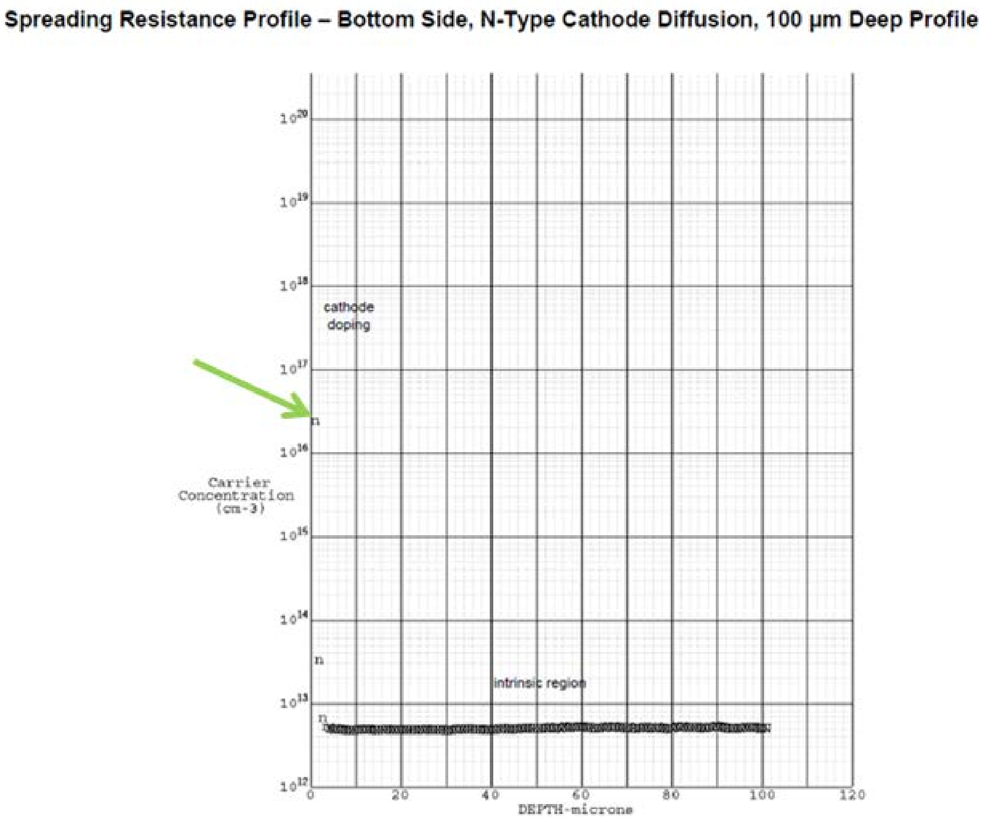


Fig. 46: Spreading Resistance Profile of Bottom Side of S11499-01 Substrate Showing N-Type Carrier Concentration ("cm-3")

231. Similarly, the graph below, prepared also by Chipworks Inc., shows the density of charge carriers ("Carrier Concentration (cm-3)") of the anode diffusion of the silicon substrate included in the Hamamatsu S11499-01 to a depth of 1.2 µm. Accordingly, upon information and belief, the silicon substrate included in the Hamamatsu S11499-01 is annealed at an elevated temperature and for a duration selected to enhance a density of charge carriers in the surface layer.

Spreading Resistance Profile – Photon-Receiving Area, P-Type Anode, 1.2 µm Deep Profile

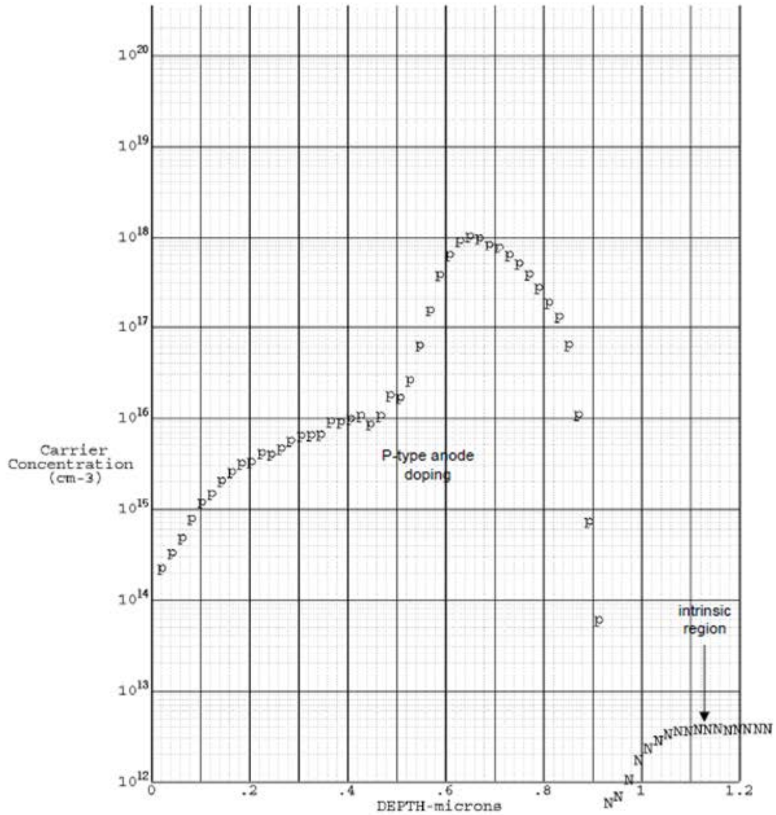


Fig. 47: Spreading Resistance Profile of S11499-01 Substrate Showing P-Type Carrier Concentration ("cm-3")

Claim 2: The method of claim 1 wherein said charge carries comprise electrons.

232. The semiconductor wafer, from which the silicon substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode is cut, is annealed to enhance the density of charge carriers in the surface layer, wherein said charge carriers comprise electrons. In particular, the secondary ion mass spectrometry profile, prepared by Chipworks Inc., shows that the silicon substrate of the Hamamatsu S11499-01 includes arsenic (chemical symbol As), phosphorus (chemical symbol P), and antimony (chemical symbol Sb). Upon information and belief, one or more of these substances are used for n-type doping of the substrate.

