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新材料と新光源の創造

地球環境を救う技術革新

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中村　修二　氏

CREATING NEW MATERIAL AND NEW SOURCE OF LIGHT

Technological innovations protecting the earth environment

Commemorative Lecture at the Twenty-First Honda Prize Awarding Ceremony on the 17th November 2000 in Tokyo

Professor Shuji Nakamura
Material Department
University of California, Santa Barbara

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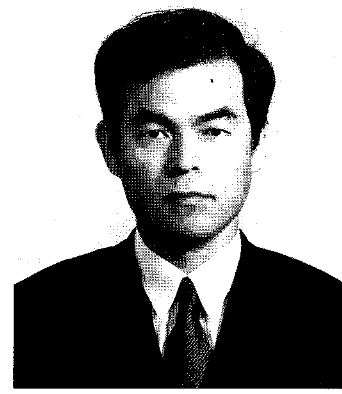

中村　修二

カリフォルニア大学
サンタバーバラ校 教授

Shuji Nakamura

Professor, University of California, Santa Barbara

■略歴

1954年	愛媛県西宇和郡瀬戸町大久で生まれる
1973～77年	徳島大学工学部電子工学専攻
1977～79年	徳島大学工学部大学院修士課程専攻
1979～88年	日亜化学工業（株）、赤外LEDとLED用結晶材料の研究、開発
1988～89年	フロリダ大学で客員研究員、Si上のGaAs結晶成長の研究
1989～99年	青、緑色LEDと紫色半導体レーザーの研究、開発
1994年	徳島大学より博士課程取得
2000年～現在	カリフォルニア大学サンタバーバラ校材料物性学部教授

■受賞歴

1996年	仁科記念賞
1997年	大河内記念賞、MRS Medal Award
1998年	IEEE Jack A.Morton Award, British Rank Prize
1999年	Julius-Springer Prize for Applied Physics
2000年	Carl Zeis Research Award

■会員資格

日本応用物理学会
レーザー学会

●主な著書：
「The Blue Laser Diode」他150件以上

■Personal History

1954	Born in Seto-cho, Nishiuwa-gun, Ehime Pref.
1973～77	Majored in electronics at Department of Engineering, University of Tokushima
1977～79	Master's Course at the University of Tokushima Graduate School of Technology
1979～88	Nichia Chemical Industries Co., Ltd.; research and development on infrared LED and crystal materials for LED
1988～89	Visiting Research Fellow at the University of Florida; reseach on crystal development of GaAs on Si
1989～99	Research and development on the blue, green LED and purple semiconductor laser
1994～	Obtained Ph.D. from the University of Tokushima
2000～	Professor, Materials Department, University of California, Santa Barbara

■Awards

1996	Nishina Memorial Prize
1997	Ohkouchi Memorial Prize, MRS Medal Award
1998	IEEE Jack A. Morton Award, British Rank Prize
1999	Julius-Springer Prize for Applied Physics
2000	Carl Zeis Research Award

■Organization

The Japanese Society of Applied Physics
The Laser Society of Japan

●Authorship, papers:
Over 150 items including 'The Blue Laser Diode.'

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New material suits the environmentally aware Eco-Technology concept

Ladies and gentlemen, it is my great honor to address this large audience on this auspicious occasion. First of all, I would like to thank Madame Honda and Mr. Kawashima, President of the Honda Foundation. I also thank Mr. Imura(a member of Council for Science and Technolgy) for his wonderful speech; and finally, all the staff members at the Honda Foundation, I really appreciate your involvement in awarding me this wonderful prize.

Fortunately, my research activities have something to do with saving energy and resources on the earth. I believe the prize comes to me because my achievements suit the concept of "eco-technology" that Mr. Soichiro Honda advocated.

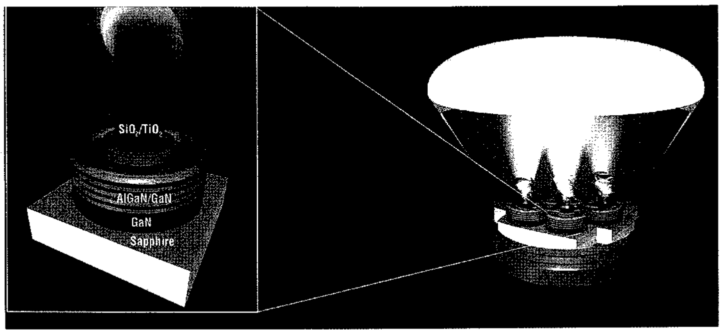
Today I am going to speak about "Creation of new material and new source of light." The new material here refers to an environment-friendly material called "gallium nitride." Few people know toxic materials have long been used for compound semiconductors. But as preserving the environment has become a global issue, most manufacturers began substituting environment-friendly materials for toxic ones. The light-emitting device made of this safe gallium nitride has been proved very efficient and energy saving. This device would last almost semi-permanently while conventional products have a service life of only several months.

