Final Phase II Report
Submitted to
U.S. Department of Energy
By
Prism Corporation

Environmentally Benign Manufacturing of Compact Disc Stampers

Contract No. DE-FG02-95ER86033

Thomas Bifano, President

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

1.0 Background

Optical data storage is currently a \$10B/yr. business[1]. With the introduction of the high capacity Digital Versatile Disc (DVD) as well as the continued growth of CD- Audio and CD-ROM, worldwide sales of optical data products as a whole are growing at rate of more than 10% per year. In North America, more than 2.5 billion optical discs will be sold in 1998. By 1999, the numbers of optical discs produced for the North American market will grow to almost three billion. The optical disc manufacturing industry is dominated by Asian and European companies (e.g. Sony of Japan and Philips of Netherlands). Prism Corporation has created a process that could significantly improve US competitiveness in the business of optical disc production.

1.1.1 The market for optical disc stampers

Compact discs are made by injection molding, with an industry average of 3000 replicas produced per stamper[2]. In 1998, the North American market will require more than 800,000 stampers, with an average sales price of \$600-\$1000 per stamper. Presently, a stand-alone mastering process line costs more than \$2.5 million, and has a peak yield of approximately 15 stampers per day. The proposed stamper manufacturing process can be used for all optical disc types, and requires only minor retooling of the optical disc manufacturing line.

1.1.2 The technical problem: manufacturing optical disc stampers

While the optical disc market is flourishing, manufacturing processes have seen little improvement since the product was first introduced more than a decade ago. Today, the industry faces intense demand for increased production speed and increased yield. In this research, a new manufacturing process was proposed for optical disc stamper manufacturing. This new process replaces several difficult and failure prone process steps with a radically improved, simpler alternative. Specifically it is proposed that the process of electroforming to generate a sub-master stamper, and the subsequent manual processes of peeling, varnishing, back-polishing, and punching can be replaced by a single, automated process: neutral ion machining of optical disc features directly onto a preformed master stamper. Ion machining, an emerging precision manufacturing technology, is inherently suited to nanometer-scale material removal. In the proposed process, ion machining of the master will be performed through a patterned photoresist mask. **By eliminating the processes that are responsible for most of the toxic waste by-products (e.g. heavy metals, acids, and solvents) generated during stamper manufacturing, the new process is significantly cleaner. Also, the processing time for fabricating a master stamper is cut in half.** As a final benefit, the process eliminates

[1]Optoelectronics Industry Development Association, <u>Technology Roadmap Recommendations</u>, OIDA, Freemont, CA, April 15, 1994.
[2]The number of disks produced per stamper is determined by the customer's order for replicas and not by the maximum possible stamper life of about 100,000 copies. The average *order* is 3000 replicas/stamper.

the manual processes that are required in conventional stamper manufacturing, so substantial increases in the process yield are expected. By industry standards these new steps represent a *revolutionary* change in optical disc mastering technology.

1.1.3 Current manufacturing process for optical disc stampers

Major steps in the current process for fabricating optical disc stampers as follows: A flat, polished glass substrate disk is cleaned and then coated with a thin layer of positive-tone photoresist. Next begins the recording process. A focused laser beam traces a spiral path on the disk surface. A control computer containing the digital information to be recorded on the disk switches the laser on and off according to a streaming binary signal. After recording, the photoresist is developed, leaving elongated pits where it was exposed to laser irradiation. The patterned photoresist is metallized with a thin layer of nickel or silver, which serves as an electrode in the subsequent electroforming process. Through electroforming, a thick film of nickel is grown on the disk substrate. This nickel *sub-master stamper* is then peeled away from the master disk substrate and cleaned. A protective varnish coating is temporarily deposited onto the stamper surface and cured. The stamper back side is polished, and the inner and outer diameters are punched on a press. The varnish is then removed from the stamper, which is now ready to be used in an injection molding machine to generate thousands of polycarbonate optical disc replicas. The total manufacturing time for a single optical disc sub-master stamper is a little more than 4 hours. The overall process yield for master stamper production is typically 60-80%.

Toxic waste byproducts of metallization and electroforming include, for each stamper generated, more than three liters of *treatable* chemical waste containing about 250 ml each of silane, palladium chloride, tannine, and stannous chloride in aqueous solutions. Chemical wastes that must be contained and treated as *hazardous* include another three liters of aqueous solutions containing about 250 ml each of nickel and silver nitrate. Exhaust gases from metallization and electroforming also contain hazardous vapors that require treatment, including methyl-ether-ketone (MEK), toluol, ammonia, nickel, and boric acid. In the processes following electroforming, further solvent wastes are generated.

Some process steps represent technology advances developed specifically for optical disc mastering, while other more conventional process steps were adapted from LP (long play) record mastering technology. Process steps from electroforming through injection molding are essentially the same as those used for manufacturing LP record masters. These later processes are the sources of nearly all toxic and hazardous wastes generated in mastering (e.g. ketones, heavy metals, solvents, etc.). They are also responsible for the relatively low manufacturing yield generally achieved in mastering, due to sensitive electroforming bath chemistry, and subsequent manual handling of the sub-master stampers. Operator mistakes or mishandling at the end of more than three hours of manufacturing are not uncommon, and generally not repairable.

In addition to waste generation and yield problems, the electroforming process fundamentally limits the speed at which optical disc stampers can be fabricated. Growth of the nickel, for example, is already performed at the maximum rate that will allow acceptable metallurgical properties in the stamper. In the first few minutes of electroforming, all of the detail and fine structure encoded on the glass master disk are replicated by the growing nickel layer. Subsequent growth serves to increase stamper thickness to allow sufficient structural rigidity for stamper use in a mold. After this long growth process, the stamper backside has to be sanded to smooth its "as-grown" rough surface, while protecting the 2 billion sub-micrometer sized features on the opposite side. Slow processing and sensitive processing chemistry make electroforming a troublesome, though universally used, step in optical disc stamper manufacturing. Batch electroforming of multiple stampers has been used in the past to increase overall manufacturing speed. However, recent industry demands for turnaround of stamper orders in 24 hours or less makes in-line processing a more competitive strategy. Most new optical disc stamper fabrication systems use in-line manufacturing, for which recording and electroforming are the principal bottlenecks. In recent years, double and triple speed recording systems have been developed, but no parallel productivity increases have been made in the electroforming process.

A revision of the optical disc manufacturing process that replaces the latter half of the processing steps with direct ion machining of the master disk could dramatically improve the process economy, speed, and yield while reducing its environmental impact.

