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Abstract:

The Tokyo District Court handed down a landmark ruling ordering Nichia Corporation to pay a whopping ¥20 billion to Nakamura Shuji for his invented method of gallium nitride crystal growth. In the present paper, I discuss that the logic of the court is inconsistent and unconvincing. Based on the investigation of the innovation path, I prove that they overestimated the value of the patent within the total innovation diagram of blue light emitting diodes. The proper value of Nakamura's input is found from ¥20.5 million to ¥205 million.

Keywords: innovation, blue LED, Nichia Corporation, patent

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The Dimness of the Blue Diode Lawsuit

Yamaguchi Eiichi

On January 30, 2004, the Tokyo District Court handed down a landmark ruling ordering Nichia Corporation to pay a whopping ¥20 billion to Nakamura Shûji for an invention he made while working for the Tokushima-based company. Nakamura, who is now a professor at the University of California at Santa Barbara, had sued Nichia claiming that he was entitled to a share of the profits from his breakthrough invention of the blue light-emitting diode. The court awarded the full amount claimed by the plaintiff, asserting that the value of Nakamura's contribution was ¥60.4 billion. Had he demanded this even larger sum, he might well have received it.

The verdict was based on the assumption that Nichia would reap ¥120.9 billion in profits from the blue LED through 2010, when its patent on the device expires. The court declared that Nakamura made his invention "with his individual power, based on completely original thinking," calling it "an utterly exceptional example of a world-class invention eagerly awaited by the industrial world" made in advance of research institutes around the globe by a man "working in a poor research environment at a small company."

In this article I hope to shed light on whether Nakamura's input was really worth ¥60.4 billion. I should clarify at the outset that I am in no way connected with Nichia and have never been directly involved in blue LED research. But like Nakamura I was involved in scientific research in the private sector, having worked at NTT Basic Research Laboratories after majoring in physics in college. Below I offer my personal reactions upon rereading the court ruling without any preconceptions.

HOW THE BLUE DIODE WAS INVENTED

The invention of the blue LED cannot reasonably be described as having virtually appeared out of thin air to Nakamura "based on completely original thinking." The seeds of this remarkable innovation were sown in earlier decades by Professor Akasaki Isamu of Nagoya University and his student, Amano Hiroshi, along with Matsuoka Takashi of NTT Opto-Electronics Laboratories (now NTT Photonics Laboratories), a research arm of Nippon Telegraph and Telephone Corp.

LEDs themselves are an outgrowth of quantum theory, arguably the highest intellectual achievement of the twentieth century. In 1939 a research team at Bell Laboratories of the United States accidentally discovered that semiconducting diodes generated electricity when exposed to light. An understanding of this phenomenon based on quantum physics eventually led to the invention of both solar cells, which convert light into electricity, and LEDs, which convert electricity into light.

The first LEDs were developed around 1960. These emitted red light, and researchers around the globe next set to work creating blue LEDs that could be put to commercial use. They were spurred by the awareness that as soon as blue LEDs became a reality, the technology could then be applied to create green LEDs, providing for all three primary colors of light and enabling the generation of a full spectrum of colors. Because LEDs last almost indefinitely, they can be used to create maintenance-free traffic lights, large-panel television monitors, and various forms of lighting. LEDs consume just a fraction of the electricity required by incandescent light bulbs, and they are far less taxing on the environment than fluorescent lamps, which leak mercury when they break.

The dream of a blue LED remained an elusive one, however. There were problems with both gallium nitride and zinc selenide, the two semiconducting materials that were being used to develop blue LEDs. Growing a crystal large enough to be used as a semiconductor requires a separate substrate with a virtually identical crystalline structure and atomic configuration. There was no known such substrate for gallium nitride.

Because a good substrate did exist for zinc selenide, most corporate labs focused their resources on this material. It had a decisive shortcoming, though, in that semiconductors made of zinc selenide could not be made to emit light continuously. So the researchers seemed to be at an impasse. But then a major breakthrough came with a discovery made by Nagoya University’s Akasaki.

Unlike most other researchers, Akasaki channeled all his energies into gallium nitride. In the early 1970s he began research on growing gallium nitride crystals using sapphire as a substrate. After a decade of trial and error, he developed what has come to be known as the MOVPE (metalorganic vapor-phase epitaxy) method of flowing reactant gases over a substrate to form crystals. Amano, who was working in Akasaki’s laboratory, succeeded—quite by accident—in producing gallium nitride crystals using this method, thus opening the door to the commercialization of the blue LED.

The key was the invention of a technology to build a sponge-like buffer layer between the sapphire substrate and gallium nitride crystal, a method employed in creating other semiconductors. Amano had been interested in applying this method to gallium nitride, and having just submitted his master’s thesis, he was free to experiment. He achieved success with aluminum nitride and immediately applied for a patent. Because both Akasaki and Amano were affiliated with a national university, the state became the patent owner. Neither of them made any money from this breakthrough invention, which was made well before Nakamura’s.