Electric bulb stays on semi-permanently

My first topic, the light-emitting diode (LED), is a semiconductor-based device. As you can easily recognize, gallium nitride makes this pale blue diode that emits blue light, and the green one here emits green light. Before these two, the only color the LED could emit was red.

The three primary colors of light are blue, green and red. By blending the same amount of them, we can have white light; and by differentiating the proportion of the three, we can make almost infinite variations of colors.(Figure-1)

White light sources are used widely in households. Major applications include electric bulb and fluorescent tube, but the issue is duration of their life. They are dead in several months.



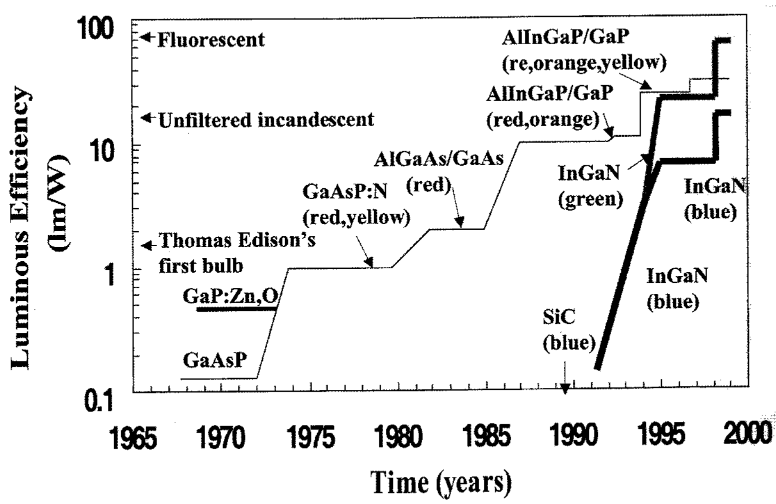
(Figure-1)

However, semiconductor-based lighting products enjoy a semi-permanent life and won't burn out. In these products, we use fluophor to turn blue into white, and the luminous efficacy of the resultant white light is more than twice as large as that of conventional electric bulbs; and again, it endures almost forever. So once you install semiconductor light bulbs in your home, there is no need for spares until you move out to a new house. One advantage of using the semiconductor LED is this energy-saving effect, and its long life saves plenty of resources, too. In this way, I suppose the LED's would become a mainstream in the lighting industry in near future.

Our next objective is to improve the semiconductor LED's luminous efficacy to the level of fluorescent tube.

Fluorescent tube's efficacy is twice as large as the current semiconductor LED.

But, at the laboratory level, a match has been almost finished while no such announcement has been out. Presumably within a few years some organization will make an announcement to pave the way for commercialization. It won't be long before all the light sources will be semiconductor-based.



(Figure-2)

The development of the epoch-making product started in Tokushima

Electric circuits were composed of vacuum tubes until Shockley apperaed to invent the transistor by using semiconductor. Now all products come in chips. LED was invented in the efforts to transistorize light sources. At first, there was only the red LED, but now we have green and blue ones, too. These newer LED's are the achievement of Nichia Corporation, a manufacturing firm based in Anan-shi, Tokushima Prefecture, where I worked for a long time. Everybody was astonished because this big invention came out of the blue from a rural, small company like Nichia.

My point here is why such a remote company gave birth to the invention. Before going further, I thank Chairman Nobuo Ogawa and President Eiji Ogawa of Nichia for giving me opportunities to devote myself to the LED researches. I also thank my young colleagues at the R&D section. My apologyies. I should've done this at the beginning of this speech.

Over twenty years ago in 1979, I was graduated from the Electronics Engineering Department of the Tokushima University with a Master of Science degree. And soon I got married and had our first daughter who is present here today. As my wife is a native of Tokushima, I decided to continue to live there. Although my plan was getting a job with a larger company in larger cities, we thought it would be better to raise our daughter in the rural environment and gave up moving to an urban area.