1.2 Prism's alternative technical approach to optical disc stamper fabrication

A radical new manufacturing process for stamper production is being developed by Prism. The technology uses a recent advance in precision manufacturing – ion figuring of ductile-ground or polished brittle materials – to improve productivity, reduce hazardous waste, and reduce costs while achieving an elusive optical disc industry goal of 100% automated production. *All critical process steps were proven feasible in the STTR Phase I research project.* The new stamper production technique calls for two major changes in the manufacturing process for stampers:

- replacement of the glass master disk substrate by a preformed master, which will be used as the injection molding stamper

- replacement of metallization, electroforming, peeling, protecting, polishing, and punching operations by a single ion machining step

All other processes, including cleaning the master disk, spinning-on a photoresist layer, laser recording, and photoresist development will remain largely unchanged. In the new process, production of a sub-master nickel stamper will no longer be necessary. The ion machined master stamper will be used *directly* for polymer injection molding. The processing time is reduced by a factor of 2 from the conventional manufacturing. More than 200 minutes of the present manufacturing processes are replaced less than 20 minutes of ion machining processes (inclusive of time for part handling, transfer through a vacuum interlock, and cleaning). Capital equipment costs and direct manufacturing costs for the proposed process are *lower* than that required for the present process. Other benefits of the proposed process in comparison with the conventional process are that it can be automated and it eliminates all process steps that produce toxic and hazardous wastes.

Ion machining as a precision material removal process has been refined for use in sub-aperture shaping of glass and ceramic substrates, and for various high technology applications such as fabrication of individual three-dimensional microstructures, sharpening of scanning probe tips, and imprinting patterns on carbides[3,4,5,6]. **The process,** which is distinct from the more well known process of *Reactive Ion Etching,* employs a plasma-generating source or "gun" that ionizes argon gas in an evacuated chamber. While still in the gun, ionized argon atoms are accelerated in a DC electric field through a grid-shaped aperture. As they leave the gun at high velocity, the collimated beam of ions is neutralized by an oblique beam of electrons emerging from an adjacent source. This stream of argon atoms, now chemically and electrically neutral, impact a target surface and sputter molecules from that surface in a finely controlled erosion process. Typical beam current densities are 1-2 mA/cm^2, accelerated by a 1000 volt potential. For most solids, this results in a sputtering rate of several tens of nanometers per minute. Guns range in diameter from 3 cm to more than 60 cm, and a number of unusual geometries of aperture (and consequently beam shape) have been reported. Adaptation of ion machining to optical surface contouring was first demonstrated by McNeil, et. al.[7]. The most visible success of this process came with the Keck mirror telescope project[8]. Although it was not part of the original manufacturing proposal for that project, ion machining proved successful in obtaining the ultraprecise tolerances required for the Keck's 36 hexagonal optical segments (each measuring more than 1 meter across.) More recently, ion machining has been used to fabricate ceramic optical elements for space-based applications by the principal investigator and others[9,10,11,12]. The process has not been

---

[3] Fawcett, S. C., Bifano, T. G., and Drueding, T., "Neutral Ion Figuring of Chemically Vapor Deposited Silicon Carbide," **Optical Engineering,** [33]3, pp. 967-974, 1994.

[4] Miyamoto, I., and Shuhara, A., "Ion Beam Machining of Tungsten Carbide Chips – Fabrication of Fine Patterns," **Annals of the CIRP,**Vol. 40, No. 1, 1991.

[5] Miyamoto, I, Ezewa, T., and Itabashi, K., "Ion Beam Fabrication of Diamond Probes for a Scanning Tunneling Microscope," **Nanotechnology,** Vol. 2, pp. 52-56, 1991.

[6]Egert, C.M., "Roughness Evolution of Optical Materials Induced by Ion Beam Milling," **SPIE 1752,** 1992.

[7]McNeil, J.R. and Herrmann, Jr., W.C., "Ion Beam Applications for Precision Infrared Optics," **Journal Vacuum Science and Technology,** 20 (3), pp. 324-326, March 1982.

[8]Allen, L.N., Keim, R.E., Lewis, T.S., and Ullom, J., "Surface Error Correction of a Keck 10m Telescope Primary Mirror Segment by Ion Figuring," **SPIE, Vol. 1531,** July 1991.

[9]Bifano, T. G., Kahl, W. K., and Yi, Y., "Fixed-Abrasive Grinding CVD Silicon Carbide Mirrors," **J. Precision Eng'g,** [16]2, pp. 109-116, 1994.

[10]Drueding, T. W., Wilson, S., Fawcett, S. C., and Bifano, T. G., "Ion Beam Figuring of Small Optical Components," **Optical Engineering,** [34]12, pp. 3565-3571, 1995.

[11]Drueding, T., Bifano, T. G., and Fawcett, S. C., "Contouring Algorithm for Ion Figuring," **J. Precision Eng'g,** [17]1, pp. 10-21, 1995.

[12]Fawcett, S. C., Bifano, T. G., and Drueding, T., "Neutral Ion Figuring of Chemically Vapor Deposited Silicon Carbide," **Optical Engineering,** [33]3, pp. 967-974, 1994.

used previously in an advanced manufacturing application requiring micrometer-sized lateral features on a large surface area. Producing billions of such features with uniform good quality on a single substrate by broad beam ion machining through a mask was a principal focus of our STTR research.

2.0 Goals and Objectives

The objectives of the Phase II STTR project were to build and test an ion machining system (IMS) for stamper fabrication, prove overall manufacturing system feasibility by fabrication stampers and replicas, and evaluate alternative materials and alternative process parameters to optimize the process. During the period of the Phase II project, Prism Corporation was able to meet these objectives. In the course of doing so, adjustments had been made to better the project and in turn, the final product. An ion machining system was designed and built that produced stampers ready for the molding process. Also, many control steps in the manufacturing process were studied to improve the current process and make it even more compatible with the industry standards, fitting seamlessly into current manufacturing lines. The patent work has continued through Phase II, with the initial patent issued in April, 1996, and the CIP issued April, 1997.

2.1 Build and test an ion machining system (IMS) for stamper fabrication , Completed June 1997

A new ion machining system was designed and built by Prism. Taking the knowledge gained from the prototype system used in the Phase I research and talking to engineers in the optical disc industry and the vacuum technology industry new additions and modifications were made to the previous system. The changes were made to enhance reliability, decrease production time, and ease use. A schematic of the IMS is shown in Figure 1.

