R&D Spirits

Taking on the Challenge of Next-generation Ultrahigh-precision Processing Technology

Akinori Shibayama
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NTT-AT Nanofabrication Corporation

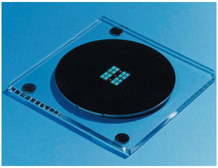
Founded in 2003, NTT-AT Nanofabrication Corporation (NTT-AT N) has the mission of developing and manufacturing leading-edge, ultrafine products using nanotechnology inherited from NTT Laboratories and NTT Advanced Technology (NTT-AT). While providing the semiconductor industry with an array of products that hold the key to next-generation LSIs, the company is also intent on applying nanotechnology to fields outside semiconductors in response to client needs. We asked President Akinori Shibayama, who has long been involved with high-precision processing technology since his days at NTT Laboratories, to tell us about current trends in this technology and the direction of new product development.

Providing ultrafine products based on X-ray lithography

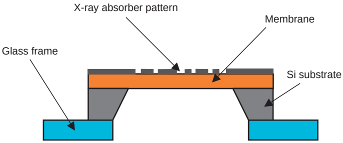
—Mr. Shibayama, could you give us an outline of NTT-AT Nanofabrication?

Well, to begin with, the parent organization of our company is NTT Advanced Technology, whose main role is to manage technology transfers from NTT Laboratories. In April 2003, the Ultra High Precision Division of NTT-AT became an affiliated company under the name of NTT-AT Nanofabrication Corporation*. Using world-class nanotechnology cultivated by NTT-AT, we develop, manufacture, and sell X-ray masks (**Fig. 1**) for lithography as our major product in

* http://www.ntt-at.co.jp/nttatn/ (in Japanese)



(a) X-ray mask



(b) Schematic of X-ray mask

Fig. 1. X-ray mask.

the field of semiconductors, as well as diffraction gratings, Fresnel lens, standard scales, and other products in the field of optics. Since NTT-AT is generally associated with software for telecommunications systems, the name "NTT-AT Nanofabrication" was chosen to make it clear that we are a manufacturing company using nanotechnology.

—What is NTT-AT Nanofabrication's distinguishing feature?

Its most outstanding feature would be the inheriting of lithography technology from NTT Laboratories, which has been researching and developing this technology for some time. To give you some background here, the last half of the 1970s saw major advances in the integration of LSI devices, and the transferring of fine circuit patterns to silicon wafers by optical means was the mainstream technology at that time. It soon became apparent, however, that minimum feature dimensions would have to exceed the limits of optical wavelengths if Moore's Law was to be maintained. This realization led to two new R&D trends: using electron beams and X-rays as alternatives to optical radiation. During my days at NTT Laboratories, my research dealt with both of these trends, but I was particularly involved in X-rays lithography using synchrotron orbital radiation (SOR). Unfortunately, This lithography itself has not found widespread use in the semiconductor field due to its high cost, but we make use of it in our X-ray masks that have become our leading product.

—What are some of the technical issues surrounding X-ray masks?

The structure of an X-ray mask is fundamentally different from that of an optical mask that transfers a pattern through the use of chrome on a reticle. Specifically, an X-ray mask is achieved by first placing a thin film about 2 µm thick having high X-ray transmittance on silicon material and then forming a pattern on that film using tantalum film as an X-ray absorber. In other words, the pattern cross section has a dimension in the vertical direction. This is significantly different from a flat optical mask, and it is this feature that makes it possible for the first time to achieve control in the vertical direction in fine processes. I might add here that the fabrication of a micro-order membrane several centimeters square is extremely difficult in itself, and the technology for achieving this is another of our strong points.

We are applying such specialized technologies even to applications outside the semiconductor field. One example is Fresnel zone plates for use in X-ray microscopes. Such a plate consists of a series of concentric rings that are used to focus X-rays. One problem here, however, is that the outermost step-like structure of this pattern can significantly affect resolution, but we have nevertheless managed to achieve a resolution of 50 nm, a world-class level. I don't think other companies in Japan are currently capable of this. We are also applying our thin-film technology to sample holders for use with X-ray microscopes for our customers in biotechnology fields.