I had no idea what and how many companies were there in Tokushima. One day my chief professor told me the only company he would recommend me to was Nichia Corporation, and I said, "OK, I'll try." Without any commitment, I became an employee and still had no idea what my company was really manufacturing. I was posted to the R&D section.

By the way I first saw Mr. Soichiro Honda, perhaps after his death, on an extensive TV program featuring his success story. I was impressed. He started his business in a barrack in a small city. Nichia's R&D section was quite like that. My small barrack looked quite similar to Mr. Honda's small factory. It was really impressive.

There were only a Section Chief and two staff members in the R&D section before I was assigned. The four-member organization shrank because a member quit soon after my assignment. Anyway in this warehouse-like barrack I started everything associated with our achievements.

Hard times despite three-men's role as development, manufacturing and sales

My first job was developing the crystal of gallium phosphide (GaP) as a material for red LED. I succeeded in commercializing after three years of struggle. I can easily imagine Mr. Honda's difficulties as my workshop was quite similar to his where there was any special facility. Carrying a sample of the GaP crystal, a fruit of my hard work, I went out and looked for purchasers.

Most of the large electronics manufacturers I visited were willing to test my product, but they insisted on the price half of the one I suggested. They would said, "If we buy products from a strange, remote company like yours, how do you convince us on the stable quality?" At that time, these manufacturers were already buying similar materials from large chipmakers. My product didn't sell after all.

My next project was the research on gallium arsenide (GaAs), a material for the crystal for infrared or red LED. Again I spent about three years to attain a product. My company was poor, so I made everything—an electric furnace and others—all by myself, and was barely able to make a product and went out to sell it. In other words, I was responsible for multiple roles—R&D, manufacturing, and marketing and sales. A trained salesman came with me, but unfortunately his expertise was with fluorescent products. I had to do anything because my partner knew almost nothing about semiconductor. GaAs did not sell at all for the same reason as GaP. Well, to be more precise, it ended up with sales of around one million yen.

Finding these products won't pick up, I switched to the development of gallium aluminum arsenide (GaAlAs). This yields an epitaxial wafer. This time the product actually glows. In about four years, I succeeded in making a red LED using this material. But my efforts turned out almost in vain for similar reasons.

Fro ten years I developed three different new products with no sales, which made my position in the company precarious (laugh). Companies worship sales, and because my products didn't sell, I was heavily criticized from all sides. That drove me nuts.

Direct appeal to president for the blue LED

Until then, I obeyed docilely the instructions of my boss on the themes of research. Like most Japanese businessmen, being "yes" man was the only way of moving up through the ranks for me. But after ten years of hardship, I finally threw a wobbler. Realizing the obedience led me nowhere, I went to President Ogawa (current Chairman) and directly appealed my aspirations for inventing the blue LED.

Although I had requested the same thing in the past, my bosses rejected flatly by saying how on earth a company without financial and human resources can develop products like a blue LED. They bit my head off, and justified saying how a company like us could succeed where giant chipmakers and academic laboratories are still struggling. But to my surprise, Mr. Ogawa simply said "Go ahead."

Being a bit frivolous, I continued and asked him to give me a budget of several hundred millions yen for the project, and again he approved it instantly. Until then, I never spent budget for my researches. I did so because I knew Nichia made layoffs due to stagnating sales one year before my entry and thought my company had no budget for me. That time I was going nuts and facing a dead-end, so I could talk for the first time about budget. President munificently accepted me, and like that, he nodded when I requested study for one year at the University of Florida as well.

Idea going abroad came from lack of knowledge and scarcity of information on a device called "MOCVD" that can be used to analyze reaction from the blue LED. So I dared to ask him. Only ten minutes were needed for all these approval. This was the power and decision of a business founder, and I was profoundly impressed.

Later I came to know why Mr. Ogawa approved so simply: He praised me for my achievements backstage. Before I came, all products of Nichia were fluophor, a white powder which glows in white and other colors and is used for fluorescent lamps and color TVs. This was invented by Mr. Ogawa, the founder of Nichia, and I was the first engineer at Nichia who developed a different type of product. He knew how hard it is to invent a product.