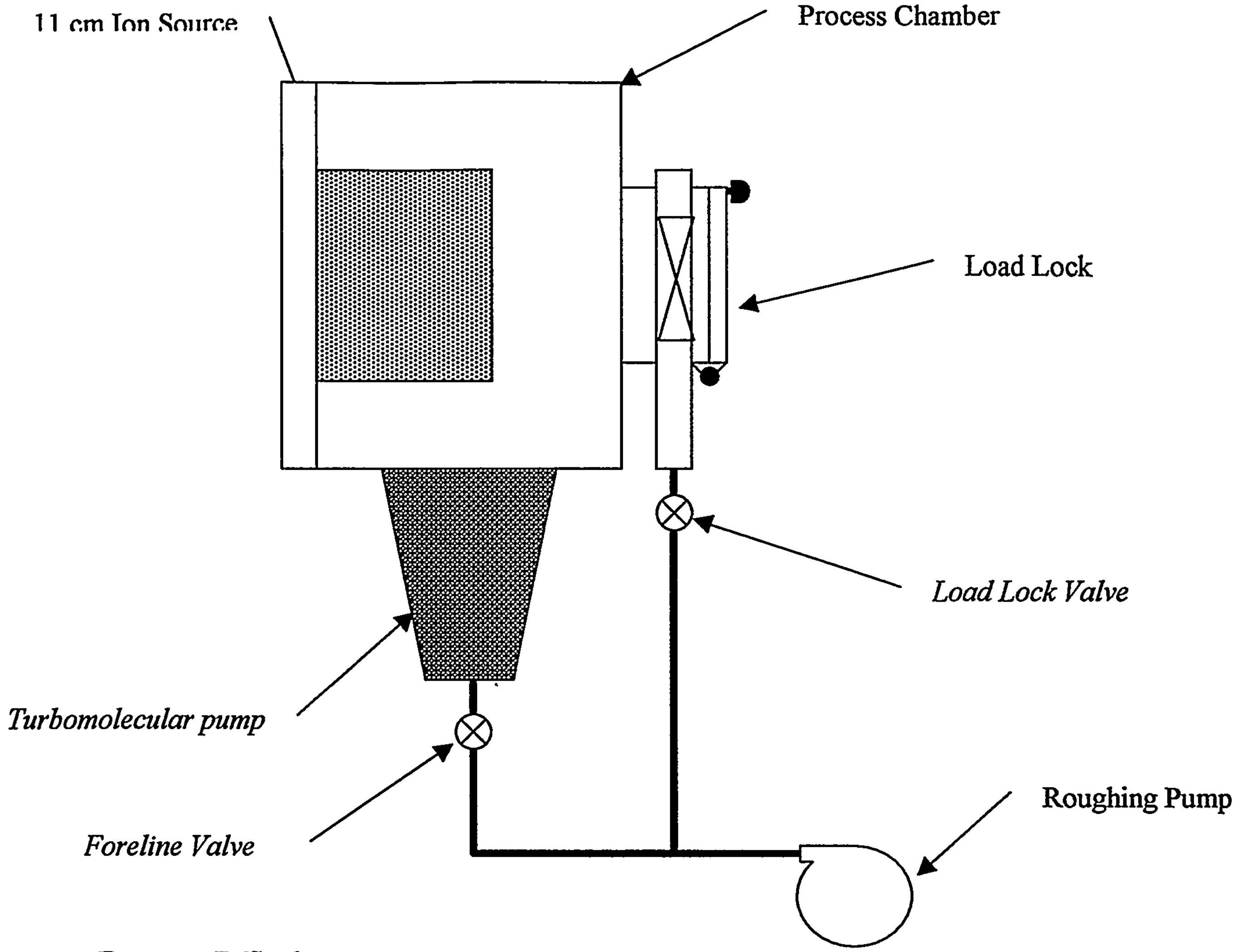

Figure 1: IMS schematic

The major component and changes from the previous system include:

- A high vacuum turbo molecular pump, decreasing pump down times and creating a more stable process

- Use of an 11cm ion source from a leading manufacturer, allowing the entire substrate to be ion machined at once to decrease production time and eliminate the need for rotation.

- The implementation of a load lock system that would allow for parts to be loaded and removed from the system without breaking vacuum and thus significantly reducing the per stamper production time.

- Using self-programmed instrumentation software for computer control of the system for ease of operator use and the ability to control the process through feedback from the different machine components and the collection of operating data for Statistical Process Control.

- Reducing the process chamber size to decrease both the pump down time needed for operation and to reduce the footprint of the machine, an important feature in clean room processes.

- Designing all part handling tools and chucks around industry standard sizes to allow for a seamless integration into the current manufacturing lines.

