Model 601
Tuned Piezo Cutting Tool

Owner's Manual and User's Guide

Part Number: 601.82002
August 2008
Revision 4

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Preface

About this Manual

This *Tuned Piezo Cutting Tool Owner's Manual and User's Guide* provides information on the Tuned Piezo Cutting Tool, Model 601 features and functions, along with procedures for installing and operating the unit. Routine maintenance and service procedures are also included in this manual.

The following typographical conventions are used for special comments:

NOTE: Recommendations for getting the best performance from the equipment.

CAUTION: Precautionary notes and advice to avoid personal injury or damage to the equipment.

The *Tuned Piezo Cutting Tool Owner's Manual and User's Guide* consists of two chapters and two appendices providing the following information.

The Owner's Manual describes the theory of operation, environmental requirements, and physical specifications of the unit. Installation instructions and any precautions to be taken are also included.

The User's Guide contains step-by-step instructions for setting up the unit, preparing specimens, and operating the cutter and microscope.

Appendix A Spares and Consumables provides a list of the spares and consumable items that may be needed for this equipment, with their part numbers.

Appendix B Gatan G-1 and G-2 Epoxies provides important background information about the characteristics and properties of G-1 and G-2 epoxies.

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Owner's Manual

1.1 Theory of Operation

The proven and most effective method for rapidly cutting brittle materials is mechanically coupling a piezo crystal to a shaped tubular cutting tool vibrating in a fine grain boron carbide slurry. The Gatan Tuned Piezo Cutting Tool uses this technology to expand the standard application beyond cutting 3 mm TEM discs. You can now quickly cut simple holes, unique shapes, or TEM discs from hard, brittle materials such as semiconductors, ceramics, and geological samples, in thicknesses ranging from < 40 µm to 5 mm. A variable frequency driver delivers the ultimate in cutting performance regardless of cutting tool size or shape. The manually tuned frequency driver optimizes cutting speed for each cutting tool while minimizing mechanical and thermal-induced damage.

1.1.1 Cutting Method

The TPC Tool employs a lead zirconate/titanate piezoelectric crystal to vibrate a tubular cutting tool at a frequency of approximately 26 kH against a specimen. A slurry of water and boron nitride grit is applied around the tip of the tool. The high-frequency vibration causes particles in the slurry to impact the specimen, eroding away a circular impression, eventually "cutting" a section from the specimen.

A spring-loaded platform applies a constant force to advance the specimen table upward, parallel to the cutting tool. The specimen table is held in position magnetically, preventing lateral movement relative to the cutting tool, which reduces edge chipping and sample damage.

The included stereo microscope with X-Y positioning table enables precise centering of a specific area on the sample relative to the cutting tool.

1.1.2 Cutting Rate

The cutting rate depends upon the geometry of the cutting head, its load and frequency, the toughness of the specimen, and the hardness of the cutting grit. To maintain the optimum tool load during cutting, the specimen table is supported on a spring-loaded, hinged platform that continually presses the specimen up against the tool. The user can view the progress in the depth of cut on a dial gauge that is connected to the hinged platform (see Figure 1-2, “TPC Tool,” on page 10).

The TPC Tool is designed to achieve the maximum erosion rate attainable without risk of microstructural damage to the central region of the specimen disc.

1.1.3 Specimen Centering

A specimen positioning table and stereo microscope are provided to center the cutting tool relative to the area of interest on the specimen surface. The cutting tool and the microscope are calibrated with each other to maintain accurate centering of the specimen during the cutting process.

1.1.4 Adjustability

Although the Tuned Piezo Cutting Tool was specifically designed for cutting specimen discs from thin wafers, it now has the power and additional features to cut a variety of shapes and holes, and can machine small cylinders from bulk materials up to 5 mm thick. Cutting cylinders directly from bulk specimens avoids the initial diamond saw slicing step, which can be slow and difficult for certain materials. Once a small cylinder has been cut, slicing thin discs is generally a much easier operation than cutting small cylinders from a large thin specimen.

Figure 1-1 Stereo Microscope and Tuned Piezo Cutting Tool

1.2 Environmental Requirements

The Tuned Piezo Cutting Tool requires no special environmental conditions for operation, other than an environment that is relatively clean and dust-free.

1.3 Precautions and Warnings

> **CAUTION:** Use only the special circular wrench provided to tighten the cutting tool. Use of any other wrench or tightening tool can damage the threaded insert on the cutting head assembly.

The circular wrench has a hexagonal center hole designed specifically for tightening many of the Gatan cutting tools without over-torquing and damaging them.

In larger size or different shaped cutting tools, holes are bored through the cutting tool, for insertion of a .050 inch (1.27 mm) hex wrench. Use only these .050 inch hex wrench tools for tightening the larger size cutting tools.