Unusual material choice yielded the blue LED

I went to the University of Florida for one year and returned to continue my researches on MOCVD. The MOCVD requires two materials: zinc selenide (ZnSe) and gallium nitride (GaN). At that time, most researchers in the world were studying ZnSe. A small portion of the researchers was studying GaN, but in comparison with the ZnSe researchers, they were close to nil.

More or less desperate in terms of business, I was inclined to GaN thinking GaN has few competitors while using ZnSe would go in the same track as large enterprises would occupy the major pie of the market once they can succeed in commercialization. True story was the blue LED happened to be mine from such a facile choice. Indeed this was the whole story.

The reason leading companies and universities chose ZnSe was it facilitates the formation of good crystals while GaN produces only jagged crystals. ZnSe has a substrate but GaN has none. Even very luminous GaN crystal is ragged. Ten years ago nobody imagined that ragged crystals would produce extraordinarily brilliant LED. Expert books in principle instruct uncluttered crystals shouldn't be used for LED.

But there was an opinion in those manufacturers and universities that suggested using GaN instead. Leading firms formed a project and discussed which of the two should be used for the blue LED. In most cases, GaN is considered a nonsense. Insisting on unrealistic choice at meetings will be condemned severely. My luck was I worked for a tiny company and nobody bothered me. The approval of Mr. Ogawa promises a smooth progress afterwards.

Inventors rewarded few for their success in Japan

My preceding ten years were reading, reading, and reading. As there had been many technical and patent-related documents on commercialized inventions, I tried hard to catch up and imitated them into my own works.

This experience shows me that reading papers inevitably only leads to mimics. I abandoned documents and relied solely on feedbacks from my own experiments. As a manufacturer already had filed about 200 patent applications when I started a decade ago, I thought my ideas would collide somewhere. But in reality I was able to apply unique patents one after another.

Now all these patents are owned by Nichia: out of 500 different applications, more than 100 have been granted, among which more than 50 are basic patents. If companies and universities in the world try to develop similar products, they would have to have something to do with one or more of these basic patents.

But my problem, as President Kawashima said earlier, is they are all Nichia's property. None is at the disposal of the inventor. All I got 20,000 yen for each of the granted patents (laugh). As Mr. Imura said, unless the official rewards the inventors more, an increasing number of researchers will brain-drain to the United States. That country rewards inventors much, much more. In Japan bonus would be, say, one to two million yen. But in the States, the amount would differ by a few orders. Without a similar rewarding system, brilliant brains would be all go across the Pacific. You've actually witnessed most of the past Nobel Prize winners live in the States. Mr. Imura promised me he would improve the situation (laugh).

Characteristics of LED

This figure has the luminous efficacy of LED on the vertical axis and the period of invention on the horizontal axis. The efficacy curve of red LED, made of toxic arsenic, has rapidly risen and reached this point here according to the data published last year. The blue and green ones have long been missing, unavailable despite frantic efforts to develop them. And a sudden announcement of the product by a small company in Tokushima surprised the world. At present the efficiency of green and blue light LED's goes up around here. This year in 2000, a laboratory has nearly finished developing a substantially efficient green and blue LED's.

The luminous efficacy at the time Thomas Edison invented the first electric bulb is at about this position here the latest one has gone up there. The efficiency of white diodes is about twice or thrice as high as this. The same for fluorescent lamps currently in use is about here. Therefore, in order to achieve the same efficiency as fluorescent lamps, LED's efficiency must be twice or thrice better. But we have the prospect of commercializing them soon.

What differentiates LED from electric bulb most is its service life. As LED is a fixed, semiconductive light-emitting element, it has an almost semi-permanent life. Electric bulbs die within several months. A longer life means saving resources, and a higher luminous efficacy saving energy. Also the material used, indium-gallium nitride, is nontoxic and environment-friendly.

After I arrived at the Santa Barbara school of the University of California, a project was proposed by establishing an LED research center. This is to use LED for lighting by utilizing another type of device.

Detailed explanations on the construction of LED would make you bored, so I will skip them. Putting it quite simple, we are accumulating knowledge on various nitride materials to yield blue LED. Their crystal is ragged.

LED displays played a big role in the Sydney Olympic Games

For what are these LED's used? One of their applications is monitor. Conventional TV sets were like this: The only brilliant color is red, and there was yellowish green but it looks dim. Thus you can find very dark and reddish displays here and there. Although developers wanted to make a full-color display with LED's, it's impossible to create it without the blue LED.