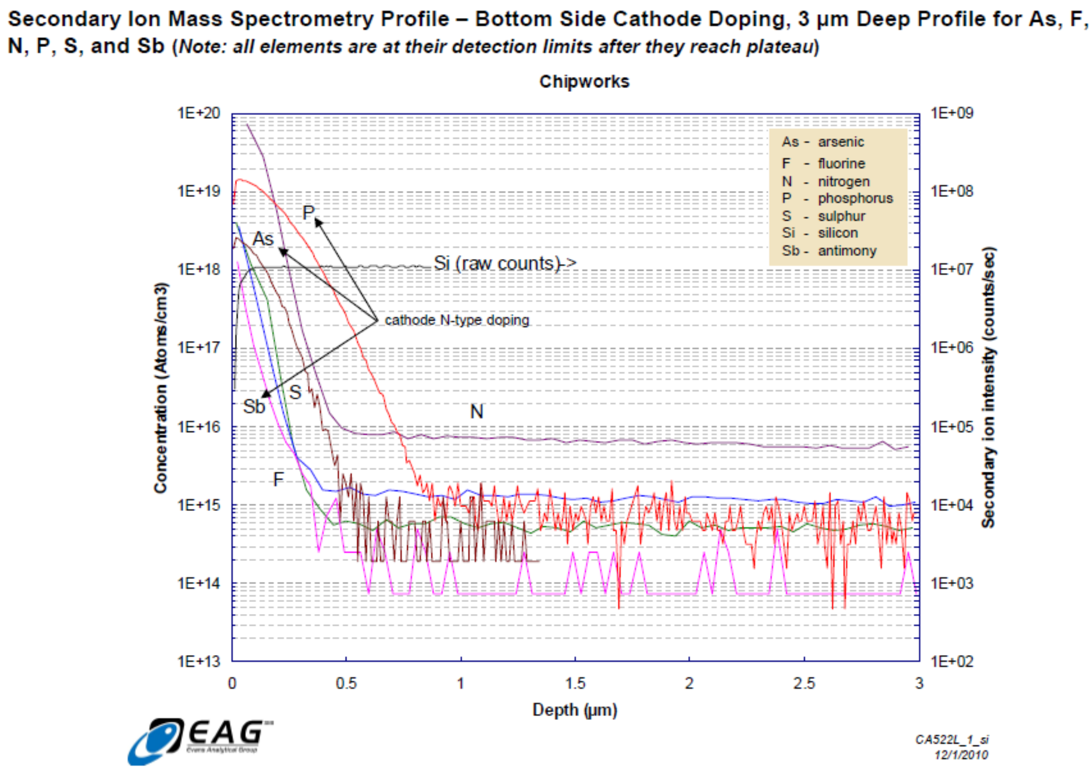


Fig. 48: Secondary Ion Mass Spectrometry of Bottom Side Cathode Doping, Showing S11499-01 Substrate Includes Arsenic, Fluorine, Nitrogen, Phosphorus, Sulphur, and Antimony Constituents

233. Further, the spreading resistance profile of the substrate included in the Hamamatsu S11499-01, also prepared by Chipworks Inc., shows high n-type carrier concentration close to the surface. Electrons are n-type carriers.

Spreading Resistance Profile – Bottom Side, N-Type Cathode Diffusion, 100 µm Deep Profile

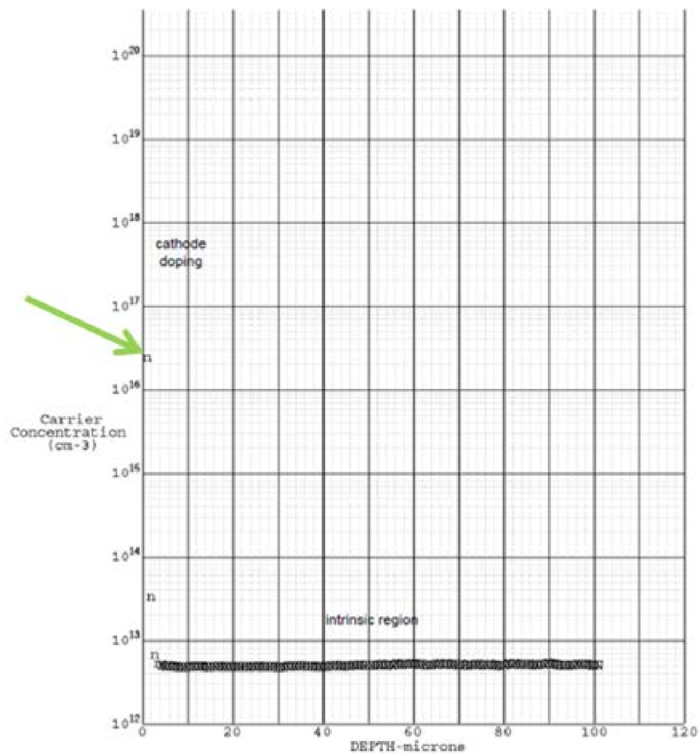


Fig. 49: Spreading Resistance Profile of Bottom Side of S11499-01 Substrate Showing N-Type Carrier Concentration ("cm-3")

Claim 3: The method of claim 1, wherein said charge carriers comprise holes.

234. The semiconductor wafer, from which the silicon substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode is cut, is annealed to enhance the density of charge carriers in the surface layer, wherein said charge carriers comprise holes. In particular, the spreading resistance profile of the semiconductor substrate included in the Hamamatsu S11499-01 below, shows the concentration of p-type carriers. P-type doping refers to the introduction of substitutional atoms with 3 valence electrons into the crystalline lattice of

intrinsic silicon. When bonding with silicon, atoms with 3 valence electrons are one electron short, resulting in a "hole."

Spreading Resistance Profile – Photon-Receiving Area, P-Type Anode, 1.2 µm Deep Profile

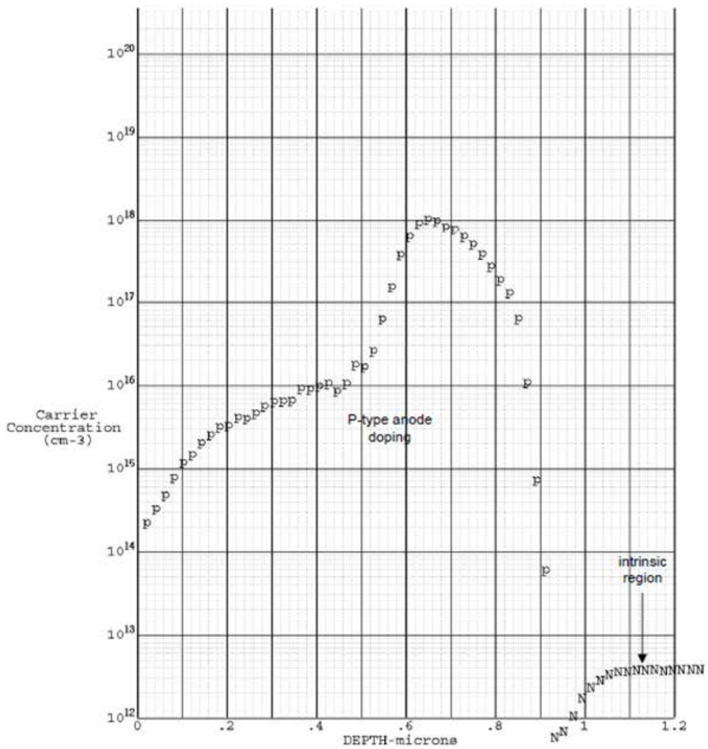


Fig. 50: Spreading Resistance Profile of S11499-01 Substrate Showing P-Type Carrier Concentration ("cm-3")

Claim 11: The method of claim 1, wherein said elevated temperature and duration are selected such that said annealed substrate exhibits a responsivity in a range of about 0.1A/W to about 100 A/W in response to exposure of said surface layer to radiation having one or more wavelengths in a range of about 1050 nm to about 3500 nm.