Following are some important cautions to observe when operating the Tuned Piezo Cutting Tool:

- Prior to use, Gatan recommends using hearing and eye protection. Eyewear should be in accordance with ANSI Z87.1-2003. AOsafety Maxim Eyewear or similar. Hearing protection should be in accordance with ANSI S3.19-1974 and provide 25 db noise reduction. E-A-R Ultrafit Earplugs or similar.
- Do not allow water to remain in the aluminum head assembly when it is not being used, since it can cause corrosion inside the cutting head.
- Shut off the power when the TPC Tool is not being used. Leaving the power on will overheat the unit and reduce the useful life of the head assembly.
- Dangerous high voltages are built up in the power supply. Electrical servicing should be performed only by a qualified electrician.
- Do not touch the end of the cutting tool if the transducer is operating; it may cause severe burns.
- Do not adjust the screws which secure the head assembly to the frame, as this will change the alignment between the axis of the cutting tool and the microscope.

1.4 Installation

The TPC Tool operates from the standard mains voltage (Universal input 100-240 VAC, 50/60 Hz) with no other external services or utilities necessary. However, for reproducible high-quality results, the TPC Tool must sit on a flat, vibration-free surface in a relatively clean environment.

1.5 Description and Specifications

1.5.1 Basic Components and Options

1.5.1.1 Basic Components

The basic components needed to accurately prepare and cut specimens are the TPC Tool and the following items, which are included in the basic package:

- Stereo microscope with viewing lamp and X-Y positioning table
- Slurry retaining ring
- 3-mm cutting tool
- Cutting tool tightening wrench (disc-shaped, with hexagonal center hole)
- Flexible hose and syringe
- 8 ml of (320) cutting grit
- Wax rods (set of 12)
- Universal DC power supply
- Microscope power cable

1.5.1.2 Options

The following optional parts and kits from Gatan may be useful in preparing SEM and TEM specimens.

Table 1-1 TPC Tool Options

PART NUMBER	DESCRIPTON	USES
601.07000	TEM Specimen Cross-Section Kit	Creation of various cross-sectional TEM specimens used in the study of the microstructure of multi-layered materials.
623.4000X	Specimen Mounting Hot Plate	A safe and reliable means of applying the low melting point wax required to securely attach specimen materials to their glass slides.

Table 1-1 TPC Tool Options

PART NUMBER	DESCRIPTON	USES
623.00000	Precision Disc Grinder	Final steps in preparing specimen stacks.
See Appendix A	Optional Cutting Tools	A broad selection of round, square, and rectangular cutting tools are available for standard TEM applications as well as those applications requiring special shapes or forms.

1.5.2 TPC Tool

Figure 1-2 on page 10 shows the Tuned Piezo Cutting Tool and identifies its primary elements and controls. In the following descriptions, the numbers in brackets refer to the callouts in the figure.

The TPC Tool is mounted on a sturdy base that contains a spring-loaded, hinged platform [8]. Two positioning pins [6] guide the placement of a notched magnetic base [9].

A specimen is placed on a glass slide [11] and glued to the circular specimen table [10], with a slurry-retaining ring around it. The specimen table is then placed on the notched magnetic base and the entire configuration is centered on the hinged platform under the cutting tool [12].

The cutting tool head assembly is raised and lowered with either one of the two height-control knobs [3] located on the left and right side at the rear of the unit. The degree to which the cutting tool is lowered onto the hinged platform is indicated by a horizontal indicator at the base of the tool [5], which allows you to manually maintain the hinged platform in a level position and perpendicular to the cutting tool. The cutting depth can be monitored using the dial indicator [2] mounted on top of the unit.

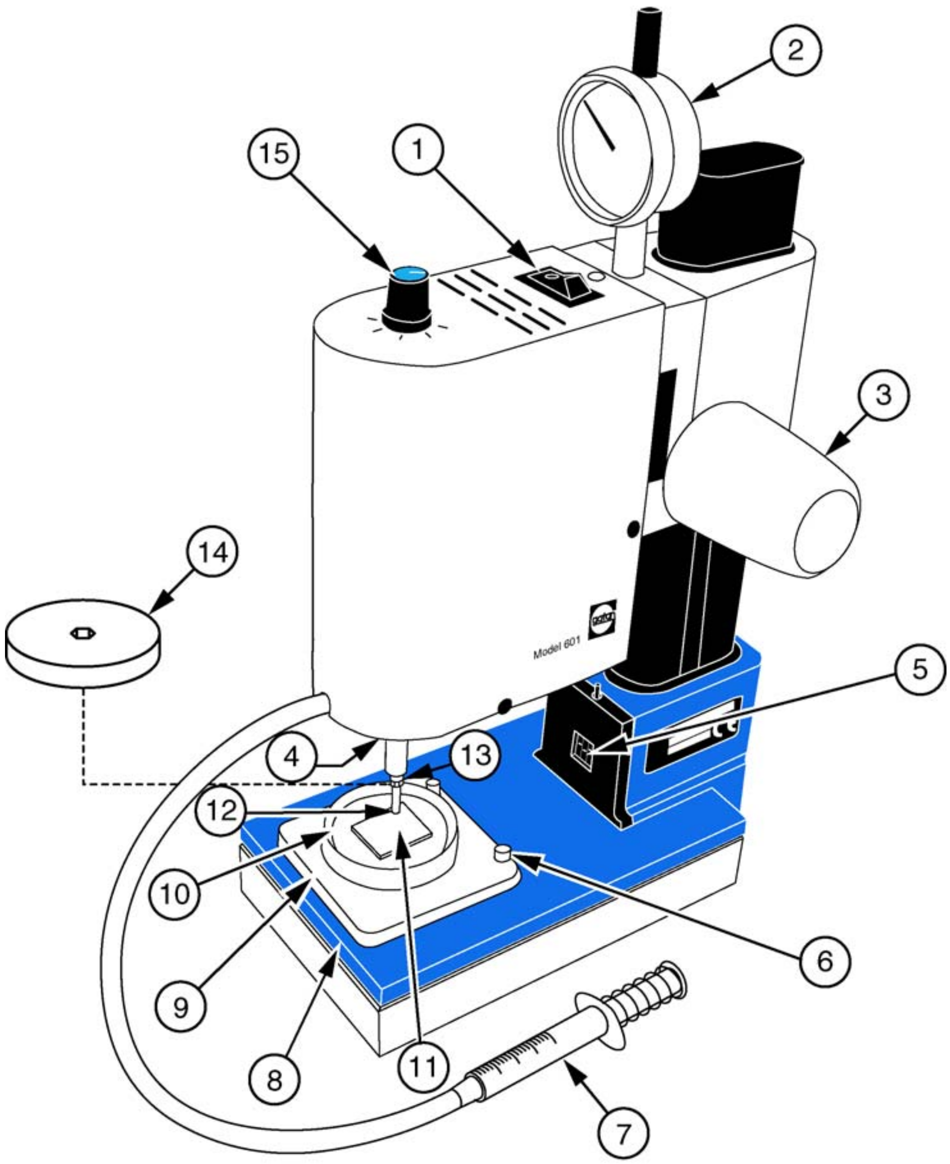
To facilitate the cutting of thick sections, a small syringe and flexible hose [7] is provided to periodically flush a fresh stream of cutting slurry between the tool and the specimen. (A standard laboratory eye dropper can also be used to add water to the slurry.)