The second major breakthrough came from the same research team. There are two types of semiconductors: The n-type has extra electrons, while the p-type has missing electrons. Building a high-luminescence LED requires putting these two types together. Akasaki and Amano were initially able to generate only n-type semiconductors. The argument was even advanced that the formation of p-type semiconductors on gallium nitride was theoretically impossible, and most researchers gave up on this pursuit.

But in the summer of 1987, while observing gallium nitride under an electron microscope, Amano witnessed an astounding phenomenon. The crystal that was exposed to electron beams began to emit light. This discovery led one year later to the first successful formation of p-type semiconductors on gallium nitride using an electron beam irradiation technique, which was later patented.

Only one step remained before the dream of blue LEDs became a reality. This step was taken by NTT's Matsuoka. When gallium nitride is exposed to electricity it emits ultraviolet light, which has a higher frequency than blue light. To lower the frequency to visible blue, some gallium atoms had to be replaced by indium, producing a compound crystal.

Matsuoka mastered the technology developed by Amano and Akasaki and in 1989, after a process of trial and error, succeeded in creating a compound of gallium nitride and indium nitride. Just three years later, in March 1992, however, Matsuoka was ordered to halt his research by his laboratory, which decided (erroneously in hindsight) to focus its resources on zinc selenide. If NTT had allowed Matsuoka to continue, he—not Nakamura—might have been celebrated as the inventor of the blue LED.

NAKAMURA'S INTEGRATION OF EARLIER BREAKTHROUGHS

Nakamura did not begin his work on the blue LED until 1989, nearly 20 years after Akasaki launched his research. Nichia at the time was a small provincial manufacturer with fewer than 200 employees. He was initially involved in semiconductor production and personally peddled the wares he had produced. Sales were flat, however, since much larger rivals developed the same types of products at around the same time, and buyers invariably demanded lower prices from an unknown manufacturer. It was out of frustration with this experience that Nakamura raised the idea of producing blue LEDs—which no one had succeeded in doing—with top management.

Nichia President Ogawa Eiji was moved by Nakamura's spirited plea and agreed to grant him research funds of ¥500 million and a year off to study at the University of Florida. For a small, obscure manufacturer, this was a truly daring decision. Nakamura pursued the path laid by Akasaki and others and opted for gallium nitride. By the time he began his research, Akasaki, Amano, and Matsuoka had already made major strides toward blue LED commercialization. He was able to ascertain the gist of what his predecessors had achieved through papers and reports they had published.

In 1990, just a year after launching his research, Nakamura succeeded in growing high-quality gallium nitride crystals by devising what he dubbed the “two flow” system of metalorganic chemical vapor deposition. He applied for a patent on his configuration, which was approved by Japan’s Patent Office seven years later. The following year he received a second patent for an adaptation of the buffer-layer technology devised by Amano. Also in 1991 research by Iwasa Naruhito, Nakamura’s subordinate at Nichia, led to the development of an easy method of creating p-type semiconductors. A patent for this technology was applied for and awarded to the joint applicants, Iwasa and Nakamura.

The last major hurdle to commercialization of the blue LED was building a compound crystal of gallium nitride and indium nitride. On this particular topic Nakamura consulted NTT’s Matsuoka directly, who kindly referred him to an approach described in a research paper. Had Matsuoka hoped to keep the fruits of research to himself, he would have jealously guarded his findings. While mindful of corporate demarcations, Nakamura and Matsuoka freely exchanged ideas in the communal spirit of professionalism, working together to create new technologies. As a result, in July 1992 Nakamura and his R&D team were able to build blue LEDs with much higher luminescence than before, opening the door to their practical application.

As suggested by the above description, Nakamura’s main feat was in adding refinements to earlier breakthroughs and integrating them into a new product. There is no denying that he is an extraordinarily gifted researcher, for in just three years he accomplished what had remained out of reach for Akasaki, Amano, and Matsuoka for two decades. For an invention to have a major impact on society, though, it must be mass-produced under a strict quality-control environment. It was Nichia’s management decision, therefore, not Nakamura’s discovery, that led to the successful mass production of the blue LED.

TAKING RISKS

As Table 2 shows, Nichia’s management invested ¥2.1 billion in LED production equipment in 1994 and continued to build up production capacity thereafter. The company’s sales of the devices began skyrocketing from 1997 on. This was thanks to an invention by Shimizu Yoshinori and other young Nichia researchers of a blue LED that produces white light, which they did by applying a coat of fluorescent directly onto the diode. After a year of trial and error, they discovered an optimum fluorescent; the white LED was commercialized in 1996 and was eagerly adopted for use in color mobilephone displays.