235. The semiconductor wafer, from which the silicon substrate included in the Hamamatsu S11499-01 IR-Enhanced Silicon PIN Photodiode is cut, is annealed wherein the elevated temperature and duration of the anneal are selected such that said annealed substrate exhibits a responsivity in a range of about 0.1 A/W (amps per watt) to about 100 A/W in response to exposure of said surface layer to radiation having one or more wavelengths in a range of about 1050 nm to about 3500 nm. In particular, the Datasheet for the S11499-01 on

Hamamatsu's website shows that the responsivity of the annealed S11499-01 substrate is about 0.65 A/W in response to radiation having a wavelength of about 1050 nanometers.

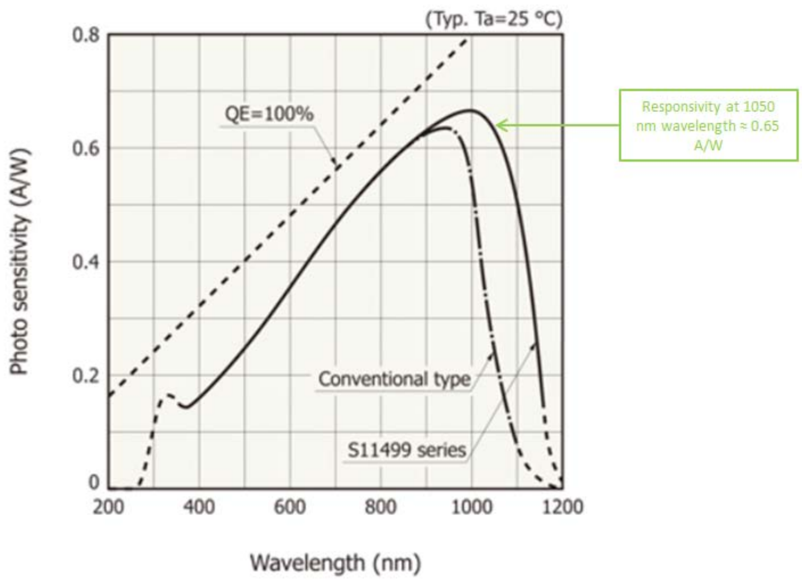


Fig. 51: Excerpt from Ex. 23 at 3 (Annotations not Original)

XXIV. COUNT XX

Patent Infringement under 35 U.S.C. § 271 of U.S. Patent No. 8,680,591 against Defendants

236. Plaintiffs hereby re-allege and incorporate by reference the foregoing paragraphs of the Complaint as if fully set forth herein.

237. Upon information and belief, in violation of 35 U.S.C. § 271, Defendants and their subsidiaries have directly infringed and continue to directly infringe, both literally and under the doctrine of equivalents, one or more claims of the '591 Patent, by, without limitation, making, using, importing, selling, and/or offering for sale products incorporating a silicon die that includes all of the limitations of one or more of the claims of the '591 Patent, within the District of Massachusetts and elsewhere within the United States. For example, Hamamatsu offers to sell and/or sells imaging devices that meet all elements of one or more claims of the

’591 Patent within the United States through its website. *See, e.g.,* Exs. 23-24 & 42-43. An element-by-element analysis showing that an exemplary Hamamatsu imaging sensor practices all elements of one or more claims of the ’591 Patent is provided below. Defendant’s products that incorporate Hamamatsu’s sensors also infringe.

238. Also in violation of 35 U.S.C. § 271, upon information and belief, Defendants and their subsidiaries have indirectly infringed and continue to indirectly infringe one or more claims of the ’591 Patents by contributing to or inducing direct infringement, either literally or under the doctrine of equivalents, by another. Hamamatsu has had knowledge of the ’591 Patent since at least the date of service of the original Complaint in this action. Further, Hamamatsu was aware that SiOnyx had intellectual property covering infrared enhanced image sensors since the beginning of the relationship between the parties. *See, e.g.,* Exs. 10 & 21. Having knowledge of SiOnyx’s Patents, Hamamatsu induced others in the United States to use, sell, and/or offer for sale in the United States, and/or import into the United States products that include Hamamatsu’s image sensors that practice all elements of one or more claims of the ’591 Patent. 35 U.S.C. § 271(b). For example, the Ocean Optics Maya2000 Pro-NIR spectrometer, which is offered for sale and sold in the United States, includes a Hamamatsu S11510 series image sensor. Exs. 40-41. As described below, the S11510 practices all elements of one or more claims of the ’591 Patent. Upon information and belief, Hamamatsu knew and intended that use of these sensors would cause direct infringement of the ’591 Patent. *Id.*

239. Further, the Hamamatsu image sensors that practice all elements of one or more claims of the ’591 Patent, such as the S11510 series sensors used in the Ocean Optics Maya2000 Pro-NIR spectrometer, have no substantial non-infringing uses. 35 U.S.C. § 271(c). Upon information and belief, Hamamatsu has knowingly contributed to the direct infringement of

another through use, sale, and/or offers of sale in the United States and/or importation into the United State of its devices that practice one or more claims of the ’591 Patent.

240. Hamamatsu’s infringement of the ’591 Patent is willful. Hamamatsu had knowledge of SiOnyx’s intellectual property since the beginning of the relationship between the parties. *See* Exs. 10 & 21. Despite knowing of this intellectual property, Hamamatsu intentionally made, used, offered for sale, or sold in the United States or imported into the United States infrared-enhanced photodiodes that practice one or more claims of the ’591 Patent.

241. Defendants’ acts of infringement have caused damage to SiOnyx. SiOnyx is entitled to recover damages in an amount subject to proof at trial, including treble damages for Hamamatsu’s willful infringement.