Four bright LED illuminators are located around the cutting head assembly [4], enhancing the area being cut and the cutting tool. These illuminators are lit when the TPC Tool power is turned on.

A special cutting-tool wrench [14] is provided for mounting many of the different cutting tools. If a cutting tool is too large for this special wrench, or if you are using a cutting tool that does not have a standard hexagonal shaped insertion end, use a .050 inch (1.27 mm) hex wrench inserted through the hole in the cutting tool to tighten it in place.

> **CAUTION:** Using anything other than the tools intended to tighten the cutting tool can damage the threaded insert on the head assembly.

Figure 1-2 TPC Tool



1. Power switch	9. Magnetic base
2. Depth-of-cut dial indicator	10. Specimen table
3. Cutter height control	11. Glass slide
4. Specimen illumination LED	12. Cutting tool
5. Horizontal indicator	13. Copper washer
6. Locating pins for magnetic base	14. Cutting tool wrench
7. Syringe kit	15. Manual tuning knob
8. Hinged platform	

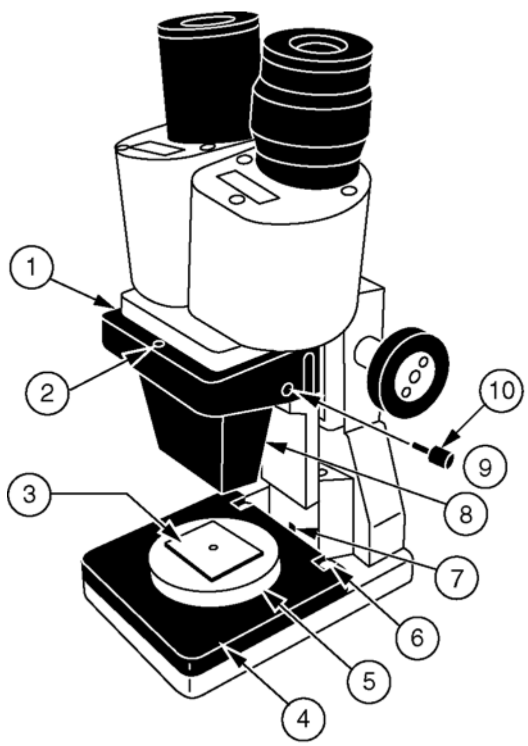
1.5.3 Stereo Microscope

A stereo microscope with X-Y positioning table enables precise alignment of a specimen before cutting.

The 50x stereo microscope projects a true image and is completely adjustable to enable precise realignment if necessary. A cross-hair within the microscope eye-piece is used to align any specific feature on the specimen. The cross-hair is calibrated to the center of the cutting tool so that the specimen feature identified will be correctly aligned under the cutting tool when the magnetic base is mounted on the TPC Tool.

The microscope contains a single lamp to illuminate specimens in reflected light, and is powered from the TPC Tool using the microscope cable provided. The illuminator is lit only when a specimen is being viewed. A contact switch at the rear of the microscope base is pressed when the specimen table is securely in place, turning on the illuminator.

Figure 1-3 Stereo Microscope



1. X left adjust	6. Locating pins
2. Y adjust	7. Illuminator contact switch
3. Glass slide	8. Lamp
4. Magnetic base	9. X right adjust
5. Specimen table	10. Adjustment tool

1.6 Troubleshooting

Symptom Power switch is on but no audible tone is emitted from the cutting tool and the LED is not illuminated.