Here is the first full-color TV set using the blue LED of Nichia produce in 1994. Adding only the blue element to the reddish, dark monitor turns it into a brilliant, full-color screen like this. In other words, TV screen is a complicated mixture of the three primary colors of red, blue and green.

In this case, since green color is also produced by a material of the GaN family, the image on the screen looks very sharp with all colors highly luminous. A large screen of the same stays highly visible even under the sun.

This example here is one used the Baltimore Stadium, and similar LED displays, I believe, are active in most football, soccer, and baseball stadiums. The blue and green diodes are the products that we developed. I hear President Kawashima watch games at various stadiums. Can you please recall Nakamura is the man behind the scene of the diode innovation (laugh)?

LED monitors were used for the Sydney Olympic Games. Big concert performers like the Rolling Stones are using the LED screen, too. These are all examples of the full-color LED display.(Figure-3)

Daylight Visible Video Displays

Mobile Color Advertising

(Figure-3)

Environment-friendly, GaN-based light sources have a wide range of applications

GaN-based light sources are used for automotives, too. I believe Honda would soon adopt them because your company is the first in the industry that started to use the blue LED. It is used for the front pilot lamp on the Honda motorcycles. In fact the auto instrument panel and its interior illumination are the biggest market for the blue, green and white LED's because the number of cars is tremendous. The industry always seeks highly reliable light sources as cars inevitably generate vibration.

As in the concept of "Eco-Technology," Honda and other car manufacturers are most environmentally aware corporate organizations. In the modern society, cars are so popular worldwide to the extent makers cannot help caring about the impact on the global environment. And currently GaN-based LED devices are the only commercially available environment-friendly light sources.

Cars used to use fluorescent lamps as light source, but they contain mercury, which is toxic. So today GaN-based LED devices are extending power because of their environment-friendliness.

In addition, white LED's are used for the backlight of the full-color LCD displays. They are now used increasingly in cellular phones.

Reasons LED traffic lights are not common in Japan

Another application is traffic light. LED's can be used for a variety of traffic light designs. Green lamp is a light source using GaN. LED's are widely used for the traffic light because of their longer, ten to fifteen years of life. Traditional lamps for the traffic light have a service life of one year. LED's are also undoubtedly energy-saving and require only 10% of power needed for the conventional traffic light system. In fact the first LED traffic light put to operation in 1994 in Tokushima and still works to this date. LED's lights last semi-permanently and energy-saving.

OK, LED's save resources and energy. But you don't see many LED traffic lights in this country, what's the problem? Politics. Take a look at product catalogues of traffic lights, and you will find all are foreign products. The United Stated and European countries are striving to save energy, and are rapidly shifting to the LED products while in Japan several LED traffic lights are put in use only for testing purposes at each prefecture level. I can say this because I quit my company, but LED's are naturally ignored in the "amakudari" (revolving door) system.

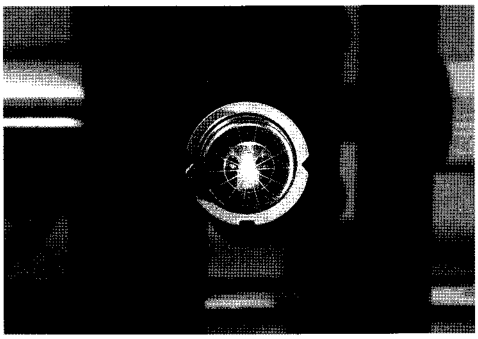
Five traffic-light manufacturers dominate the market and make money out of maintenance jobs for every year. In other words, these people need traffic lights that soon burn out and require a replacement of bulbs. The maintenance for each traffic light costs about several tens of thousand yens, and you can calculate the total amount spent nationwide by multiplying the total number of traffic lights by the unit price. I guess the total would be several billions of yen. Every year this amount of budget automatically flows into the books of the five companies.

If LED's are used, maintenance is reduced and these companies would starve (laugh). Guess who are the management of these companies? The former officials of the National Police Agency. This is my imagination and I don't have any evidence here (laugh). At least no "amakudari" system is evident in other countries, and the private sector complete to produce better traffic light system. This improves overall quality in products. I am safe to say this in public as I don't belong to any Japanese firm and am a U.S. resident right now.