242. Plaintiffs have been, and continue to be, damaged and irreparably harmed by Hamamatsu’s infringement, which will continue unless Hamamatsu is enjoined by this Court. *See eBay Inc. v. Mercexchange, LLC*, 547 U.S. 388 (2006). In particular, SiOnyx is a practicing entity in the business of selling sensors that practice all elements of one or more claims of the ’591 Patent. *See, e.g.,* Ex. 43 (“Sensors” page from SiOnyx’s website describing SiOnyx’s XQE sensors). Hamamatsu is a direct competitor to SiOnyx in the field of infrared-enhanced sensors. Further, the inventions of the ’591 Patent are central to SiOnyx’s business. Thus, remedies available at law are inadequate to protect SiOnyx from Hamamatsu’s infringement and the balance of hardships favors enjoining Hamamatsu’s actions. Finally, the public interest would not be disserved by a permanent injunction preventing Hamamatsu from selling products that infringe the ’591 Patent.

243. An element-by-element comparison of Hamamatsu’s S11510 series sensors to the claims of the ’591 Patent is provided below. This analysis is exemplary and not intended to limit

Plaintiffs' allegations to the S11510 series of sensors. Rather, Hamamatsu produces products with improved near-infrared characteristics that meet all elements of one or more claims of the '591 Patent. , including at least the following sensors: C11008MA; C11010MA; C5964-0901; C5964-1011; C8484-03; C9408MA; C9410MA; S11499; S11499-01; S11510-1006; S12028; C9405CB; S11500-1007; S11518-10; S11518-30; S11519-10; and S11519-30. Defendants' products that incorporate these sensors also infringe.

244. Further, the claims analyzed below are exemplary only and not intended to limit Plaintiffs' allegations. The analysis is based on information available to Plaintiffs before discovery in this action. Plaintiffs preserve the right to add additional asserted claims alleged to be infringed based on discovery conducted in this action.

Claim 1

a. [Preamble] A photosensitive imager device, comprising:

245. The Hamamatsu S11510-1106 sensor, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, comprises a photosensitive imager device. In particular, Hamamatsu's website describes the S11510 series as "a family of [full frame transfer charge-coupled device ("FFT-CCD")] image sensors for photometric applications that offer improved sensitivity in the near infrared region at wavelengths longer than 800 nm." Ex. 41 at 1. The image below shows S11510 sensors.

Fig. 52: Excerpt from Ex. 41 at 1

b. [Element 1a] a semiconductor substrate having a substantially planar surface and multiple doped regions forming at least one junction

246. The Hamamatsu S11510-1106, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, comprises a semiconductor substrate having a substantially planar surface and multiple doped regions forming at least one junction.

247. The image below, from the Datasheet for the Hamamatsu S11510 series of sensors, shows that the S11510 is a back-thinned CCD. The "Note" below the Figure identifies the direction of the incident light by explaining that, "when viewed from the direction of the incident light, the horizontal shift register is covered with a thick silicon layer (dead layer)."

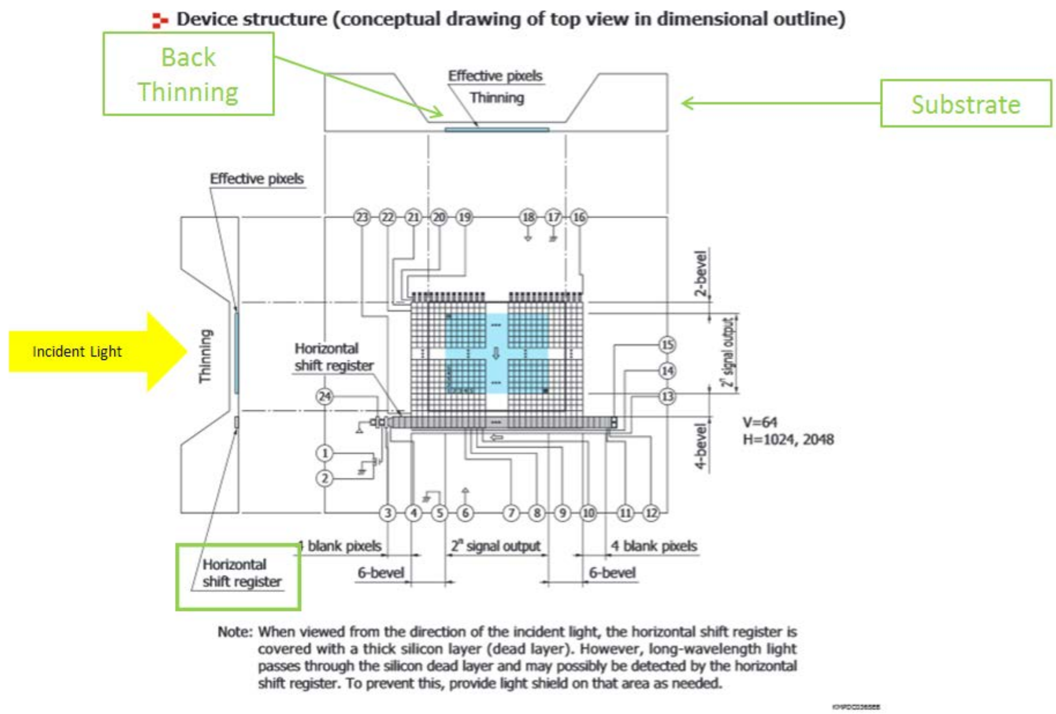


Fig. 53: Excerpt from Ex. 41 at 4

248. The same figure as above is also included in Hamamatsu's Image Sensor Handbook to describe back-thinned CCDs. Ex. 39 at 9. Figure 1-16(c) of the Image Sensor Handbook reproduced below, shows the "[i]nternal structure" of Hamamatsu's "[n]ear infrared-enhanced back-illuminated CCDs," "[f]ine structure type." The figure shows a semiconductor substrate having a substantially planar surface. Multiple doped regions are shown, as identified by the "P+," "P-," and "N" labels.

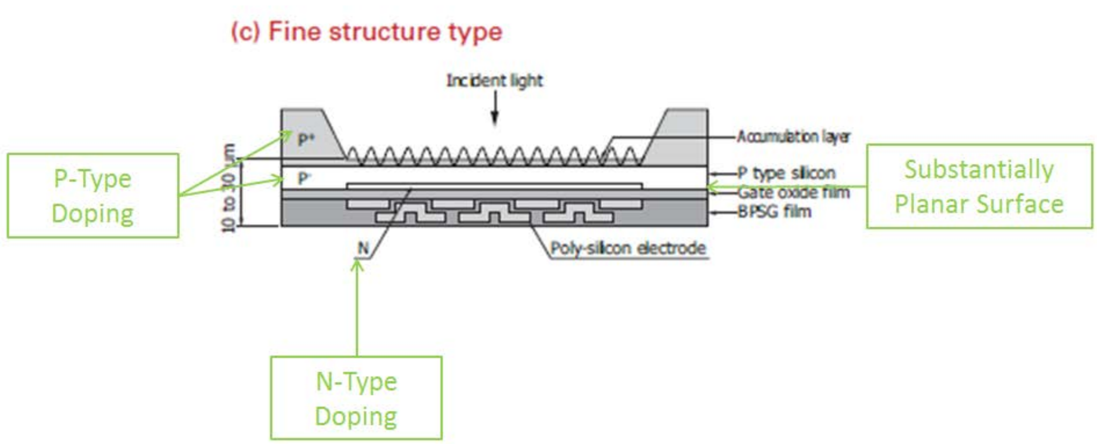


Fig. 54: Excerpt from Ex. 39 at 10 (Annotations not Original)

249. The zoomed in reproduction of Figure 1-16 from Chapter 5 of Hamamatsu's Image Sensor Handbook shows that the doped regions form at least one junction.

