Sample Preparation of Optical Crystals: Cutting and Polishing Methods

Lapping and Polishing

1.0: Purpose

Optical crystal preparation is common among many different fields of research. The preparation of such crystals imposes many difficult specimen preparation challenges due to the stringent requirements the specimens inherently contain. Obtaining an optically smooth, polished surface on brittle, easily damaged optical crystals requires careful specimen preparation and the proper preparation equipment. This report describes techniques adapted for the preparation of quartz crystals used in various optical applications.

2.0: Experiments and Procedures

A 3" (75mm) diameter glass optical substrate was obtained for cutting and polishing experiments to be performed. The samples were to be cut into sections 10mm wide x 20mm long using a suitable cutting method. Following cutting of the devices, the samples were then to be polished using a suitable mounting fixture. The only portions of the samples to be polished were the end faces (edges) following the cutting process. The methods used in specimen preparation are described below.

2.1: Wire Sawing

The quartz wafers were to be cut using the Model 850 Wire Saw to obtain the proper specimen dimension required for each specimen. Wire sawing offers several advantages compared to diamond wheel sawing including reduced damage and edge chipping, minimal saw kerf, and process selectivity. The quartz wafer was mounted onto a graphite mounting plate used on the Model 850 for holding specimens during cutting. To avoid scratching to the wafer surface, wafers were mounted to the graphite plate using a plastic adhesive tape (Semiconductor Equipment Corp.). The wafers and protective mounting tape were then waxed to the graphite plate using a low temperature, thermoplastic mounting wax. Following the mounting process, the wafers were mounted onto the Model 850 Wire Saw for cutting. A micrometer controlled indexing table allows for precise measurements of the cut dimensions enabled precise measurements to be made during the cutting process. A boron carbide (B_4C) abrasive suspension was used for cutting the wafer samples, mixed to 1 part powder, 4 parts glycerine, 1 part water (by weight) ratio. An Abrasive Slurry Recirculating System (Model 85030) was used for automatically feeding the abrasive slurry to the surface of the wafer during cutting. This system minimizes the user interface and allows for semi-automatic cutting to proceed. The following parameters were used during the cutting process:

ABRASIVE:	23 µm B_4C abrasive suspension
WIRE:	0.010" stainless steel
LOAD:	100 grams (10 notch)
SPEED:	4 on dial (220 rpm wire speed)
SLURRY PUMP:	5 on dial
CUTTING TIME:	5-8 minutes / cut

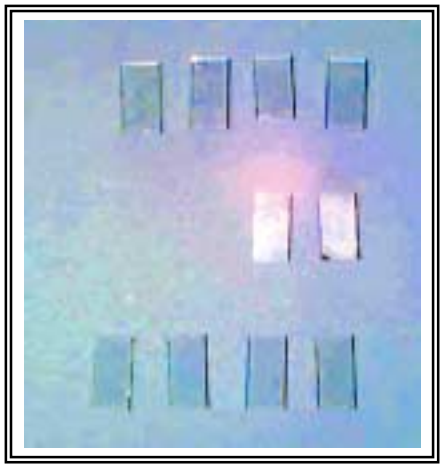

Figure 1: Image taken of several glass pieces following cutting on the Model 850 Wire Saw. Note the uniform size of the specimens and the lack of damage to the surface of the crystals. The crystals were subsequently removed and cleaned in acetone and isopropyl alcohol to remove any residue from the cutting process.

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2.2: Crystal Mounting

Following the cutting process of the wafer, each specimen was then mounted to a modified mounting block for the Model 153 Laser Rod Polishing Fixture. The Model 153 was originally designed for polishing rod ends and other long, irregularly shaped specimens. A schematic illustration of this design is shown in Figure 2.

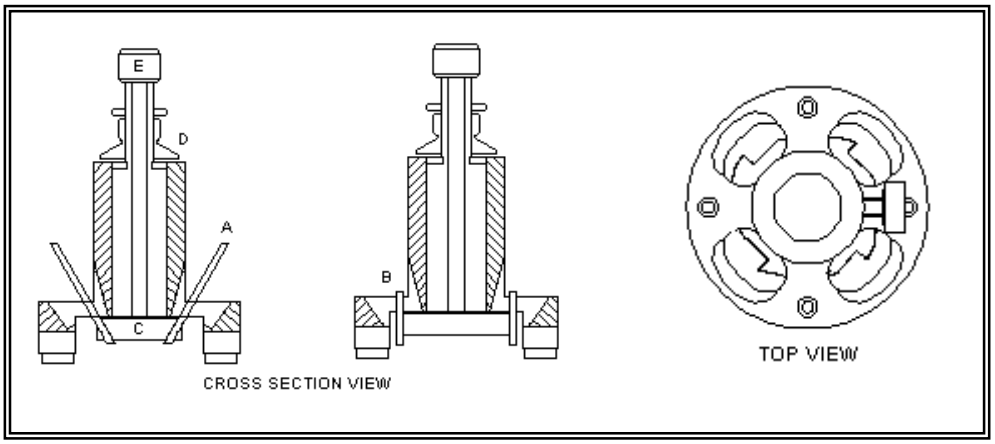

Figure 2: Schematic illustration of the Model 153 Laser Rod Polishing Fixture. The illustration on the left shows the original design for lapping and polishing laser rod crystals. The illustration at right shows a modified mounting block designed to accommodate square wafer pieces as prepared in this report.
A- Laser rod; B- Wafer piece; C- Mounting plate; D- Micrometer dial; E- Draw rod