Action

- Make sure the universal power source is properly connected to the mains supply.
- Make sure the DC plug from the universal power source is properly connected to either the left or right jack at the back of the TPC Tool.

Symptom Power switch is on, LED is illuminated, but no audible tone is emitted from the cutting tool after tuning.

Action The PC board or high-voltage transformer may be defective. Return the complete TPC Tool to the Gatan factory for repair.

Symptom The threaded insert is loose in the tip of the cutting tool head assembly.

Action

- Order a replacement head assembly (part number 601.03000).
- Remove the head assembly from the TPC Tool and return the head to the Gatan factory for repair. You may also return the entire TPC Tool to the Gatan factory for repair.

Symptom Cutting tool is not oscillating properly (little or no audible sound)

Action

- Readjust the manual tuning knob.
- Make sure the copper washer between the cutting tool and the threaded insert is in place.
- Make sure the copper washer between the cutting tool and the threaded insert is not damaged or brittle; replace it, if necessary.

1.7 Maintenance

1.7.1 Care of the TPC Tool

The Tuned Piezo Cutting Tool should be kept clean and protected from unnecessary vibration or dust.

- Wipe down the hinged platform and the base of the tool periodically to remove any stray grit.
- Keep dials and indicators clean for accurate reading.

- Do not allow foreign matter to accumulate on the magnetic specimen table or on the pins that are used to align the specimen table.

1.7.2 Care of Cutting Tools

The slurry used in cutting can quickly build up on the end of the cutting tool and impair the tool's ability to function properly.

- Always clean cutting tools thoroughly when you are finished using them.
- Flush the cutting tool thoroughly in running water and wipe clean with a suitable laboratory wipe.
- Blow off excess water in the threads with compressed air.

1.7.3 Care of the Stereo Microscope

The stereo microscope should be kept clean and protected from unnecessary vibration or dust.

- Care for the lens surfaces as you would any laboratory microscope.
- Do not allow foreign matter to accumulate on the pins that are used to align the magnetic specimen table.

1.7.4 Microscope Lamp Replacement

To replace the lamp in the microscope, follow these steps:

1. **Unplug the DC supply cable from the microscope.**
2. **Using the focus knob, raise the microscope to its maximum height.**
3. **Rotate the black reflector while pulling it out. It is not threaded.**
4. **Pull the lamp out of its socket.**
5. **Verify that the pin lengths on the removed lamp and its replacement lamp are the same.**
6. **Carefully plug in the new lamp, making sure each pin is properly inserted.**
7. **Push the black reflector back into position.**
8. **Lower the microscope to its working position and plug in the power supply cable.**

1.7.5 Determining Cutting Tool Wear

The cutting tool incurs wear over time, and this must be compensated for when measuring the depth of cut with the Dial Indicator.

To determine the amount of wear

1. **With the power on, raise the cutting tool from the specimen.**
2. **Switch off the power and position the magnetic base assembly with a glass slide on the specimen table so the tool can be placed against the glass.**
3. **The amount the dial indicator moves beyond the original zero is the total tool wear.**

NOTE: Make a note of the (tool wear/mm depth of cut) since this information will enable you to estimate the change in the dial indicator zero position you can expect for any depth of cut in the same material. Be sure to include the major divisions on the dial indicator.

1.7.6 Replacing the Cutting Tool

Once a cutting tool has become damaged or severely worn, it should be replaced. See Appendix A, Spares and Consumables, for cutting tool part numbers.

To replace a cutting tool

1. **Loosen the cutting tool using the special wrench provided.**
2. **Flush the threaded end of the cutting tool with water and compressed air to remove any grit.**
3. **Place a new copper washer on the threaded insert of the head assembly and screw on the new cutting tool using the special wrench provided.**

CAUTION: Do not apply a high torque. The use of a wrench other than the one supplied may severely damage the threaded insert on the ultrasonic head. If this happens, the complete TPC Tool or the head assembly must be returned to the factory for repair.

1.7.7 Aligning the Microscope

The cross hair within the stereo microscope eyepiece is aligned so that the center of a specimen will be precisely at the center of the cutting tool. This allows you to locate a specific feature to be cut from a specimen.

Should re-alignment of the microscope become necessary, follow these steps.

To align the microscope

1. **Mount a clean glass slide on the specimen table (see Section 2.3, “Working with Specimens,” on page 20), with or without a slurry retaining ring.**
2. **Place the specimen table (with glass slide) on its magnetic base.**
3. **Position this assembly against the two locating pins on the TPC Tool hinged platform.**
4. **Lower the cutting tool onto the glass slide until the horizontal indicator is aligned (see Figure 2-2 on page 22), and switch on the power.**
5. **Cut a shallow depression into the glass slide.**

A characteristic high pitched sound will indicate that you are cutting the glass slide.