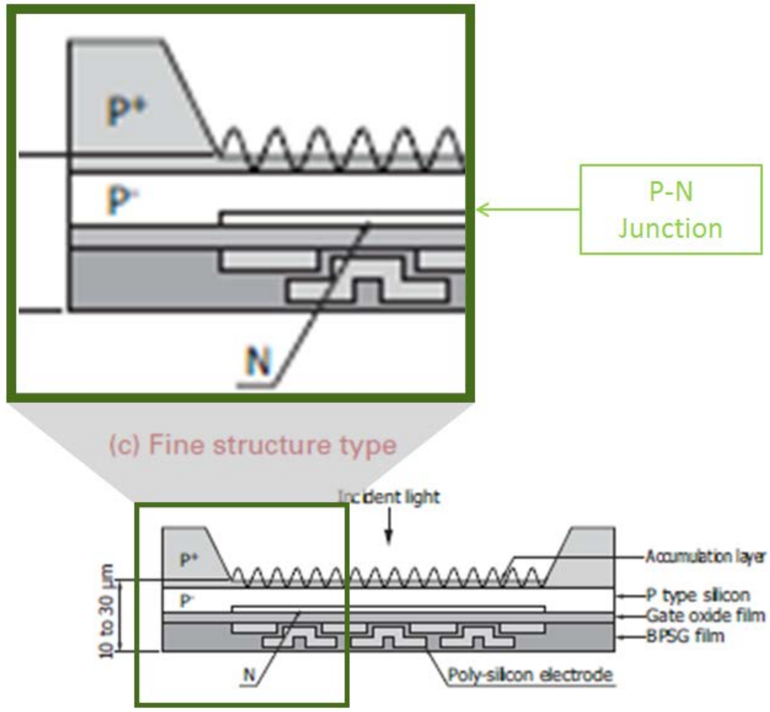


Fig. 55: Excerpt from Ex. 39 at 10 (Annotations and Zoom not Original)

c. [Element 1c] a textured region coupled to the semiconductor substrate on a surface opposite the substantially planar surface and positioned to interact with electromagnetic radiation

250. The Hamamatsu S11510-1106, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, sensor comprises a textured region coupled to the semiconductor substrate on a surface opposite the substantially planar surface and positioned to interact with electromagnetic radiation. In particular, Hamamatsu's website describes use of laser processing to produce texture on the backside of the S11510 series sensors as follows:

> The S11510-1106 is a family of FFT-CCD image sensors for photometric applications that offer improved sensitivity in the near infrared region at wavelengths longer than 800 nm. Our unique technology in laser processing was used to form a [micro-electrical mechanical] structure [("MEMS")] on the back side of the CCD.

> This allows the S11510-1106 to have much higher sensitivity than our previous products (S10420-01 series).

Ex. 41 at 1.

251. Figure 1-16(c) from Hamamatsu's Image Sensor Handbook, reproduced below, shows the texture created by laser processing.

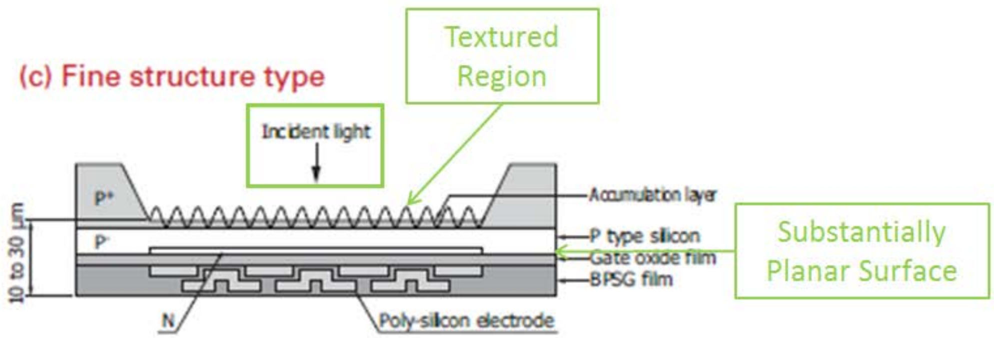


Fig. 56: Excerpt from Ex. 41 at 10 (Annotations not Original)

252. As shown in the schematic above, the laser texture is coupled to the semiconductor substrate on a surface opposite to the substantially planar surface. Ex. 41 at 10. Further, the direction of incident light shown in Figure 1-16(c) shows that the textured region is positioned to interact with electromagnetic radiation. Ex. 41 at 10.

253. The microscope images below show texture on the surface of the S11510-1106 included in the Ocean Optics Maya 2000 Pro.