Achieving even finer processing with next-generation technology and promoting new applications

—What are some current trends in lithography technology development?

I previously mentioned that processing technology using light will encounter a barrier due to wavelength limits. Discussion on this problem continues even to this day. The wavelength used in the 1970s was about 440 nm, while that used today is about 193 nm. The argon laser is the most commonly used light source at present, and this laser is expected to be followed by the fluorine laser. As for processes that use wavelengths beyond light, the development of exposure technologies using electron beams is progressing including electron projection lithography (EPL) and low energy e-beam proximity projection lithography (LEEPL).

—Are you developing products for electron-beam systems?

Yes, of course. But the problem when using electron beams is that they do not pass through thin films, in contrast to light and X-rays. An obvious solution to this problem is to make holes in the film, but the film itself can break down from stress if hole punching is not performed carefully. In our products, stress is strictly controlled and no breakdown occurs even if holes are formed. For film with a thickness from 1 to 2 µm, we have been able to make openings of sub-100-nm-wide lines or holes in several centimeters square. Using this technology, we can form holes and lines that form an LSI device pattern in diamond or SiC film to produce stencil masks for the lithography market.

Another new product is a fine-hole fluorine resin sheet (**Fig. 2**) that we achieve by forming an array of uniform holes each with a diameter of about 1 µm on perfluoroalkoxy (PFA) material using a semiconductor process. This product is receiving much attention for use as various types of filters in the field of biotechnology and as electrolytic films in direct methanol fuel cells (DMFC) to be incorporated in cell phones and PDAs (personal digital assistants). I should note here that controlling ion transmission in conventional macromolecule-film products is difficult due to significant dispersion in hole density and diameter. Our product, however, is man-made and allows processing even on the sub-micrometer order, which simplifies control. While PFA is a chemically stable material and somewhat difficult to process, I believe that the technical significance of this product will be apparent as this problem is overcome. By the way, we developed this fine-hole fluorine resin sheet through a combination of our specialized technologies.

—What direction do you expect product development to take from here?

I would like to see it respond to the various needs arising at sites involved with the development of leading-edge technology. The nanoimprint mold (**Fig. 3**) is one example of a new product that falls into this category. This is a kind of a stamp for producing nano-order patterns at low cost. At NTT-AT Nanofabrication, we fabricate patterns of various shapes up to several tens of nanometers in size in accordance with customers' designs. What makes our molds stand out is that processing can be performed in the depth direction and that mold material can be chosen from four types, namely, silicon carbide (SiC), quartz, silicon, and tantalum. By the way, nanoprinting equipment is still in the research stage—technology and systems are far from mature. And as can be expected, a variety of requests are being made concerning materials. Under these circumstances, our policy is to satisfy these requests as far as possible. At the same time, we don't intend to limit our work to simply responding to customer needs. We also plan to present our customers with our own proposals.

Having a personal impact on both R&D and business

—Mr. Shibayama, what kind of R&D have you been involved with up to now?

Well, as a university student, I researched high-frequency devices using indium-phosphorus semiconductors. At that time, gallium arsenide was a common topic of research, but even crystals of indium phosphorus could not be made then without difficulty, so I think I was involved in advanced research of a sort.

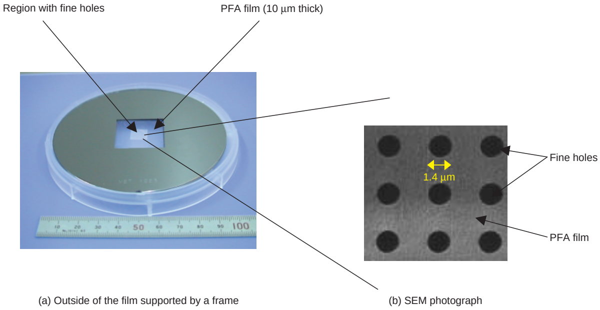
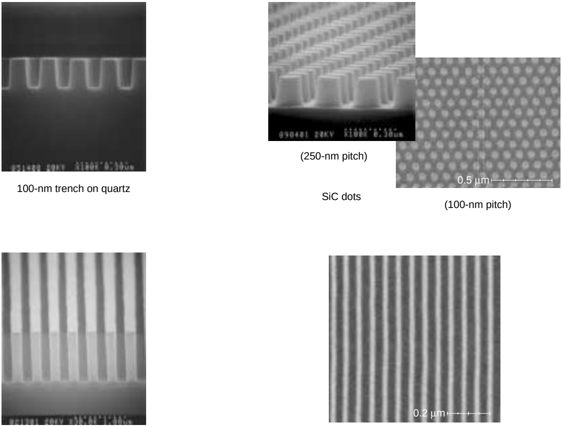