6. **Allow the cutting to proceed for about 30 seconds, then switch off the power.**
7. **Carefully transfer the specimen table and magnetic base to the microscope.**
8. **Position the magnetic base against the locating pins on the microscope.**
9. **Viewing through the eyepiece, align the microscope cross hair to the circular depression.**

   Use the adjustment tool provided with the microscope (see Figure 1-3 on page 11) to make adjustments, following these steps:

   - Rotate the “Y” adjustment screw to shift the cross hair front to back relative to the circular depression.
   - Screw the “X” left adjustment screw *out* and the “X” right adjustment screw *in* to shift the cross hair to the right.
   - Screw the “X” left adjustment screw *in* and the “X” right adjustment screw *out* to shift the cross hair to the left.

User's Guide

2.1 Overview

The preparation of bulk transmission electron microscope (TEM) specimens generally involves five steps:

1. **Cleaving a 0.2–0.5 mm thick section from bulk material.**
2. **Mounting the section on a support plate (microscope slide) with a low melting-point wax and cutting 3-mm diameter discs, using the Tuned Piezo Cutting Tool.**
3. **Polishing the discs to a thickness of approximately 80 µm using a precision polishing machine.**
4. **Dimpling the discs.**
5. **Ion-milling or electro-polishing the discs to electron transparency.**

2.2 Setting Up

To set up the TPC Tool for cutting, you must first install a cutting tool and zero the dial indicator to gauge when the cutting tool has cut through the specimen to the glass slide reference surface.

2.2.1 Installing a Cutting Tool

> **CAUTION:** Use only the tightening tools specified, for mounting a cutting tool. Use of any other tools may damage the equipment.

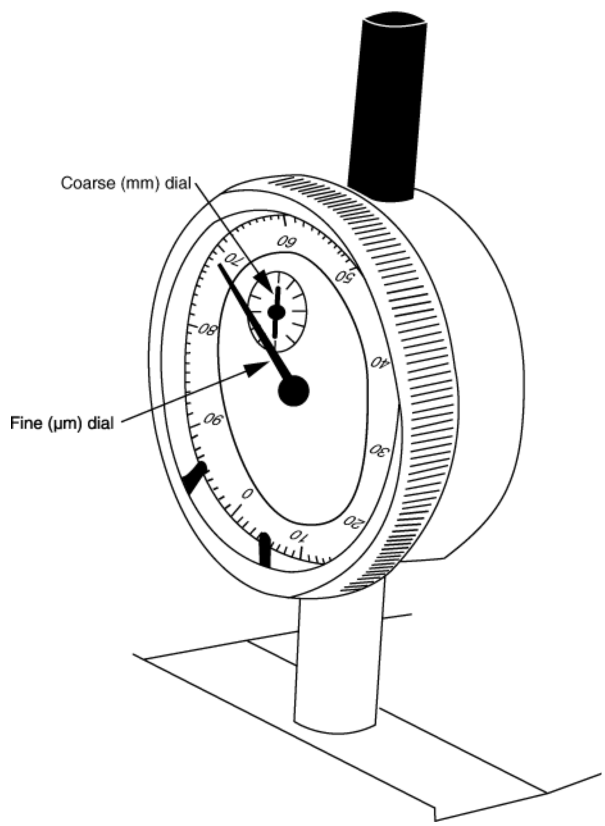
1. **Select the cutting tool you want to use. See "Appendix A Spares and Consumables" for a list of cutting tools available.**
2. **Place a copper washer on the threaded insert at the end of the head assembly.**
3. **Thread the cutting tool onto the insert so that the copper washer is centered and held in place.**

- For most standard size cutting tools, use the circular tightening wrench with the center hexagonal hole (included with the TPC Tool) to tighten the cutting tool.
- For larger cutting tools or those with non-standard shapes, insert a .050 inch (/ (1.27 mm) hex wrench through the hole in the upper part of the cutting tool to tighten.

2.2.2 Zeroing the Dial Indicator

It is important to know when you have cut through a specimen to the reference glass slide on which it rests. By setting the dial indicator on the TPC Tool to zero before doing any cutting, you will have an accurate reference point for knowing when you have reached the surface of the glass slide. Use the following procedure to set the dial indicator to zero, referring to Figure 2-1.

Figure 2-1 TPC Tool Dial Indicator



To zero the dial indicator

1. **Mount a section of a clean glass slide on the specimen table (see Section 2.3, "Working with Specimens," on page 20).**

   Do not add slurry to this slide.

2. **Position the specimen table on its magnetic base beneath the cutting tool, using the positioning pins to hold it in place on the hinged platform.**

3. **Gently lower the cutting tool onto the glass, using either the right or left large knob at the back of the tool.**

   Watch the dial indicator as you are lowering the cutting tool. The dial indicator shows the relative depression of the cutting tool onto its base. The larger dial indicates movement in microns. The smaller “coarse” dial indicates movement in millimeters.

4. **When the cutting tool makes contact with the glass, the dial indicator reading ceases to change, since the tool and the table are now moving together.**

5. **Continue lowering the cutting tool onto the glass slide until the horizontal indicator is aligned (see Figure 2-2 on page 22).**

6. **Rotate the outer ring of the dial indicator to move the markings on the dial. Align the zero mark with the dial needle (0 μm on the large dial).**

   Be sure to note also the reading on the smaller coarse dial to obtain a specific zero reading. Standard laboratory glass slides are 1 mm thick. When you zero the large dial indicator, the needle on the coarse dial should be at 1.