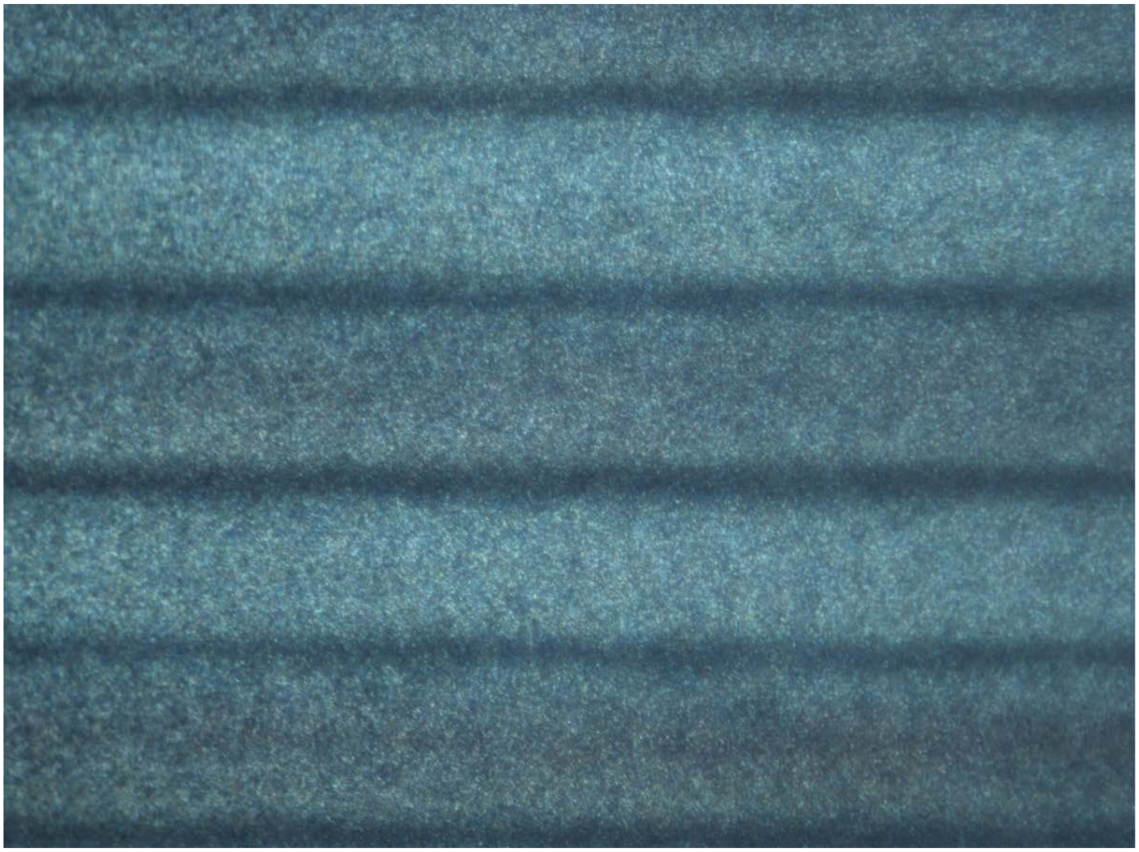


Fig. 57: Microscope Image of S11510 Sensor in Ocean Optics Maya2000 Pro

d. [Element 1c] integrated circuitry formed at the substantially planar surface

254. The Hamamatsu S11510-1106, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, sensor comprises integrated circuitry formed at the substantially planar surface. In particular, Figure 1-16(c) from Hamamatsu's Image Sensor Handbook, reproduced below, shows the "[i]nternal structure" of Hamamatsu's "[n]ear infrared-enhanced back-illuminated CCDs," "[f]ine structure type." The "[g]ate oxide film," "BPSG film," and "[p]oly-silicon electrodes" comprise the integrated circuitry formed at the substantially planar surface of the S11510 series of sensors.

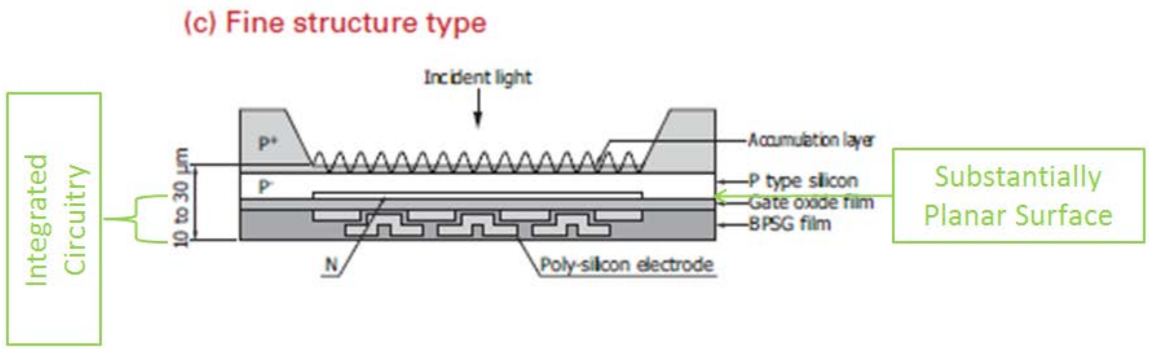


Fig. 58: Excerpt from Ex. 39 at 10 (Annotations Not Original)

e. [Element 1d] an electrical transfer element coupled to the semiconductor substrate and operable to transfer an electrical signal from the at least one junction.

255. The Hamamatsu S11510-1106, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, sensor comprises an electrical transfer element coupled to the semiconductor substrate and operable to transfer an electrical signal from the at least one junction. In particular, Figure 1-16(c) from Hamamatsu's Image Sensor Handbook, reproduced below, shows the "[i]nternal structure" of Hamamatsu's "[n]ear infrared-enhanced back-illuminated CCDs," "[f]ine structure type." The "Poly-silicon electrodes" shown comprise electrical transfer elements coupled to the semiconductor substrate and operable to transfer an electrical signal from the at least one junction.

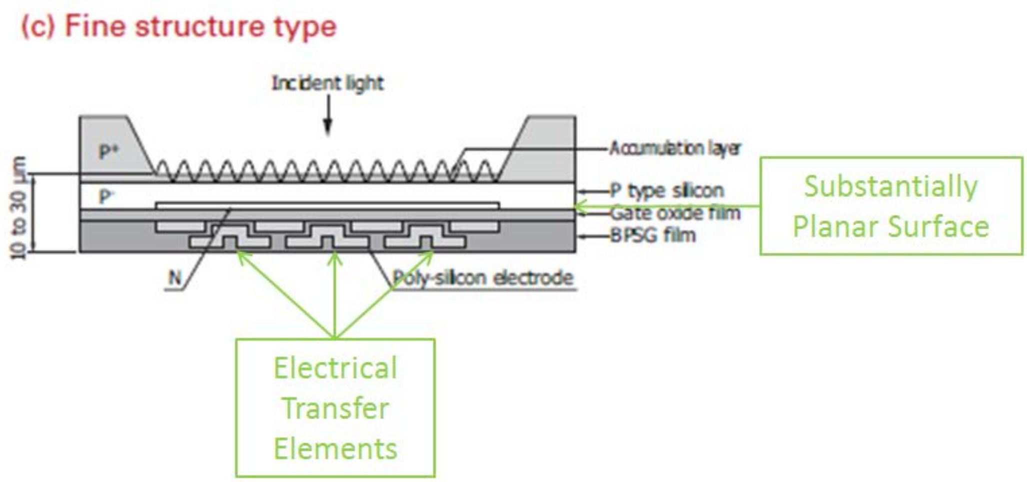


Fig. 59: Excerpt from Ex. 39 at 10 (Annotations Not Original)

Claim 9: The device of claim 1, wherein the textured region has been formed by a process selected from the group consisting of lasing, chemical etching, and combinations thereof

256. The Hamamatsu S11510-1106, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, sensor comprises the photosensitive imager device of Claim 1, wherein the textured region has been formed by a process selected from the group consisting of lasing, chemical etching, and combinations thereof. In particular, Hamamatsu's website describes use of laser processing to produce texture on the backside of the S11510 series sensors as follows:

> The S11510-1106 is a family of FFT-CCD image sensors for photometric applications that offer improved sensitivity in the near infrared region at wavelengths longer than 800 nm. Our unique technology in laser processing was used to form a MEMS structure on the back side of the CCD. This allows the S11510-1106 to have much higher sensitivity than our previous products (S10420-01 series).