Mounting of the quartz wafer pieces was done using a thermoplastic mounting wax applied to the modified mounting block manufactured specifically for polishing end faces on the as-cut quartz wafer pieces. The mounting block was placed onto a hot plate using a small pedestal to allow for the rod pieces to mounted uniformly onto the mounting block. Small amounts of wax (MWH 135) were applied to the mounting block and the wafer pieces were attached. Below is an illustration of the mounting procedure and an image showing the resulting mounted wafer pieces.

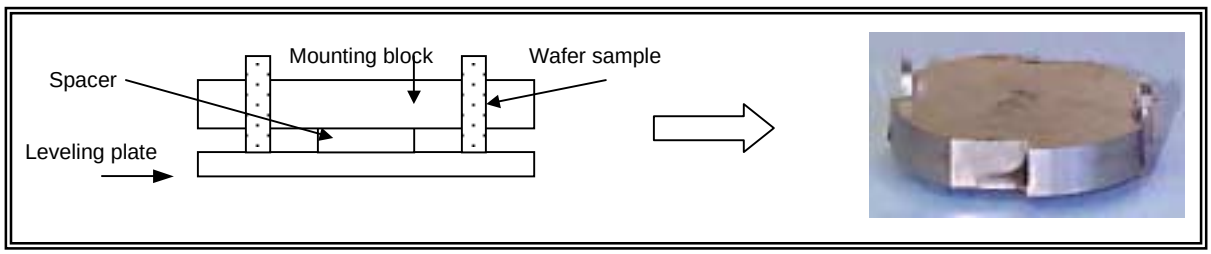

Figure 3: Illustration of the mounting process used for attaching the wafer pieces to the mounting block. The mounting block is placed onto a spacer and leveling plate all on the surface of the hot plate to facilitate even mounting of the wafer pieces. Wax is applied to the mounting block and the assembly is allowed to cool.

Following crystal mounting, the mounting block is assembled into the Model 153 and setup for lapping and polishing.

2.3: Lapping and Polishing

Lapping and polishing the end faces of the quartz wafer pieces is needed to remove mechanical damage from the sawing process and to produce the smooth, high quality polish necessary for most optical materials. The first step in most applications is to lap the specimen to produce a flat, uniform surface. This is required for making the edges perpendicular to the surface of the wafer piece and to eliminate any uneven edges that may have been produced in the wire sawing operation.

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Initial lapping was completed using a flat, cast iron lapping plate with an aluminum oxide abrasive suspension (Al_2O_3). The plate is first conditioned to remove any surface irregularities present on the lapping plate and to charge the plate with the desired abrasive particle size. Conditioning is carried out for about 30 minutes using a 12 µm Al_2O_3 abrasive suspension with a conditioning ring and Model 92002 Workstation. After plate conditioning is completed, the specimen is ready to be lapped. The Model 153 is set up to remove 500 microns and the fixture is lapped for 12 minutes. Below are images showing the basic setup for plate conditioning as well as the specimen surface following lapping.