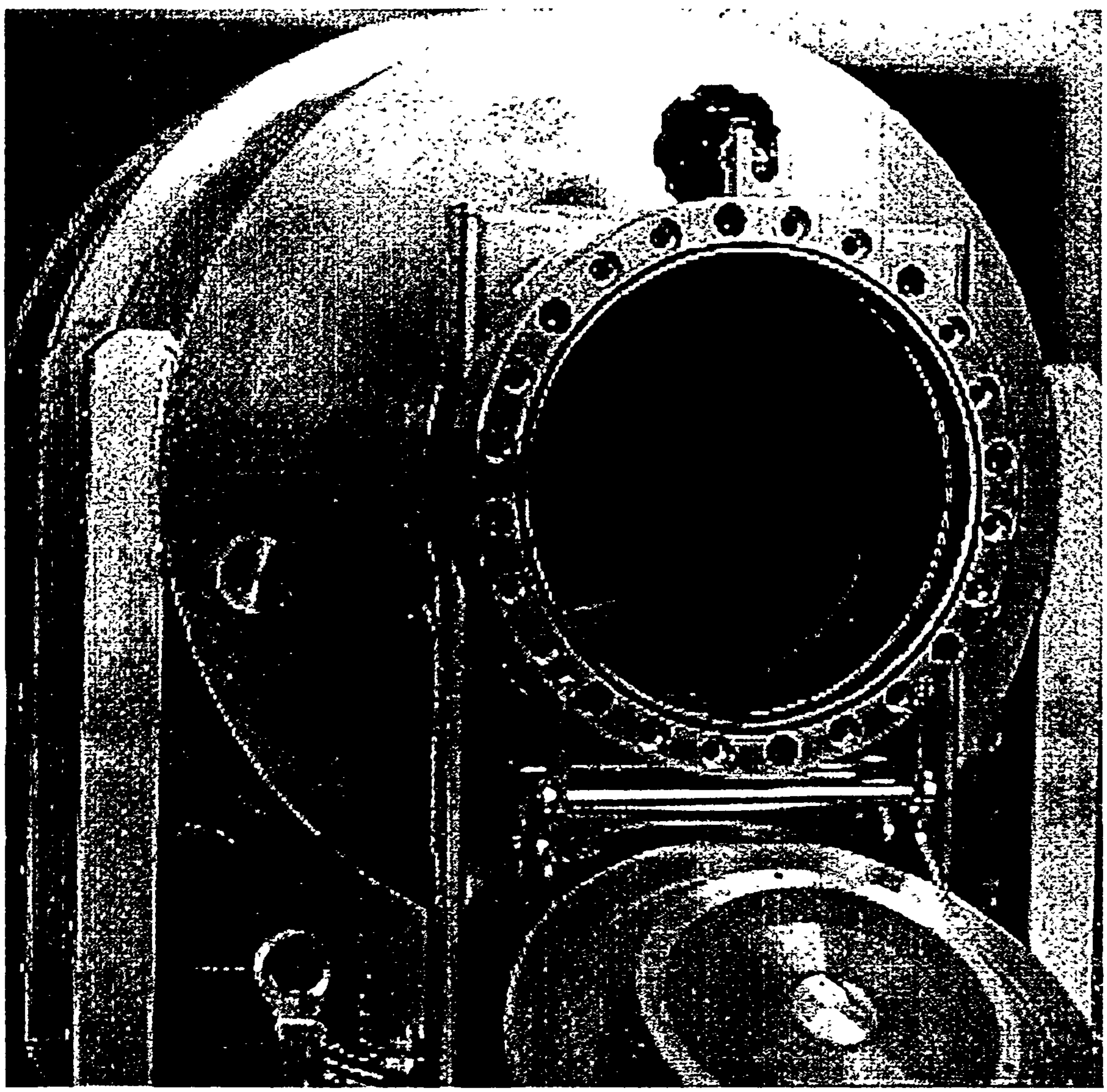

Figure 2: Photo of IMS

A photgraph of the IMS during construction and testing can be seen in Figure 2. The combining of all these components lead to a system that was shown at an international trade show for replicators and duplicators of optical media, *REPLItech International,* in San Jose, California. This introduction of Prism's IMS technology to the industry as a whole brought great interest from both optical disc equipment manufacturers and replicators.

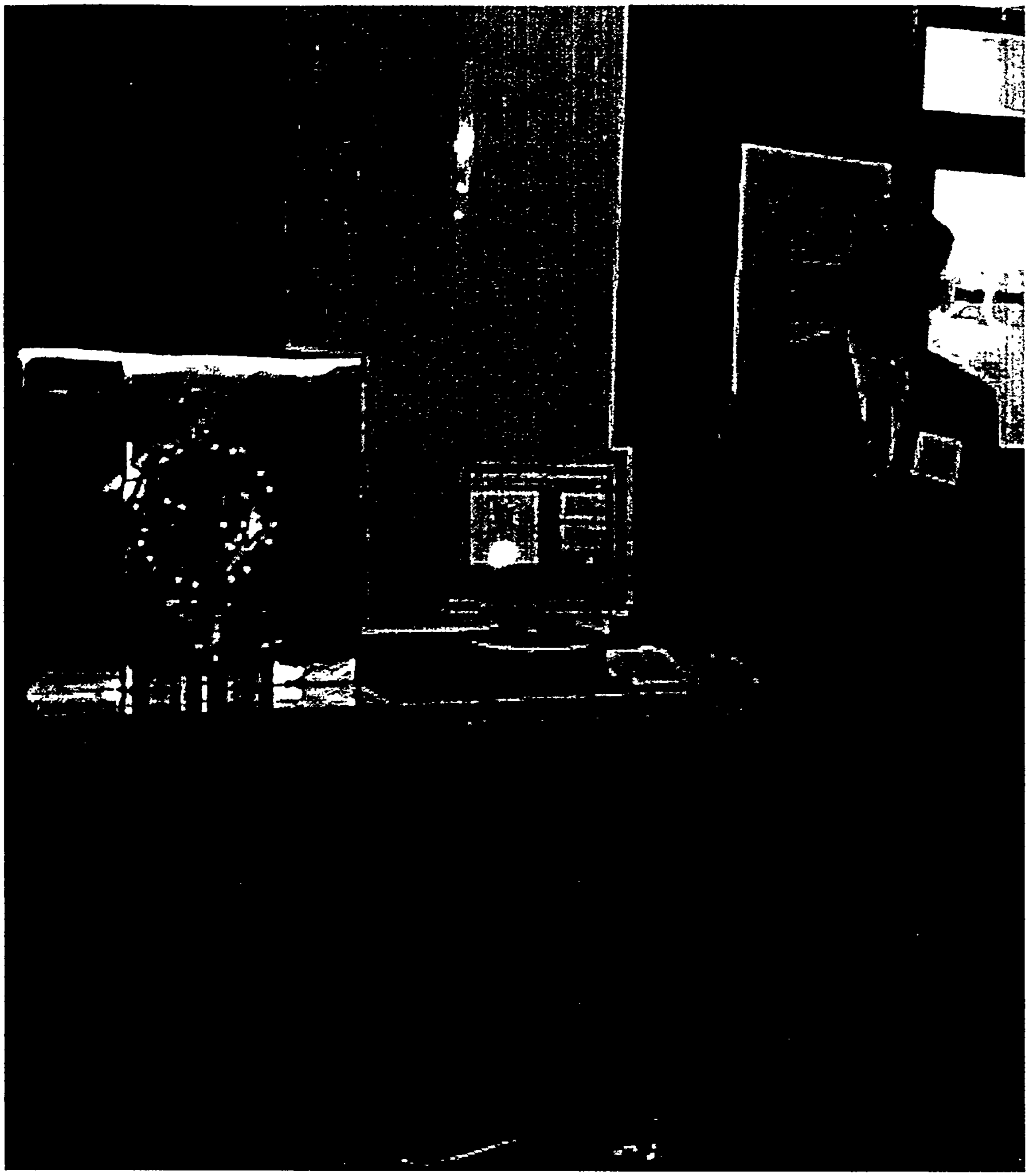

Figure 3: IMS introduced at Replitech International

2.2 Prove overall manufacturing system feasibility by fabricating stampers and replicas

To prove the manufacturing system feasibility, we worked with three companies involved with optical disc manufacturing: Disc Manufacturing Incorporated, a manufacturer of optical disc, Netstal, a manufacturer of injection molding equipment, and Nimbus Technology and Engineering, a world leader in optical disc mastering equipment. By working with these three companies, we were able to test all aspects of the manufacturing process.

The first step in proving feasibility was to fabricate the images in photoresist needed for optical disc process. This was done both at DMI and NT&E. When exposing the substrates with the Laser Beam Recorder (LBR) the primary variable that could be adjusted was the power of the laser. During the initial tests is was observed that the width and length of the features increased with an increase in exposure power. It was also observed that at a certain lower power range, the feature were prone to "washing away" during the development process. While the difference in feature size varying with exposure power was also observed in the Phase I research the washing away was a new phenomenon.