Ex. 41 at 1.

257. Further, the microscope image below shows the textured surface of the S11510-1106. Upon information and belief, the linear shapes visible in this image are caused by the laser moving back-and-forth across the substrate to create the MEMS texture.

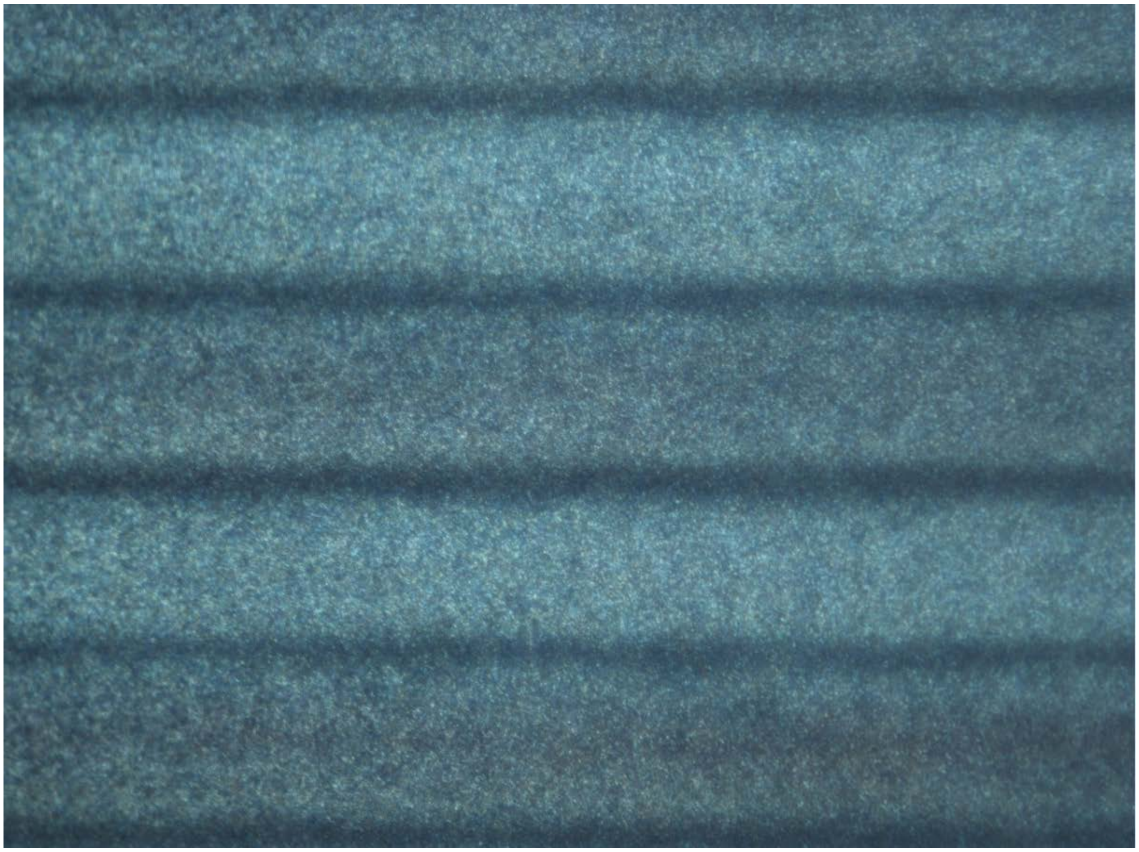


Fig. 60: Microscope Image of S11510 Sensor in Ocean Optics Maya2000 Pro

Claim 24: The device of claim 9, wherein the textured region has been formed by lasing.

258. The Hamamatsu S11510-1106, included in products such as the Ocean Optics Maya2000 Pro-NIR, Ex. 36 at 1, sensor comprises a device according to claim 9, wherein the textured region has been formed by lasing. In particular, Hamamatsu's website describes use of laser processing to produce texture on the backside of the S11510 series sensors as follows:

> The S11510-1106 is a family of FFT-CCD image sensors for photometric applications that offer improved sensitivity in the near infrared region at wavelengths longer than 800 nm. Our unique technology in laser processing was used to form a MEMS structure on the back side of the CCD. This allows the S11510-1106 to have much higher sensitivity than our previous products (S10420-01 series).

Ex. 41 at 1.

259. Further, the microscope image below shows the textured surface of the S11510-1106. Upon information and belief, the linear shapes visible in this image are caused by the laser moving back-and-forth across the substrate to create the MEMS texture.