This is a table of hues. It shows the range of various colors and hues. Use of nitride could cover the nearly entire range hue associated with blue, bluish green, green, amber, and white, except for the area of red. Only red is made of conventional materials. So the biggest issue in my expertise is to create red by nitrides. Why? Because the material used for red in contain toxic arsenic. Creating all the colors from safe material is a critical issue in this field.

Violet laser becoming essential in the age of digital TV

In 1995 I turned to the development of laser when finishing my researches on the blue and green LED's. Although the only color laser can emit had long been red, we knew we could have violet using nitrides. Changing red to violet reduces the wavelength and the size of spot through condenser lens, as small as nearly 1/4 of the spot the red laser creates.(Figure-4)



(figure-4)

This condensation is applicable to the DVD. Now a single DVD disc can contain a maximum of a two-hour movie. If you use violet instead of red, the DVD capacity will be multiplied by ten provided you also change the lens on the equipment. Theoretically, a violet-laser DVD device can contain ten two-hour movies.

Digital TV is now beginning to spread. But it's not possible right now to record a two-hour movie in high resolution onto a single disc. The violet laser is a solution. So everyone is frantically developing this type of DVD device. Increasing popularity of digital TV accelerates the competition. So the most promising small-scale application of violet laser is the DVD.

In addition, smaller spot size of violet laser would enhance the share of laser printers and laser displays. You may have seen people use a hand-held, red laser-beam device to point objects or guide someone in the dark. Adding blue and green to red will make all of necessary colors and scanning these laser beams will constitute a vivid TV screen. The laser TV will be the ultimate high-resolution TV with brilliant colors.

Now we can produce blue laser by nitrides. As for green, it can be created either by exciting other materials using violet laser beams, or by using the SHD technology. The laser TV is now actively developed in various firms and laboratories.

Another application of the laser is in the medical area. Cancer is vulnerable to high-energy blue or violet laser beams. So you may project these beams to kill cancer cells, or by injecting a fluorescent light-emitting material into the cancerous part, you can pinpoint the affected spot or area. I heard you could also use LED light sources for blood testing.

This figure shows how the wavelength of laser and the numerical aperture of lens for the CD device are changed in the DVD. The numerical aperture of lens is calculated by this formula. In short, the current DVD uses the red semiconductor laser, and the conventional CD can only contain music or so with its limited capacity. CD devices use infrared laser, a laser with a longer wavelength. Replaced by violet laser of a 400nm wavelength made of nitride, their recording capacity will be multiplied by five. Combined with the use of a double-layer technology, the capacity of CD will ultimately be tenfold larger than now.

In other words, until 1990's CD were used to record only music, and then red-semiconductor-based DVD enabled to record a two-hour moving images. I suppose DVD devices with violet semiconductor laser will be soon on the market. This means all that is recorded in an optical format can be accommodated within discs made by the violet laser devices.

Traditionally movies are preserved in tapes. This will be replaced by laser devices. Violet-laser-based DVD is a high-density storage medium. Other applications include car navigation and I believe Honda Motors can find many applications. There is plenty of market for the violet LED.

Being despised in the U.S. led to writing papers

I returned from the Florida University in 1989 and started professionally studying blue and green LED's and then laser for the following ten years in Japan. I spent about three years for each of the subjects. Looking back, my academic and professional path has been coincidentally staged in three-year clusters.

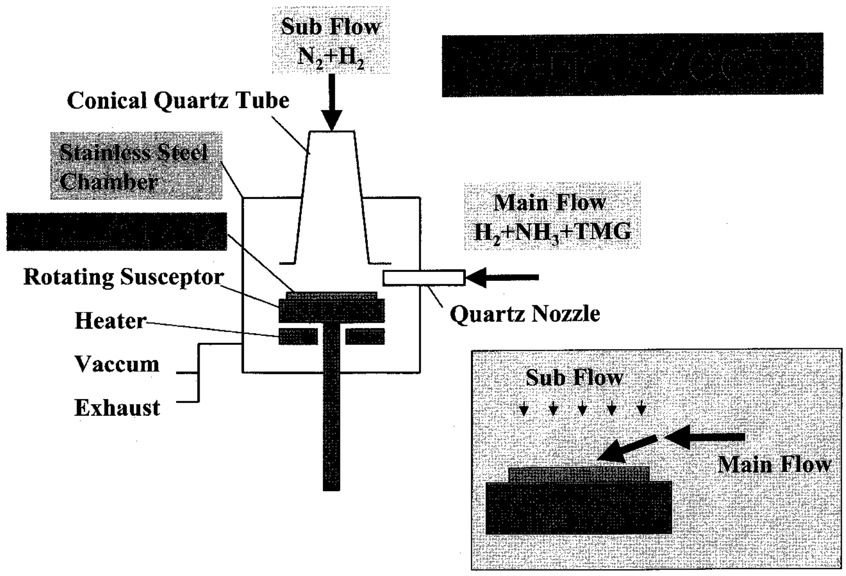
I came back to Japan to study the blue LED, and during my visit in Florida, there was an incident that upset me enormously: The first question I was interviewed at the university was: "Do you have a doctorate?" I answered, "No." And the next question was, "So have you written any scientific papers?" No sooner than I replied again "No," the interviewer changed his attitude toward me. In the United States, academic people wouldn't consider you an equal without papers or when you don't have a doctorate. Without these, they take you as a mere technician.