The spectacular success of the white LED gave the company an insurmountable lead over the competition. It has become the world's top producer of gallium nitride LEDs, its LED division ringing up ¥150.8 billion in sales in 2003. Its closest rival was Osram Opto Semiconductors, a subsidiary of the German electronics giant Siemens, which registered sales of ¥40 billion. And on the domestic front, Toyoda Gôsei, which is a much larger company than Nichia and which received technical guidance from Akasaki and Amano when it embarked on the blue LED business, has always been a step behind Nichia in introducing new products; its blue LED sales in 2003 were only around ¥31.5 billion, about a fifth of Nichia's figure. What has enabled Nichia to beat rivals like these? The real key to the company's success is the 1993 decision by President Ogawa to proceed with the development of gallium-nitride-based blue diodes—unlike the rest of the industry, which was going with zinc selenide—despite strong opposition from other Nichia directors.

Creating a market from scratch entails much higher risks than competing in an already established market. The failure to attract buyers for several years will mean the death of many smaller companies that take such a gamble. If, on the other hand, a new market does emerge, the company that claims the top position through prior capital spending will reap the biggest rewards. With Toyoda Gôsei standing before it like Goliath, Nichia was confronted with a truly life-or-death decision in 1993.

The choice was made even more daring by the fact that Nakamura's two-flow method was not suited to mass production, since it was hard to maintain a steady volume in the flow of reactant gas. In 1996 Nichia's research team developed an alternative method better suited to mass production and began a phased introduction of the new system; by May 1997 it had completely discarded the two-flow approach. The lawsuit filed by Nakamura pertains specifically to the two-flow method, so the Tokyo District Court mistakenly premised its calculations of Nichia's earnings from Nakamura's work on a technology that Nichia no longer uses.

Had Nichia chosen to play it safe and rejected Nakamura's plea, he would not have been given the opportunity to engage in leading-edge research. On the other hand, had Nakamura not ascertained the optimum conditions for crystal growth, Nichia would still be a small, obscure manufacturer of fluorescent materials. The true answer to why Nichia was able to virtually monopolize the blue and white LED markets, then, can be traced to the bold 1993 management decision to concentrate its resources on a still-unproven technology, enabling it to clear the myriad obstacles that manufacturers confront before launching mass production. Society has since conferred on Nakamura the distinction of being the inventor of the blue LED. Without the 1993 decision, though, Toyoda Gôsei, with guidance from Akasaki and Amano, would no doubt have won the mass-production race and would now be enjoying unchallenged dominance over the blue LED market.

The economic value of a company is not generated simply by its technical innovations. It is engendered by management decisions on when and how such innovations are launched onto the market to create value for the company and by marketing efforts to win over new buyers and enhance that value. Even if we make the tremendous leap of supposing that the court was correct in labeling Nakamura's invention a product of "individual power" and "completely original thinking," the efforts to win markets for the blue LED and generate value for the company were certainly not undertaken by the inventor alone. They were made by Nichia managers in defiance of formidable risks.

WHAT IS NAKAMURA'S INVENTION WORTH?

The court credits Nakamura with having made his invention with his "individual power" while working in "a poor research environment at a small company." This, however, is utterly contrary to fact. Research funds at the disposal of each researcher at even the most generous laboratories, such as those affiliated with NTT, are on the order of tens of millions of yen per year. Matsuoka, for instance, worked with an annual budget of just several million yen to grow gallium nitride crystals. Nakamura's ardent plea, meanwhile, moved Nichia President Ogawa to provide ¥500 million in an initial grant of research funds. This was by no means a "poor research environment." On the contrary, the company put all its resources behind Nakamura, giving him red-carpet treatment. He was able to work with a budget that would be unthinkable even for researchers at Japan's biggest companies.

Nakamura recounts that he was ordered on several occasions by President Ogawa not to present his findings in research papers. Unlike NTT's Matsuoka, who saw his research cut short by his laboratory's decision to focus on zinc selenide, Nakamura simply ignored his boss's wishes and continued to publish, yet he was never penalized. One can surmise that he was basically given free rein to continue his research on gallium nitride from 1989 until his resignation from the company in 1999.

Nakamura claims that the only reward he received from Nichia for his invention was a meager ¥20,000. After the invention of the blue LED, though, his bonus was substantially increased, and he was promoted at an unusually fast pace. Over his final nine years with the company these special measures gave him an estimated ¥62 million more than he would have earned without the invention. This sum can be perceived as the company's reward for Nakamura's invention.