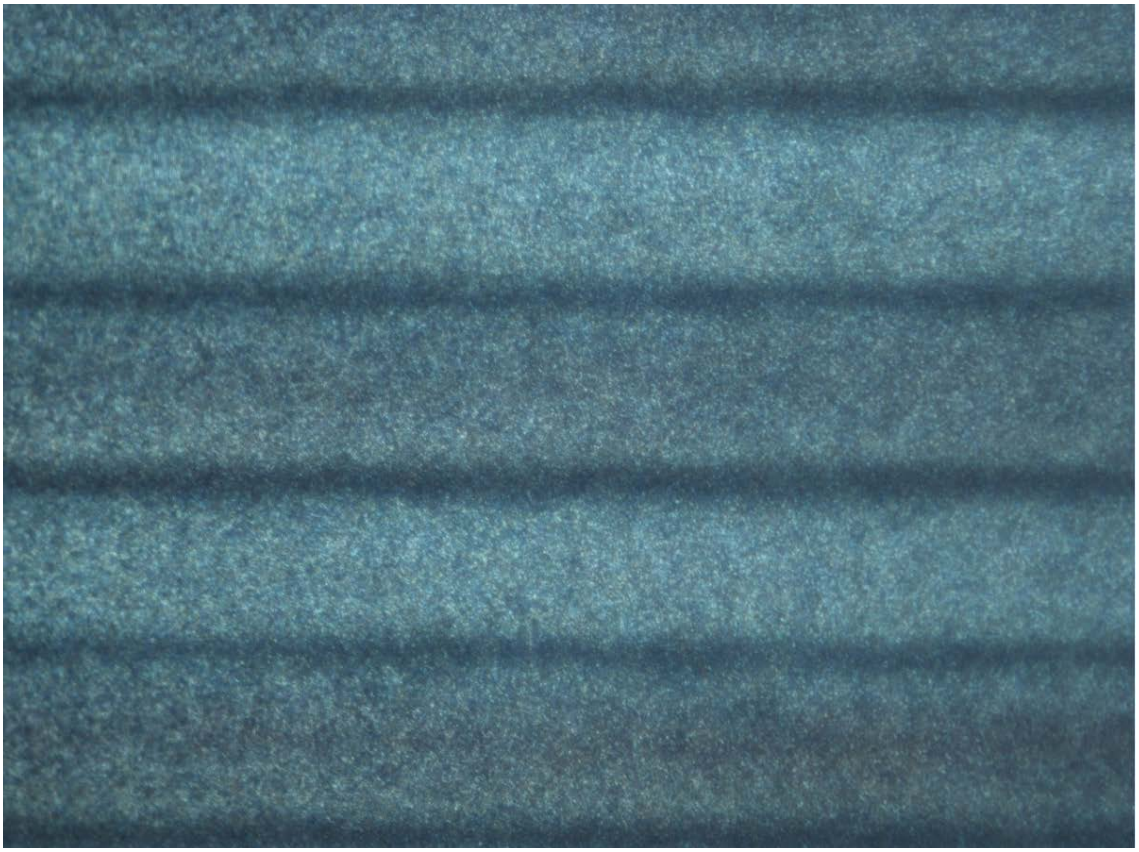


Fig. 61: Microscope Image of S11510 Sensor in Ocean Optics Maya2000 Pro

XXV. PRAYER FOR RELIEF

260. WHEREFORE, Plaintiffs request that the Court grant the following relief:

A. Judgment in Plaintiffs' favor on each count;

B. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 8,564,087 to name Prof. Mazur and Dr. Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '087 Patent.

C. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 8,564,087 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’087 Patent.

D. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 8,742,528 to name Prof. Mazur and Dr. Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’528 Patent.

E. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 8,742,528 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’528 Patent.

F. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 8,916,945 to name Prof. Mazur and Dr. Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’945 Patent.

G. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 8,916,945 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’945 Patent.

H. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 8,629,485 to name Prof. Mazur and Dr.

Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’485 Patent.

I. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 8,629,485 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’485 Patent.

J. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 8,884,226 to name Prof. Mazur and Dr. Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’226 Patent.

K. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 8,884,226 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’226 Patent.

L. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 8,994,135 to name Prof. Mazur and Dr. Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’135 Patent.

M. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 8,994,135 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’135 Patent.

N. Order the United States Patent and Trademark Office to correct the inventorship of United States Patent Number 9,190,551 to name Prof. Mazur and Dr. Carey as the sole inventors, or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’551 Patent.

O. Alternatively, order Hamamatsu to sign the requisite documents to correct inventorship of United States Patent Number 9,190,551 to name Prof. Mazur and Dr. Carey as the sole inventors or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’551 Patent.

P. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,564,087 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’087 Patent.

Q. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,742,528 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’528 Patent.

R. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,916,945 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’945 Patent.

S. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,629,485 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’485 Patent.

T. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,884,226 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’226 Patent.

U. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,994,135 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '135 Patent.

V. Issue a declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 9,190,551 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '551 Patent.

W. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,564,087 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '087 Patent.

X. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,742,528 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '528 Patent.

Y. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,916,945 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '945 Patent.

Z. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,629,485 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the '485 Patent.

AA. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,884,226 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’226 Patent.

BB. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 8,994,135 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’135 Patent.

CC. Pursuant to 28 U.S.C. § 2202, issue any injunctions necessary to enforce the declaratory judgment naming Prof. Mazur and Dr. Carey as the sole inventors of United States Patent Number 9,190,551 or, in the alternative, as joint inventors to the individuals currently listed as inventors on the ’551 Patent.

DD. Order a constructive trust over all information, patent applications, patents, technology, products, and other materials in the possession, custody, or control of Hamamatsu that wrongfully constitute, contain, were based on, and/or derived in whole or in part from the use of Plaintiffs’ intellectual property, and an order that Hamamatsu immediately transfer to Plaintiffs all right, title, and interest in such information, patent applications, patents, material, technology, and products;

EE. Order Hamamatsu Photonics K.K. to disgorge all monies and/or profits derived from breaching the Mutual Non-Disclosure Agreement between SiOnyx and Hamamatsu Photonics K.K.

FF. Award Plaintiffs the amount by which Hamamatsu Photonics K.K. has been unjustly enriched by ownership of patents on Harvard and SiOnyx’s technology.

GG. Order an accounting of any monetary or other benefits received by Hamamatsu as a result of their breach of the Mutual Non-Disclosure Agreement, including consequential damages flowing from [redacted]

HH. Hamamatsu has directly infringed and continues to directly infringe one or more claims of the ’446, ’467, and ’591 Patents, either literally or under the doctrine of equivalents;

II. Hamamatsu has willfully infringed and continues to willfully infringe the ’446, ’467, and ’591 Patents;

JJ. Hamamatsu has indirectly infringed and continues to indirectly infringe one or more claims of the ’446, ’467, and ’591 Patents, either by contributing to or inducing direct infringement by another, either literally or under the doctrine of equivalents;

KK. Plaintiffs be awarded royalty and lost-profit based damages adequate to compensate them for Hamamatsu’s infringement of the ’446, ’467, and ’591 Patents, such damages to be determined by a jury;

LL. Plaintiffs be awarded treble damages for Hamamatsu’s willful infringement of the ’446,’467, and ’591 Patents;

MM. Hamamatsu, its officers, agents, employees, and those persons in active concert or participation with it or any of them, and its successors and assigns, be permanently enjoined from continued acts of infringement of the ’446, ’467, and ’591 Patents, including but not limited to an injunction against making, using, selling, and/or offering for sale within the United States, and/or importing into the United States, any products that infringe the ’446, ’467, and ’591 Patents;

NN. Hamamatsu, its officers, agents, employees, and those persons in active concert or participation with it or any of them, and its successors and assigns, be permanently enjoined from continued acts of indirect infringement of the ’446, ’467, and ’591 Patents, including but not limited to an injunction against acts that contribute to or induce the infringement of another;

OO. Award prejudgment interest according to proof;

PP. Plaintiffs be awarded such other and further relief as this Court deems just and proper.

XXVI. DEMAND FOR JURY TRIAL

261. Plaintiffs hereby demand a jury in accordance with Rule 38 of the Federal Rules of Civil Procedure.

Dated: 12/17/2015

Respectfully submitted,

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