7. **Raise the cutting tool.**

8. **Remove the specimen table.**

   You are now ready to position a specimen beneath the tool. When you lower the tool onto the specimen, the dial indicator will display a reading for the thickness of the specimen, glass slide, and wax. You will be able to gauge your cutting depth by watching the dial indicator as it approaches zero, and by listening for the distinctive change in pitch.

2.2.3 Attaching a Hose and Syringe

It is important to keep the cutting slurry thin and liquid by adding water as needed. If you are working with thick specimens requiring a great deal of slurry, you may want to attach the flexible hose and syringe to drip water onto the slurry in a controlled way through the cutting head. (You can also use a laboratory eye dropper for this purpose.)

To attach a hose and syringe

1. **Fill the syringe with water.**
2. **Attach one end of the hose to the nozzle of the syringe.**
3. **Attach the other end of the hose to the intake pipe protruding from the front of the TPC Tool (see Figure 1-2 on page 10).**
4. **To discharge water onto the specimen, use the plunger to eject the water slowly from the syringe.**

2.3 Working with Specimens

The TPC Tool can cut samples from specimens of less than 1 mm up to approximately 5 mm in thickness. Following are procedures for mounting, positioning, and cutting both thin and thick specimens using the TPC Tool.

2.3.1 Mounting a Specimen

Specimens must be firmly mounted during ultrasonic cutting. Normally, a low melting-point, thermoplastic wax is used for this purpose. The mounting wax supplied by Gatan (part number 623.01100) is liquid at 130 °C.

NOTE: If the temperature of the wax is allowed to exceed 130 °C, the wax will begin to decompose. While this may not appear to affect its adhesive strength, the specimen may become detached during cutting.

It is recommended that you use a section of glass microscope slide as a base upon which the specimen is mounted on the specimen table. There are a couple of advantages to this:

- The glass prevents the specimen table surface from being damaged by the cutting tool.
- The glass can be used as a means of determining when the specimen has been cut through. There is a change in pitch of the cutting frequency when the tool begins cutting the glass. See Section 2.2.2, “Zeroing the Dial Indicator” for more information.

To mount a specimen

1. **Remove the slurry-retaining ring from the specimen table.**

   Using your thumbs, pop the specimen table loose from the retaining ring.

2. **Place the specimen table on the hot plate (130 °C).**

   CAUTION: Do not heat the specimen table on the hot plate while the slurry retaining ring is attached. The O-ring in the slurry retaining ring may be damaged.

3. **After 5 minutes, apply some wax to the specimen table.**

   Touch the end of a wax stick against the surface of the table, allowing the wax to melt and flow.

4. **Place the glass slide onto the pool of molten wax.**

   Gently press the glass slide onto the specimen table. Move the glass in small circles to ensure the wax is evenly and thinly distributed under the entire surface of the glass slide. Avoid getting wax on the upper surface of the glass.

5. **Apply a small amount of wax to the center of the top of the glass slide.**
6. **Place the specimen on the small pool of molten wax on the glass slide.**

Gently press the specimen down, moving it in small circles to ensure the wax is evenly and thinly distributed. Avoid getting wax on the upper surface of the specimen.

NOTE: Bulk specimens can be glued to the specimen table in the same way except that more wax may be required to form a secure bond.

7. **Remove the specimen table from the hot plate and allow it to cool.**
8. **Attach the slurry-retaining ring around the specimen table.**

   NOTE: The ring is omitted when mounting large specimens that overhang the edge of the specimen table.

9. **When the specimen table has completely cooled, place it on the center of the notched magnetic base.**

   Do not attach the specimen table to the magnetic base with wax.

2.3.2 Positioning a Specimen

For precise specimen positioning, use the stereo microscope and magnetic base assembly. The locating pins on the base of the TPC Tool are positioned so that the center of the cutting tool corresponds with an accuracy of ±0.2 mm to the center of the microscope field-of-view. The magnetic base prevents any specimen movement during cutting.

To position a specimen

1. **Place the specimen table and magnetic base assembly (prepared in Section 2.3, "Working with Specimens") on the microscope base.**

   Position the notches of the magnetic base assembly against the two locating pins on the microscope base (see Figure 1-3 on page 11).

2. **Position the specimen's area of interest.**

   Check that the magnetic base is pressed firmly against the microscope locating pins so that the magnetic base does not move and the microscope lamp is on.

   Position the specimen table on its magnetic base until the area of interest is centered under the microscope cross hair.

   The field-of-view corresponds to an approximate 4-mm diameter area on the specimen.

3. **Once the area of interest on the specimen is centered, do not move it.**
4. **Carefully transfer the entire magnetic base and specimen table to the platform of the cutter, without disturbing the position of the specimen.**
5. **Position the magnetic base assembly against the locating pins on the cutting tool platform.**

   The specimen table is now precisely centered for cutting.

2.3.3 Cutting Thin Specimens

NOTE: Specimens less than 1 mm thick are considered “thin.”

To cut thin specimens

1. **Position the specimen table on the magnetic base assembly and slide the assembly onto the base of the TPC Tool.**

   See Section 2.3.2, “Positioning a Specimen” for more information on determining a precise location to cut.