Fig. 2. PFA film with artificially formed holes.



100-nm trench on quartz

(250-nm pitch)

SiC dots

(100-nm pitch)

200-nm line-and-space tantalum patterns
(400-nm pitch)

20-nm Si nanolines
(60-nm pitch)

Fig. 3. Nanoimprint molds.

But after entering the research laboratories of Nippon Telegraph and Telephone Public Corporation, I took up research themes completely different from those I had pursued in my university days. The first was the development of electron-beam exposure equipment, which I was engaged in for about eight years beginning in 1975. This work included joint research with manufacturers that contributed to the development of practical equipments.

Then, in 1985, I became a member of the SOR lithography project that I mentioned earlier. I was mainly in charge of the SOR ring, which is used to extract wavelengths for exposure purposes from light radiated when an electron orbit bends. This equipment was traditionally large because it used electromagnets whose relatively weak magnetic fields cannot easily bend electron orbits. Consequently, with the aim of constructing smaller equipment, I took on the development of a superconducting SOR ring. At that time, though, it was thought that a practical ring-type superconducting magnet was not feasible, and a number of respected researchers from other research institutions were known to have unanimously said “stop useless research.” At the same time, research based on a similar concept was also being conducted in Germany, and we became strongly aware of each other’s direction. The project became very exciting as a result. In the end, the German group, though later bearing fruit in the United Kingdom, was not successful, and our team became, in 1988, the first research group in the world to successfully develop a superconducting ring. For this, we received a Presidential Commendation from NTT.

I also conducted joint research from 1997 to 2000 with the Association of Super Advanced Electronics Technologies (ASET), an organization associated with the Ministry of International Trade and Industry (currently the Ministry of Economy, Trade and Industry). I then became involved in management and moved to NTT-AT in 2001, becoming president of

NTT-AT Nanofabrication upon its founding last year.

—What do you consider your role to be at NTT-AT Nanofabrication?

In one word, I would say "business," but with that being said, I must tell you that only a small percentage of my activities involves approaching customers directly. That is because our products and technologies are introduced through Web sites and journal articles, or even exhibitions, which are often followed up by inquiries or consultations where business really begins. Many of our customers are scientific or research institutions, and most products are made to order. In fact, manufacturing a single product for a customer is not unusual. At the same time, we are a private enterprise that must keep profits in mind if we are to survive, and this is where I step in. My job is to find good matches between our technologies and customer needs.

Our business area, moreover, is one of advanced, specialized technologies, and there are many cases in which we ourselves take a second look at technology we have developed and say "couldn't we also apply this to that field?" A good example of this would be the fine-hole fluorine resin sheet that I mentioned earlier, which we found could be applied to fuel cells. This field is completely outside my area of expertise, but after being approached about this possibility and investigating it thoroughly, I realized that our technology and facilities could make it work. This is why our policy is to accept customer requests as far as possible. In accepting such work, the most important criterion, I believe, is whether our technology can be made good use of and whether we can discover a product market that cannot be easily entered by other companies.

—Is there anything that you have kept in mind in your work up to now?

Yes, that would be the need to ascertain what kind of impact your work will have. Let me give you an example. When attempting to improve the performance of some type of equipment, it might be possible to achieve the level desired by combining that equipment with existing technology. If that were the case, I think that the technology should be used—there's no reason to create new technology and systems specifically for that purpose. Yet, in many cases, existing technology is not sufficient to get what you need. In that situation, we would then spend the money and take the time needed to develop new technology. However, achieving just a minor improvement in performance does not make for interesting research. If we are going to go to the trouble of developing new technology, then it better have a major effect. For this reason, I always try to determine what kind of impact one thing will have on another. This makes up most of my work, not only in R&D but also in business matters.