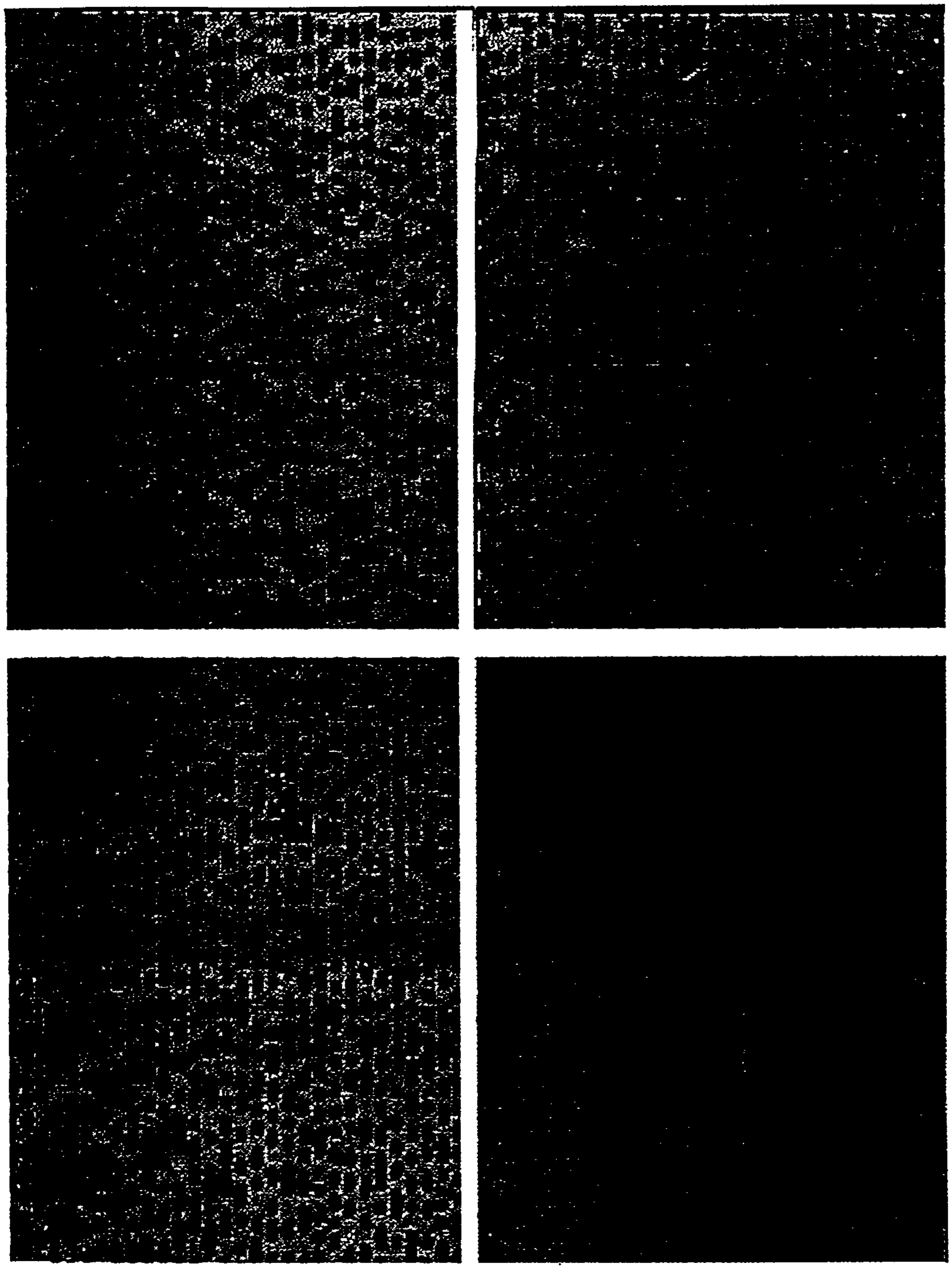

Figure 4: Clockwise from upper left: 0.2, 0.4, 0.1, and 0.3 mW exposures on 270 nm thick photoresist developed for 30 S.

To determine the cause of this, the features were studied in detail with both an atomic force microscope (AFM) and a scanning electron microscope (SEM). The AFM was particularly useful in this development project for its capacity to measure feature height and width. Unfortunately, since the negative tone photoresist tends to have negatively sloped walls, the sidewall images produced using AFM are often not useful, and occasionally misleading. Scanning electron microscope (SEM) images produce a much more satisfying qualitative picture of the features, particularly when the sample is viewed at a large (80-85°) angle from surface-normal. The results of looking at the features with both forms of metrology can be seen in Figure 5. The AFM image show that the features are XXXX tall and have a width of XXX. In the SEM photo, one can clearly see that the photoresist features are severely rounded and deeply undercut. The attachment region between photoresist and nickel looks to be no more than 50% of the feature width.

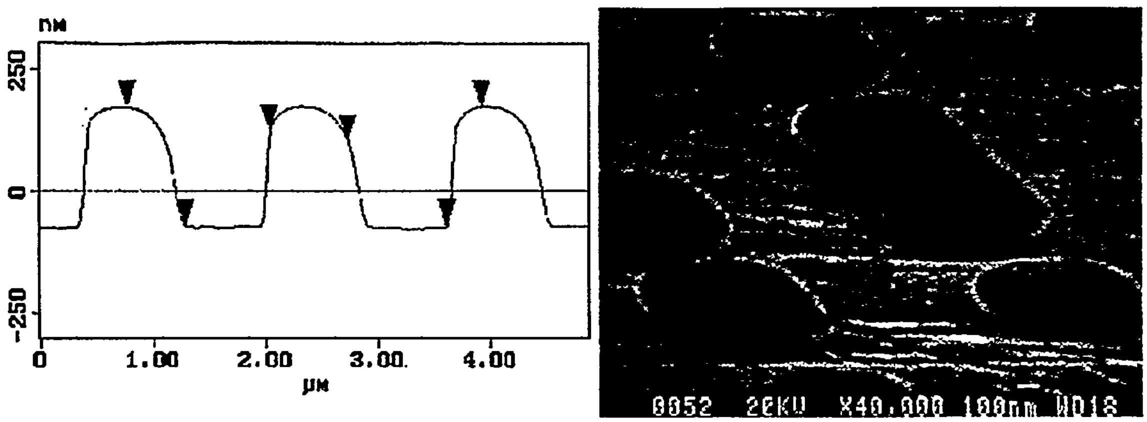

Figure 5: SEM and AFM images of features.