   Make sure the magnetic table is properly positioned against the two locating pins on the base of the cutting tool.

2. **Apply the cutting grit and make the slurry.**

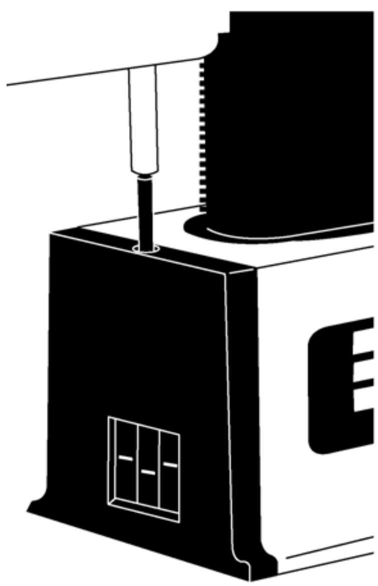
   Use a spatula to make a small conical pile of cutting grit over the specimen area. Add a few drops of water to make a slurry.

3. **Lower the cutting tool into the slurry until the hinged platform is properly deflected (the horizontal indicator is aligned).**

   You can gauge the proper deflection of the platform using the horizontal reference indicator, a set of small white lines located on the base of the cutter. When the cutting tool is correctly lowered and the hinged platform is applying the appropriate pressure, the center white line will be just below the level of the two white lines on either side of it. See Figure 2-2.

   If the dial indicator has previously been zeroed (see Section 2.2.2, “Zeroing the Dial Indicator”), it will display the thickness of the specimen plus wax.

Figure 2-2 Horizontal Reference Indicator



4. **Switch on the power and follow the progress of the cut on the dial indicator.**

   NOTE: The point at which the specimen has been successfully cut through can often be detected quite accurately by listening for the change in frequency which occurs when the tool breaks through the bottom surface of the specimen and begins cutting the wax and the glass slide.

5. **Monitor the depth of cut using the horizontal reference indicator.**

   The alignment of the horizontal reference indicator will change as cutting progresses and the spring-loaded platform continues to press the specimen table upward. The range of movement of the hinged platform is only ±1 mm. Thus, the cutting tool must be lowered periodically to maintain the platform at the appropriate level.

   Check the horizontal reference indicator frequently and continue to lower the cutting tool so that the horizontal reference indicator maintains a consistent position just below the white lines on either side of it.

6. **Adjust the cutting rate using the tuning knob.**

   Different sizes of cutting tools operate most effectively at different resonant frequencies. The “tuning” implied in the name Tuned Piezo Cutting Tool refers to this process of optimizing the cutting rate for different tools.

   When the cutting tool makes contact with the specimen to be cut, rotate the tuning knob (see Figure 1-2 on page 10) slowly through the range of numbers (1 through 7) around the knob.

   NOTE: These numbers are for relative positioning only. They do not correspond to absolute frequencies.

7. **Notice the change in sound made by the TPC Tool, and set the tuning knob to the most effective frequency.**

   Effective cutting frequencies will emit audible sounds and the rate of cutting will be high as shown by the speed of the needle movement on the dial indicator. Ineffective frequencies will have little or no sound and movement.

8. **Raise the cutting tool when the large dial indicator needle just passes through the zero mark.**

9. **Repeat the cutting process in a new location if needed.**

   Use the stereo microscope and positioning table if a precise area of interest is to be cut. See Section 2.3.2, “Positioning a Specimen” for more information. If random samples are to be cut, simply reposition the specimen table on the magnetic base.

10. **When all cuts have been made, switch off the power and remove the specimen table.**

11. **Wash off the slurry and remove the cut sample of the specimen.**

Sometimes cut samples will remain lodged in the cutting tool. See Section 2.3.5, “Removing Specimens” for further instructions.

2.3.4 Cutting Thick Specimens

NOTE: Specimens from 1 to 5 mm are considered “thick.”

When cutting thick specimens, use the syringe kit to properly dispense a consistent flow of slurry through the cutting tool. Once the cutting has begun, it is important to pump the syringe throughout the cutting cycle to gently flush the cutting slurry back and forth through the tool.

Note the position of the coarse needle on the dial indicator, when cutting thick specimens, since several rotations of the fine needle may occur before the specimen is cut through. See Figure 2-1 on page 18.

To cut thick specimens

1. **Position the specimen table on the magnetic base assembly and slide the assembly onto the base of the TPC Tool.**

   See Section 2.3.2, “Positioning a Specimen” for more information on determining a precise sample cut.

   Make sure the magnetic table is properly positioned against the two locating pins on the base of the cutting tool.

2. **Apply the cutting grit and make the slurry.**

   Use a spatula to make a large conical pile of cutting grit over the specimen area. Add enough water to make a slurry.

3. **Slowly suck enough slurry up into the syringe to have a reserve for the cutting cycle.**

   Depressing the syringe plunger expels slurry; releasing the plunger will suck slurry into the cutting tool. This pumping action forces the slurry in and around the edge of the cutting tool to assist the cutting action.