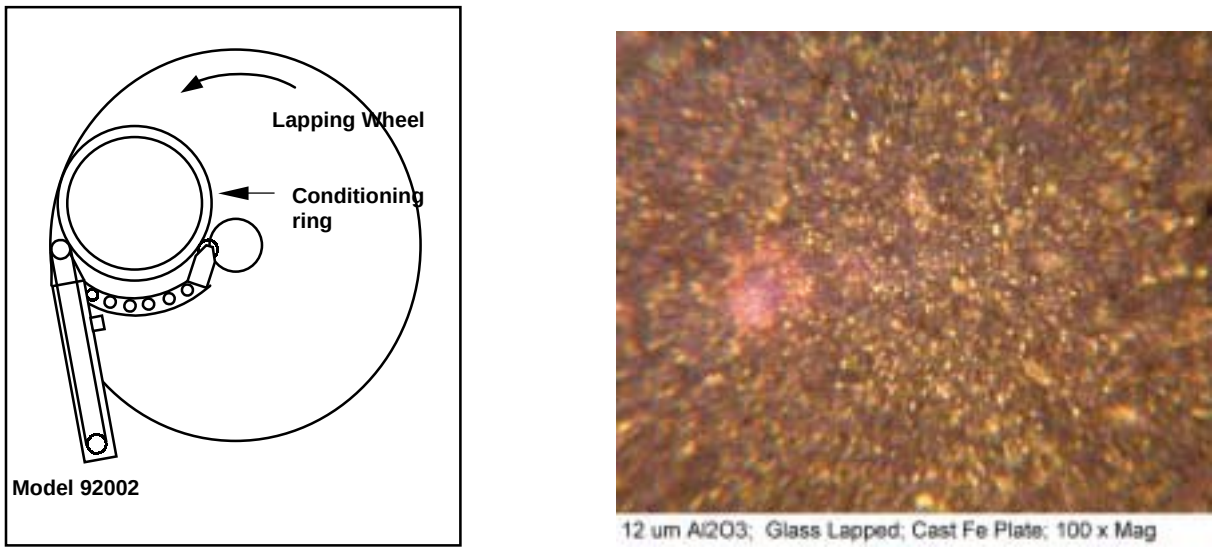

Figure 4: At left, schematic illustration showing the setup used for conditioning the cast iron lapping plate. The same configuration is used during specimen mounting with the Model 153 mounted in place of the conditioning ring. At right, OLM image showing the as lapped surface of the glass wafer pieces after lapping on the cast iron plate. Note the roughened surface characteristic of a lapped specimen.

Following initial lapping of the specimens, polishing of the specimens is required for removal of damage and to produce the polished surface. After polishing was completed the specimens were inspected under a reflected light microscope and evaluated based on the removal of lapping damage, remaining scratch pattern, edge quality, and overall polishing capability. Different polishing media and polishing cloths were used and therefore each step will be discussed individually below.

ShanyPol Polishing Cloth

Rough polishing of the lapped specimens was carried out using a ShanyPol Medium polishing cloth. This cloth has little to no cloth nap (fiber) to it and behaves more like a pad material. The following parameters were used during the rough polishing step:

LAP SPEED:	2 (110 RPM)	LOAD:	100 GRAMS
ARM SPEED:	5 (21 RPM)	ABRASIVE:	12 µm Al_2O_3
CLOTH TYPE:	ShanyPol Medium	TIME:	10 minutes
SLURRY DRIP RATE:	1 drop / 10 seconds		

CeriPol Polishing Cloth

Fine polishing of the specimen was carried out using a CeriPol polishing cloth. This cloth also behaves more like a pad material and is designed for optical crystal polishing. The following parameters were used during fine polishing:

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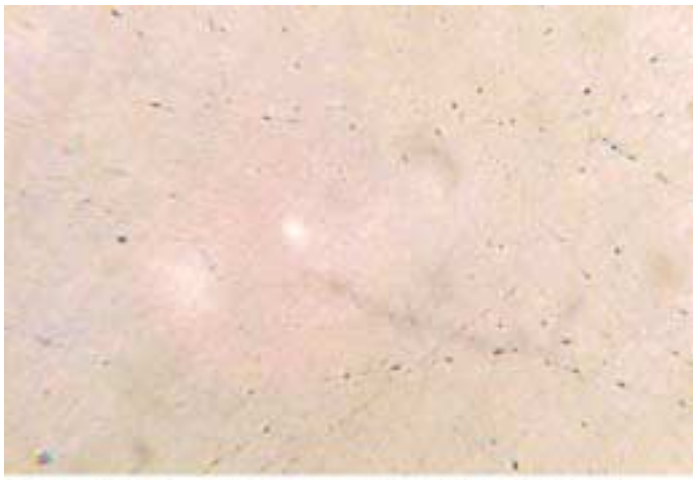
LAP SPEED:	2 (110 RPM)	LOAD:	100 GRAMS
ARM SPEED:	5 (21 RPM)	ABRASIVE:	1 µm Al_2O_3
CLOTH TYPE:	CeriPol	TIME:	5 minutes
SLURRY DRIP RATE:	1 drop / 10 seconds		

3.0: Results

Below are images illustrating the surface of the glass specimens at each stage of preparation.



5 um Al2O3; Glass Lapped; ShanyPol Med Cloth; 100 x Mag

1 um Al2O3; Glass Lapped; CeriPol Cloth; 100 x Mag

As can be seen from the images above, the surface finish produced following the lapping process is quite good. The image at the left shows the removal of most of the lapping damage created from the cast iron lapping process, and exhibits a good uniform surface with mild scratching. The image at the right shows an optically smooth surface free of scratches and mechanical damage, indicating a good polishing process and the proper surface preparation.

4.0: Conclusions

Using the Model 850 Wire Saw for producing the desired crystal size and shapes has proven to be an effective method for initial preparation of these optical devices. Following the cutting process, optical polishing using a modified lapping fixture also shows excellent promise in preparing optical quality devices for fabrication. The following process was developed for preparation of optical quality devices:

1. Cut into the desired shapes using: Model 850 Wire Saw; Model 85030 Abrasive Recirculating System.
2. Mount into a Model 153 Laser Rod Polishing Fixture with a modified mounting block for end polishing of wafer edges.
3. Lap the end faces of the crystals using: Model 920 Lapping and Polishing Machine; Model 92002 Workstation; LP 920M Cast Iron lapping plate with 12 µm aluminum oxide suspension.
4. Polish the end faces of the crystals using: ShanyPol polishing cloth with 5 µm aluminum oxide suspension; CeriPol polishing cloth with 1 µm aluminum oxide suspension.

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