This deep undercut is likely to be responsible for the "washing away" that is observed on narrower features (e.g. those recorded at lower exposure powers).

Conceptually, the development process can be pictured using the schematic in Figure 6, of a cross-section of an exposed feature in a photoresist film on a nickel substrate. The lines drawn in the film correspond to contours of constant exposure dosage. Clearly, the highest exposure occurs at the center top of the photoresist, directly beneath the beam. With a gaussian beam profile, it would be expected that the contours move down and outward, while getting progressively steeper. Development is a dissolution of the photoresist polymer, and this process is retarded by a greater extent of cross-linking. So, one expects lines of development to proceed roughly along the contours drawn (neglecting the fact that the developer begins at the top surface alone, which would tend to round the top corners from those shown).

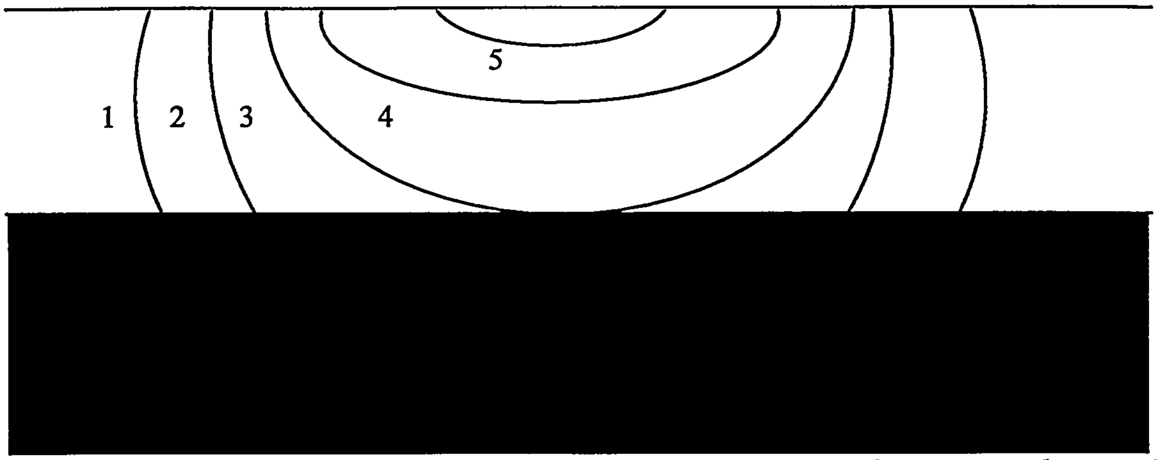

Figure 6: Schematic cross section of photoresist contours of exposure dose and development path.(Note: the profile of the beam and the absorbency of the photoresist could markedly change the shape of these contours, and in particular their relative slopes from vertical.)

One way to steepen the sidewalls, then, would be to shorten the development time for a given exposure and photoresist thickness. We decided to try this approach, and at the same time we decided to make the photoresist. A series of tests were conducted where the laser exposure power was varied from 0.1 mW to 0.45 mW and the development time was varied from 2 seconds to 30 seconds. To eliminate any variation in recording, one sample was used for the development tests, being cut into pieces and developed separately. Conclusions that can be drawn are:

- The shorter development times produce wider features.
- With shorter development times, exposure powers that previously were washed away in development are now stably connected to the substrate.

The latter is demonstrated in Figure 7, an SEM image of the photoresist feature developed for only 10 seconds (compared to the 30 seconds used previously).

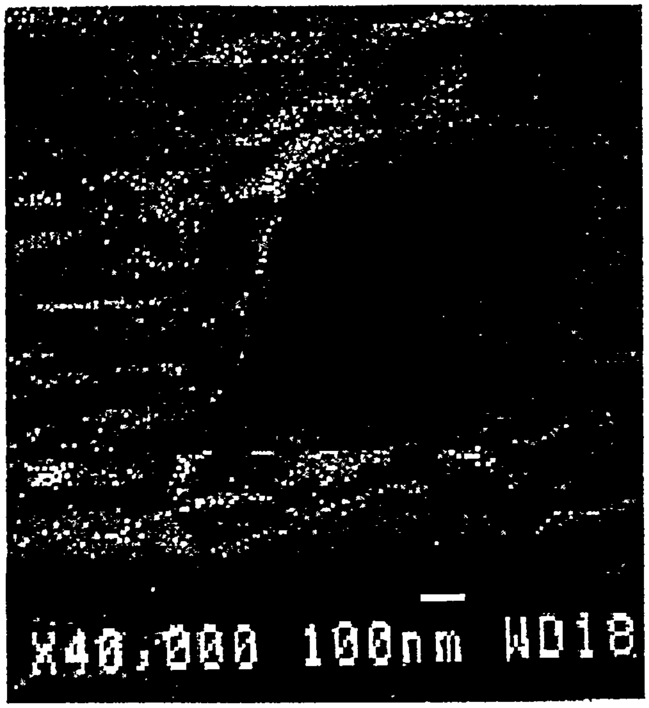

Figure 7: SEM of a feature having broad attachment to substrate as a result of development-process modification.

Once the control of the photoresist image was achieved, the ion machining of the substrate could be refined. It was observed, in the results of the first few exposure and ion machining experiments, that the photoresist features recorded on the nickel substrate appeared to narrow in width and shorten in length as a result of ion machining. Figure 8 shows differential interference contrast (DIC) microscope photos of a sample taken before and after ion machining, respectively. The narrowing after ion machining is apparent, even in these low-resolution photos. With the control in photoresist shapes, we were then able to control the post ion machined shapes. Testing different exposure powers and development times did this. Another issue of concern (which was also brought up in the Phase I research) was the heating of the resist during the machining process due to the bombardment of argon atoms and electrons. This caused a breakdown in the resist and caused the resist to flow. This was compensated for by installing an active cooling system to draw heat away from the part during the machining process and by reducing the machining rate, which would in turn reduce the heat flux into the part.

When these were implemented a stamper with the proper feature height and width was generated. An SEM micrograph of the features can bee seen in Fig 9.