Article 35 of Japan’s Patent Law grants researchers working at corporate labs the right to claim from their employer a sum commensurate with the value of their invention when they transfer patent rights and exclusive licenses to the company. The law does not stipulate, however, how this amount should be objectively and quantitatively determined. The court ruled that the value of Nakamura’s contribution to the innovation that led to the creation of the blue LED industry was at least 50% of Nichia’s profits on the device, meaning that his invention was worth ¥60.4 billion. This ruling, as I have already outlined, confuses the value of an invention with the value of a risk-carrying management decision. It will shake our social framework if people who take no share in the risk of a bold undertaking are allowed to claim a share of the profits after it turns out to be successful and the profits have already been earned.

How much, then, is the invention reasonably worth? This author believes, first of all, that the risk-taking element should be completely eliminated from consideration of an invention’s value. Let us assume, for argument’s sake, that Nichia had adopted a strategy of licensing its patents to a company interested in building blue LEDs. It would then have received income from such licenses without taking any risks. Secondly, the value of Nakamura’s invention should be deemed to apply only to the period through April 1997 at the latest, since, as noted above, Nichia began phasing out the two-flow method in 1996 due to problems with mass production and completed its switch to an independently developed approach by May 1997. Extending the growth curve for sales between 1996 and April 1997 back to 1993 yields an estimate of cumulative sales of ¥8.2 billion. Because royalties from licensed patents are commonly between 1% and 5% in the semiconductor industry, the income from the blue LED patent can be estimated to be between ¥82 million and ¥410 million.

Nichia’s bold management decision and its provision of abundant funds were key factors behind the invention, so the contribution of the inventor can be deemed to have been between 25% and 50%—figures commonly applied to researchers at public-sector research institutions. Thus the proper value of Nakamura’s input is anywhere from ¥20.5 million to ¥205 million.

VALIDITY OF NAKAMURA’S PATENT

Many corporate researchers in Japan became the victims of retrenchment policies during the slowdown in the 1990s, as one R&D center after another was shut down. These people in many cases lost their jobs, and all of them suffered severe anguish. Not only that, but in this same period big corporations lost the energy to embark on risky undertakings. In this context, Nakamura’s case has been useful in provoking a reexamination of the relationship between the corporation and individual researchers.

If individuals are awarded excessively high sums for their inventions, however, firms are liable to lose interest in undertaking R&D. This, ironically, will have negative repercussions on many researchers. A great majority of them stay with their corporate labs because of their love for research; their chief motivation is not so much the promise of lucrative compensation but the freedom to make new discoveries.

For these researchers, the greatest joy is seeing their inventions move out into society and help create new industries. Companies that have lost their risk-taking spirit are not likely to develop practical applications for such inventions; they will simply sit on their patents without commercializing them, just to prevent their rivals from using them or developing similar technologies. Patents and exclusive licenses arising from the work of corporate researchers are owned by the company that employs them. The inventor is thus prevented from using his or her own invention (and if the company does not use it either, no profits are generated, so the inventor cannot claim commensurate compensation). If they do not own the patent rights, researchers cannot use their own inventions even if they start their own companies.

I would suggest, therefore, that Japan's Patent Law be revised so that former employees are granted the right to use their own inventions should they file such a request with the patent-owning company. If exceptions to this requirement are made for companies that are already actively using or have concrete plans to use the patent, then there should be no loss of corporate incentive to conduct R&D activities.

In concluding this article I would like to call attention to an invention that has the potential of overturning the underlying assumptions on which the lawsuit rests. Five years before Nakamura applied for a patent on the two-flow method—which is the centerpiece of the suit—a very similar invention was made by M. Matloubian at the University of Southern California. In a paper presented in 1985, Matloubian describes a similar method of growing gallium nitride crystals. A diagram of the apparatus that appears in the paper, moreover, has the same configurations as that used by Nakamura in his patent application. In his patent, Nakamura claims that the two-flow method is different from Matloubian's approach because it uses a pair of gases, hydrogen and nitrogen, whereas Matloubian uses one gas, ammonia. In fact, however, Matloubian also writes in his paper of using a pair of gases, ammonia and hydrogen.

Perhaps even more damaging to Nakamura's case is that a Japanese semiconductor equipment manufacturer had already applied for a patent for a system very similar to the two-flow method in 1986. The application was for the creation of semiconductors with a reactant gas flowing roughly parallel to the surface of a substrate and an inert gas flowing perpendicularly. Nakamura's application is for an identical approach in terms of not using a reactant gas for the perpendicular flow. Examiners may have overlooked this earlier patent. If that is the case, then a third party may file for the nullification of the patent awarded to Nakamura. If the suit is upheld, the patent will be annulled under Article 125 of the Patent Law, and the question of awarding Nakamura a sum commensurate with the value of his invention, as stipulated in Article 35, will vanish.

Translated from "'200-oku-en hanketsu' Nakamura Shûji wa eiyû ka," in Bungei Shunjû*, April 2004, pp. 162–69. (Courtesy of Bungei Shunjû).*

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