So when I returned to Japan in 1989, my decision was to publish papers on the blue LED by all means as I hadn't written any paper until then. My former company Nichia prohibited the publication and presentation of papers at academic societies. But being no "yes" man anymore, I dared to break rules. I ignored the company rules and instructions from my boss to make my papers out there in the academic.

Remodeled the commercial product all alone to devise a two-flow MOCVD

In 1991, one year and half from the start of research, I achieved a good result on blue LED. Until then, from 1989 to 1991, no fruit was mine. I used a MOCVD as a reactor.

At first I bought a MOCVD commercially available and tried to refine gallium nitride. I couldn't refine anything without any results, but kept remodeling the MOCVD device until I completed a two-flow MOCVD.(Figure-5)



(Figure-5)

I was by nature very good at remodeling. During the ten years after beginning working in a small barrack, a "factory" resembling Mr. Soichiro Honda, I made tools all alone by assembling and reforming used parts. Remodeling is my strongest asset. As commercial devices were not perfect with my purposes, I kept on remodeling them by welding and cutting them to my own design. For remodeling quartz components, carbon is used. And everyone tells specs and let external venders to make a device. It takes several months for delivery. Being impatient, I still enhance the existing equipment every day to study reactions. After a year-and-half series of remodeling efforts, a two-flow MOCVD was devised at last. By using this apparatus for reaction, I succeeded in making a gallium nitride film in the finest quality in the world.

Writing papers backstage

When the two-flow MOCVD was completed, I secretly wrote and submitted papers on this subject. Upon submission, I knew my company sooner or later would notice and so wrote about five patent applications for the sake of Nichia. I thought one or more of these patents are granted, the company would be satisfied even if my ignorance of the internal rules was uncovered.

In those days, however, all the patents were kept in confidence. My company tried not to disclose our patents. When I brought patent applications on gallium nitride to the Patent Section, the section manager asked me what it was for. I told him it would sell once the blue LED was commercialized, but he wouldn't accept it and said, “Filing a patent application costs us ¥300,000, but where do you think is the money?” But my papers would be in vain without the patent right. I had to submit the patent applications.

Then a young employee came into the room, and I told him to make copies of all the patents I wrote and submit them on behalf. I added that all the responsibility was mine. Having worked for ten years, I had a higher position than his only by the difference in age (laugh). It was precisely the Japanese seniority system. In this way, I secretly filed about five patent applications for each piece of my papers.

Without the incentive to publicize papers, I wouldn't dare to apply for these patents. In my company, the reward for writing a patent is ¥10,000 and another ¥10,000 is added as a bonus when the patent is granted. ¥20,000 in total! In this case, my humiliation at the Florida University and a sense of self-respect were the driving force.

Beginning in 1991, I wrote about five papers and 20 to 30 patent applications every year. This process was continued until my company finally noticed the fact late in 1992. Nobody at Nichia read academic journals. But it was started early in 1992 when I submitted a paper on the faintly glowing blue LED.

It was my close to the tenth paper. A man with a large semiconductor manufacturer read it and made a call to our Osaka Office. “Hello, I came to know you have ended up with a terrific blue LED, haven’t you?” The guy responded was the salesman with whom I visited various firms for sales. He called me saying, “Nakamura, I was asked if our company has made a blue LED. Don’t you know anything about it?” I pretended ignorance saying, “Such a product is beyond the wildest dream of our company. Who has made it?” (laugh). He answered, “That may be true.” And that was all. At that time, outsiders knew the fact better than Nichia.