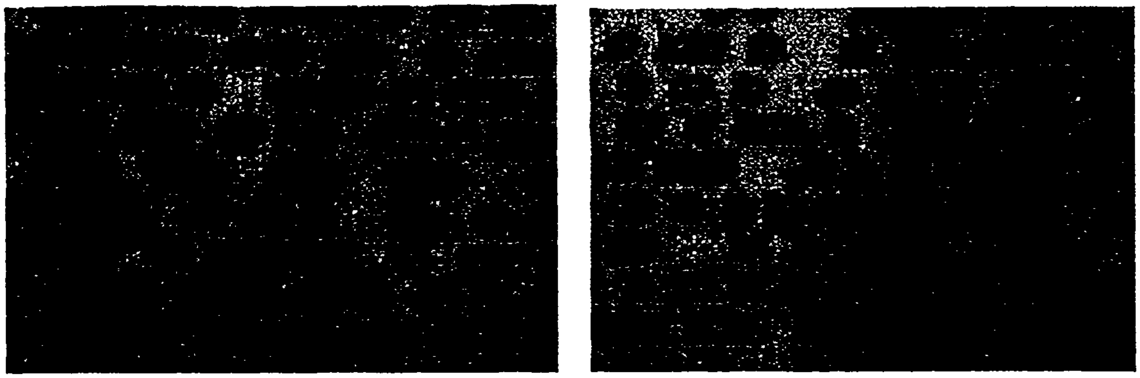

Figure 8: Optical microscope photos of sample, Left: photoresist, before ion etching; Right: nickel, after ion etching.

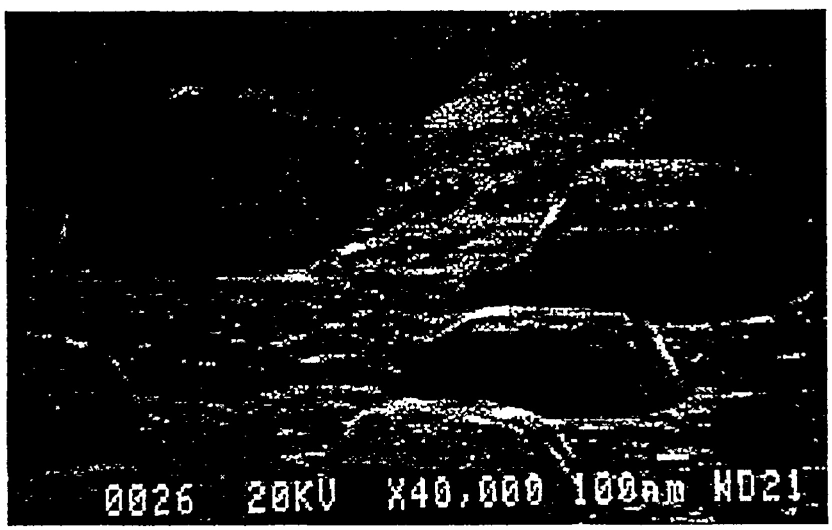

Figure 9: Ion etched feature after removal of most photoresist

With this stamper made with the Prism mastering process, we molded replicas using an industrial injection molding machine. Since we were using the same substrate material as conventional mastering process (nickel) made to the same physical dimensions, the molding process was a straightforward operation. An AFM image of the replica made from the Prism process compared to the conventional process can be seen in Figure 10.

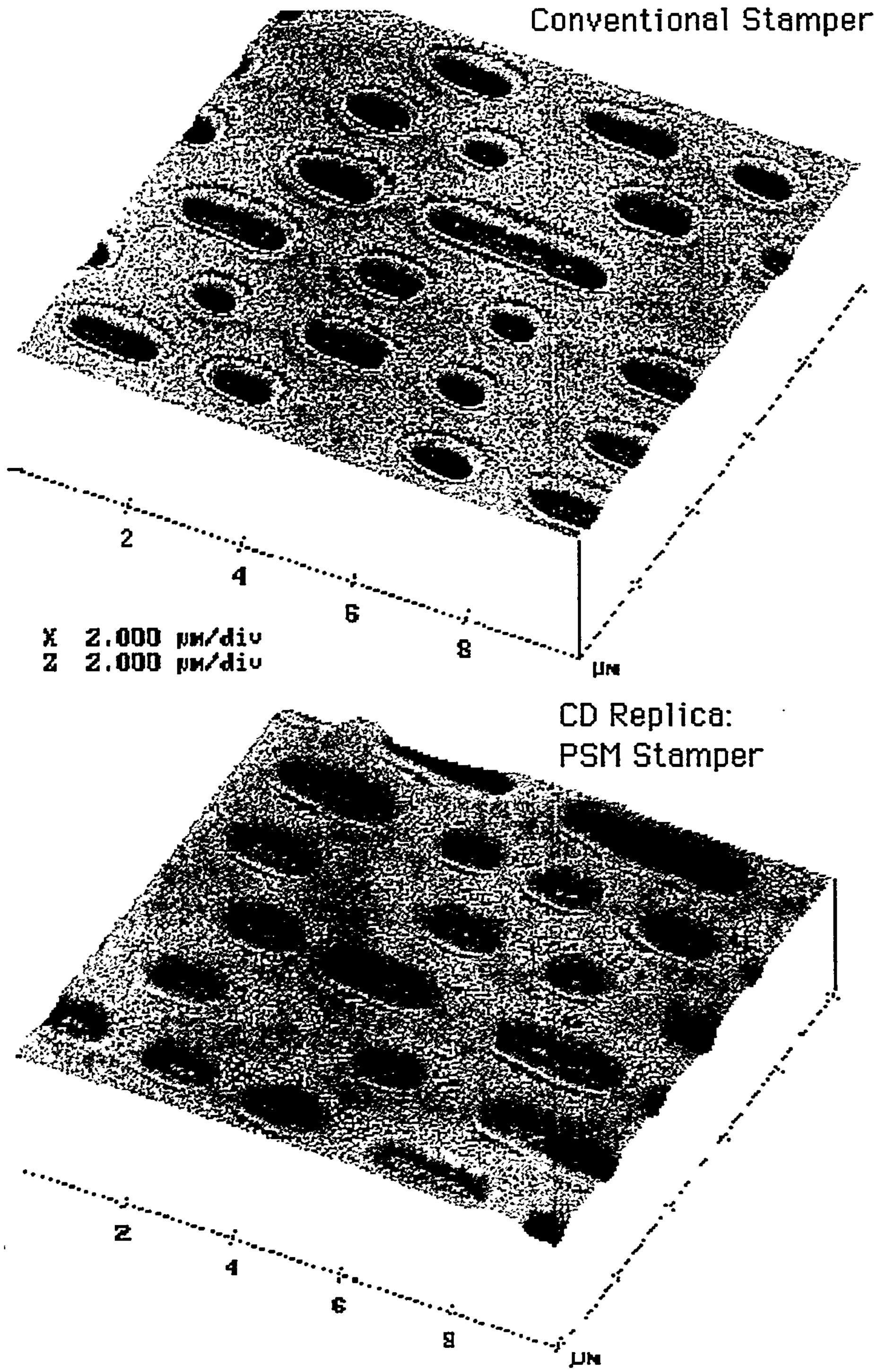

Figure 10: comparison of conventional process replica and a replica made using Prism's process