Applying the achievements of NTT Laboratories

—Mr. Shibayama, what is the future outlook for NTT-AT Nanofabrication?

First, let me point out that the Ultra High Precision Division of NTT-AT was set up in 1992 and NTT-AT Nanofabrication was founded in 2003. In other words, it took about ten years for one division of NTT-AT to grow and develop before becoming an independent company. How the company will continue to develop over the next ten years is a matter of vital importance. The most desirable approach for the company's business is to become a user and incubator of NTT technology. To this end, my role in the coming years will be to construct a solid stage for this process. By the way, of the 40 employees making up our staff, about 30 are young up-and-coming people. My sincere hope is that, in ten years time, they will say "we're glad that we came to work at NTT-AT Nanofabrication." As for myself, I have not given much thought to where I might be ten years down the road, but I know that I would like to be facilitating the use of research results from NTT Laboratories in some way, shape, or form.

—How do you view the relationship between NTT Laboratories and NTT-AT Nanofabrication?

Our technologies are not ones that can be created in a single day. For example, X-ray mask technology has been researched at NTT Laboratories from various angles since the 1970s. But it was only after several decades of results that this technology could be turned into a business. And it is for this reason that I believe this relationship cannot be a one-sided affair. Even superior research will not bear much fruit unless it can see the light of day in the outside world. This is where NTT-AT Nanofabrication comes in. Finding the most effective way to apply research results to the real world is where we can demonstrate our abilities.

—Do you have any suggestions for NTT Laboratories?

Looking back at the history of NTT Laboratories, I would say that they have been through several phases. First, there was the period up until the 1960s or so during which they began to accumulate technology starting from nothing. The next period was the time up to NTT privatization when they endeavored to be a driving force in the industry through telecommunications technology. The technical level of surrounding companies, however, has since risen significantly. The direction of NTT itself, moreover, has been changing. I think the reason for this is that NTT Laboratories is now anxious for results and makes too much use of outside technology. The feeling is that existing technology only covers part of what it takes to get a new product out the door. In my opinion, though, this does not make for smooth product development and also hinders the full use of existing technology. I am also afraid that NTT's traditional research scheme connecting basic research with product development and application will be lost as a result. Even if 100% of existing technology is not necessary, it is vitally important, I think, that most of the key technologies in question are those that belong to us, especially in the case of hardware. Of course, achieving fast results is often essential today, but it is also important that the overall picture not be overlooked. Though the present period is a difficult one, I would hope that the positive elements of NTT that have been built up over its long history are not lost.

—Mr. Shibayama, could you conclude with a message for young researchers?

Yes, certainly. I believe it is important and necessary that a synergistic effect be produced between the young researchers of NTT Laboratories and the alumni of those laboratories including myself who are now working at group companies. The LSI technology that we have come to develop is of course important, but the times are changing. Today, it is imperative that we give birth to the things that this age demands. I would therefore like to ask all young researchers to do more "dreaming." I would like to see them engage in more talk like "that would be amazing" or "I would love to make that possible." Such talk should lead to more talk like "we can do that in this way—let's give it a try." If better interaction like this can take place, I think even greater strength can be generated in the NTT Group leading to a scheme whereby researchers play a more active role in the business world by making optimal use of research results.

Interviewee profile

■ Career highlights

1975 Completed the graduate program at Tokyo Institute of Technology and entered the Musashino Electrical Communications Laboratory of Nippon Telegraph and Telephone Public Corporation.

1990 Senior research engineer at NTT LSI Laboratories.

1998 Research manager at NTT Telecommunication Energy Laboratories.

2001 Director of the Precision Technology Division in the Leading-Edge Key Technology Business Headquarters of NTT Advanced Technology.

2003 President and C.E.O of NTT-AT Nanofabrication Corporation.

■ Major awards

1989 Presidential Commendation from NTT for "Research of Superconducting SOR Ring."

1994 MNE '94 Best Poster Award