And a week later after that incident, another leading electronics manufacturer in the Kansai area gave our Osaka Office a call. This time, they sent a copy of my paper by fax. The following day, on my desk there was a note saying, “Publication and presentation of papers at academic societies are prohibited without permission.” Instantly I tore it into pieces, and still submitted another paper within a month.

Current U.S. prosperities driven by flourishing venture businesses

I now understand my behavior was only allowed in rural companies like Nichia whose culture is laidback in many ways, in which nobody dares to object to the permission of the leader. But in a sense, this is very close to the spirit of venture business. Only a venture business can do "peculiar" researches with results. I know betting on unusual choice of materials is not a business for anybody, but what I try to emphasize here is the spirit to challenge is crucial. In my opinion, the prosperities in the United States have been driven by vigorous new ventures.

How are venture businesses in Japan then? They are very close to nil. This is a big reason of the Japanese long recession. The people are mentally beaten. Japanese enterprises have grown by making better things, but the U.S. has revived and technological level of the countries like China, Taiwan and Korea is getting closer and closer, Japan is now being squeezed from both sides. This caused a spiritual distress, and depressed the stock markets. I believe Japan should reform the investment system so venture businesses can grow.

Differences of academic environments between the U.S. and Japan

The U.S. venture businesses are formed around universities. About half of the professors at the University of California have their own companies. At the MIT where I was invited to give a lecture, all of the ten or so professors I met had their own venture businesses, too. Being prohibited to be president, they are advisors and their pupils are assigned president and employees.

At the Santa Barbara school of the University of California, Professor Heager won the Nobel Prize together with Professor Shirakawa for their researches on the conductive plastics. Comparing these Nobel laureates, we have a clear picture of the differences of universities in Japan and the United States. They are both aged 64, and Mr. Shirakawa already resigned from his university and revealed his intention of doing home gardening as a hobby while Mr. Heager is still a professor because there is no retirement age in the U.S. system. In addition, Mr. Heager runs a conductive plastic firm. If the company succeeds, he would be a billionaire. In other words, he is working actively as a professor and keeping up his research activities both in the academic and business worlds.

The Japanese system is uniform. In the American system people are allowed to pursue their subject of study as long as they wish and are capable. If Professor Shirakawa works for a U.S. university, he would also be like Professor Heager. I think this is a big issue with the Japanese system.

Also professors over there have their own venture, their students have opportunities to learn business while studying. The Japanese universities and colleges are entirely committed to researches. Bringing business into the academic is considered greedy. In the States even students are talking about business and go like, "That guy founded a venture business and made million bucks."

For example, the famous WWW (Web) search facility Yahoo is a venture started by a student at the Stanford University. Bill Gates got several million dollars in his college years. When I delivered a lecture at the MIT, I heard that a second-year student on a doctorate course had founded a venture firm a few years ago and become a billionaire. A professor who taught that student said to me this youngster should have quit the university but he was still studying. The professor continued, "I must instruct a billionaire. Don't you think it's funny?" Yes, this is really funny (laugh).

That billionaire student just developed a software program that enables characters and drawings on the white board to be displayed on the computer screen as they are, and three years ago, declared he would establish a venture company. Even the products sold a bit, as soon as his company was listed on the stock market, the stock certificates originally valued at one penny go up to several hundreds of dollars. He became a billionaire overnight. When such a lucky star appears, it's quite naturally everybody wants to do the same thing. Thus many smart kids follow the path and launched their own venture.

In contrast, the Japanese higher education is supposed to be academic. This inelasticity, in my view, spoils students' morale. Even if ambitious ones want to start a venture, they have no place to learn how. In lectures for the Japanese universities, people often ask me how they could possibly motivate youngsters. My answer is always the same: "Tell them to go to America."

The Japanese system is so stubborn and wouldn't change easily no matter what the people insist. I guess all issues get to politics. But criticizing politics in this sense is criticizing anything else. Still politicians make ultimate decisions. I know it takes much time for those politicians make a distinct move, but hope they reform many systems anyway. Meanwhile, I guess an increasing number of able Japanese youngsters would go abroad to pursue their liberty.

Because a constellation of notable people is present here, I dare to claim something relevant to the future of this country (applause). In conclusion, I really appreciate this many people gathered here to kindly congratulate me. Thank you.