2.3 Evaluate alternative materials and alternative process parameters to optimize the process

2.3.1 Substrate Materials

One of the tasks set up in the Phase II proposal was to focus on the materials and processes that were found to be the most unrepeatable or costly in our Phase I research, and select new materials and processes based on the experience gained in that preliminary effort. Two major changes were made due to results of experimentation and evaluation of the processes. The first significant change occurred in our selection of substrate materials. In evaluating our substrate materials, three issues arose which indicated that glasses and ceramics were not the ideal materials for high volume production of optical disc stampers. First, in fabricating the substrate to the thickness of a conventional nickel stamper (300 μm) it was extremely difficult to hold the tolerance for flatness and parallelism (10μm total thickness variation) and made the stamper too fragile for handling. The solution to this problem was to increase the stamper thickness (900 μm) which would make the substrate easier to fabricate and more robust. The drawback to this is that it made the stamper unable to fit into a standard injection-molding machine without a modification to the mold. The mold modification was obtained, but required an hour to be fitted into the mold: an unacceptable time for a "seamless" integration. The second issue with the ceramic stampers was the center hole needed for clamping into the molding machine. A hole needed to be made in the center of the stamper which would be used to lock the stamper into the injection molding machine during the molding process. This hole needed to be made in the stamper during the manufacturing of the blank because the polishing of the substrate needed to be done after the center hole was made to remove any roughness generated in the fabrication. This center hole made it difficult to apply an even coating of the photoresist using the standard process for coating, puddling the photoresist at the center of the disc and then spinning the disc to evenly coat the substrate. Without the ability to dispense to the center of the substrate, an edge effect was observed on the inner diameter of the part, with a bulge in the photoresist at the inner. Also, the center hole eliminated the possibility of using different makes of injection molding machines (some injection molding machines require center holes of 22.0 mm while others need 35.4mm or 27.0 mm). Third, the cost of materials and fabrication of a ceramic or glass substrate, especially the lapping and polishing was very high when compared to the conventional stamper making method. What this showed to us is that while ceramics and glasses would work, they were not the most ideal materials for the high volume of stampers needed for standard optical disc fabrication. They would be suitable for a process in which a stamper was used for a high volume of discs with the same information on it (i.e. CD-R and DVD-RAM where the numbers are in the tens of millions of discs needed that are identical).

With these ideas in mind, we then studied the possibility of making metallic stampers. The key components to the metallic stampers would be the same as for the ceramic stampers, toughness, thermal shock resistance, and the ability to be ion machined without damaging the surface finish. Past research had proven that amorphous metals, such as electroless nickel could be ion machined without roughening the surface. We looked into manufacturing metal substrates that consisted of a hard, stiff base, with a thin electroless nickel coating on the surface. This substrate could be polished to a surface finish similar to that of the current stamper (Ra = 30 Å). This goal was achieved with a steel shim stock base and a high phosphorous content (12-14%) electroless nickel plating on the surface. The substrates could be made with a thickness the same as conventional stampers (300μm) without increasing the cost allowing the standard injection molding machines to be used. Since the substrate material was metal, the center hole could be punched after the part has been ion machined. This made it easier to coat and process before ion machining. Also, this gave the ability to change the size of the ID for the different injection molding machines. The outer diameter of the part did not have to be a specific size, because it too could be punched to fit the molding machine. A size of 150mm OD was chosen because it was slightly larger than the needed final size for the standard injection molding machine (138mm) and there was already a number of different handling tools and casings for this size disc as it is a standard sized for silicon wafer fabrication. The cost for manufacturing was much lower than compared to the ceramics and glasses, as the materials cost was very low and the manufacturing cost much less.

The implementation of the metallic substrates revealed that they would fit into the current manufacturing process without any modifications needed to the injection molding machines. Also, there was no significant change in the ability to process these substrates compared to ceramic and glass substrates studied in Phase I and the early stages of Phase II.

Figure11: Process for fabrication of metal substrates. 1) A circular part (150 mm diameter) is punch from a sheet of shim stock. 2) The part is lapped to both reduce the thickness of the part and increase the flatness. 3) A layer of nickel/phosphorous is deposited onto the surface of the part using an electroless process. 4) The substrate is polished to give an optical finish to the surface.

2.3.2 Process Chemicals

The second significant change in the process was the selection of photoresist. We continued to look into new developments in the manufacturing of negative tone resist. A number of different negative tone photoresists were analyzed to determine the best for the Prism process. Parameters such as spin uniformity, sensitivity to the exposing laser, final feature shape controllability and the ease with which the photoresist could be removed after ion machining were taken into account when analyzing the photoresists. While four different negative photoresists were tested, two were immediately rejected due to a large potential for pin- holes (minute holes in the resist coating). The other two have been tested for the above mentioned parameters and one was determined to best suit our process. The two photoresist NFR-012R from JSR Corporation and an experimental photoresist from Shipley Corporation, XP 9603 (later named Ultra-i 300 after it was introduced to the commercial market). The two resists worked equally well in the coating process with the limit of coating uniformity (±5 nm) coming not from the resist but from the coating procedure itself. The two resist had different sensitivities to the exposing laser with the NFR resist being more sensitive to both the Krypton and Ultra-Violet laser used in recording (λ= 412 nm and 351 nm, respectively). The difference in sensitivity was approximately 50%, but this increase in exposure power needed by the XP resist was easily achievable with the power of laser used in recording. In terms of the final feature shape controllability, again the limit was determined not by the resist but by the process, so the two were deemed the same. The final parameter, ease of material removal after ion machining separated the two. While it was difficult to remove the NFR resist from the substrate after ion machining (we were unable to remove the resist in a number of tests), the XP resist could be removed with a heated, ultra-sonic chemical bath. An "intangible" parameter that separated the two resist was that the chemical composition of the XP was similar to the positive tone photoresists that were being used by optical disc mastering companies, making it easier for companies to switch to the Prism mastering process.

3.0 Conclusion

All technical objectives of the Phase I and Phase II research plans were achieved within the timeframe and budget allocated. After proving feasibility of the new process, a prototype ion machining system was fabricated and tested before being introduced at an international trade show. The results of this advanced testing and development led to commercialization of the process and IMS design by Prism, with the assistance of three well-established and high profile manufacturers in the Compact Disc production industry – a mastering equipment manufacturer, a molding manufacturer, and one of the largest independent CD and DVD replicators in North America.

Continuation with Phase III is proceeding according to plan, and it is expected that the process developed through this research product will begin to have a significant effect on the manufacturing infrastructure of optical disc components in the near future.