4. **Lower the cutting tool into the slurry until the hinged platform is properly deflected.**

   You can gauge the proper deflection of the platform from the horizontal reference indicator, a set of small white lines located on the base of the cutter. When the cutting tool is correctly lowered and the hinged platform is applying the appropriate pressure, the center white line will be just below the level of the two white lines on either side of it. If the dial indicator has previously been zeroed (see Section 2.2.2, “Zeroing the Dial Indicator”), its reading will display the thickness of the specimen plus wax.

5. **Switch on the power and follow the progress of the cut on the dial indicator.**

   Gently flush the slurry back and forth through the tool during cutting.

   NOTE: The point at which the specimen has been successfully cut through can often be detected quite accurately by listening for the change in frequency which occurs when the tool breaks through the bottom surface of the specimen and begins cutting the wax and the glass slide.

6. **Monitor the depth of cut using the horizontal reference indicator.**

   The alignment of the horizontal reference indicator will change as cutting progresses and the spring-loaded platform continues to press the specimen table upward. The range of movement of the hinged platform is only ±1 mm. Thus, the cutting tool must be lowered periodically to maintain the platform at the appropriate level.

   Check the horizontal reference indicator frequently and continue to lower the cutting tool so that the horizontal reference indicator maintains a consistent position just below the white lines on either side of it. See Figure 2-2 on page 22.

7. **Adjust the cutting rate using the tuning knob.**

   Different sizes of cutting tools operate most effectively at different resonant frequencies. The “tuning” implied in the name Tuned Piezo Cutting Tool refers to this process of optimizing the cutting rate for different tools.

   When the cutting tool makes contact with the specimen to be cut, rotate the tuning knob (see Figure 1-2 on page 10) slowly through the range of numbers (1 through 7) around the knob.

   NOTE: These numbers are for relative positioning only. They do not correspond to absolute frequencies.

8. **Raise the cutting tool when both the coarse and fine dial indicator needles pass through the zero mark, or the tool has reached the glass slide.**

9. **Repeat the cutting process in a new location if needed.**

   Use the stereo microscope and positioning table if a precise area of interest is to be cut. See Section 2.3.2, “Positioning a Specimen” for more information. If random samples are to be cut, simply reposition the specimen table on the magnetic base.

10. **When all cuts have been made from this specimen, switch off the power and remove the specimen table.**

11. **Wash off the slurry and remove the cut sample of the specimen.**

    Sometimes cut samples will remain lodged in the cutting tool. See Section 2.3.5, “Removing Specimens” for further instructions.

2.3.5 Removing Specimens

Once a sample has been cut, it can be removed from the specimen table.

To remove a specimen

1. **Be sure the power is off.**
2. **Remove the specimen table from the magnetic base assembly.**
3. **Remove the slurry-retaining ring around the specimen table.**

4. **Place the specimen table on the hot plate (130°C) to melt the wax.**

> **CAUTION:** Do not heat the specimen table on the hot plate while the slurry retaining ring is attached. The O-ring in the slurry retaining ring may be damaged.

5. **Slide the specimen cut to the edge of the glass slide and carefully pick it up with tweezers.**
6. **Wash the cut samples in acetone to remove the wax.**
7. **Remove the specimen table from the hot plate and let it cool.**
8. **If necessary, remove the glass slide from the specimen table.**
9. **Use a *new* glass slide for the next cut, if necessary.**

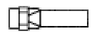
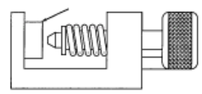
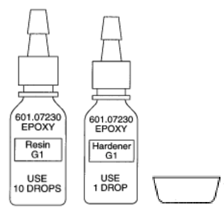
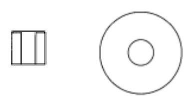
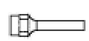
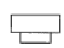
NOTE: Cut specimens, especially long cylindrical ones, may become trapped in the cutting tool. Usually they can be removed by flushing water through the tool while the power is still on. If this procedure is unsuccessful, remove the cutting tool with the special wrench supplied and push out the cut sample with a toothpick.

2.4 Preparing Cross-Sectional TEM Specimens

Cross-sectional TEM specimens are used extensively to study the microstructure of multi-layered materials. The TPC Tool and a special Cross-Section Kit (part number 601.07) developed by Gatan can greatly facilitate the preparation of these cross-sectional TEM specimens. The cross-sections prepared using this technique are suitable for low-angle ion milling, which is generally required for the production of high-quality specimens.

2.4.1 Cross-Section Kit Components

Table 2-1 Cross-Section Kit Components

PART NO.	DESCRIPTION	ILLUSTRATION	WHERE USED
601.07010	Rectangular Cutter 4 x 5 mm		“Cutting Rectangular Dummy Wafers” and “Cutting Precise Rectangular Wafers”
601.07020 601.07100	Teflon Jaw (removable) Specimen Clamping Vise		“Coating and Stacking Wafers”, “Coating and Stacking Precision Cut Wafers”, and “Pressure Bonding the Specimen Stack”
601.07130 601.07230	Epoxy Mixing Cup 1 bottle Epoxy Resin G1, 1 bottle Epoxy Hardener G1 (mix 10:1 by weight)		“Coating and Stacking Wafers”, “Coating and Stacking Precision Cut Wafers”, “Preparing Epoxy Mixture Discs (Powders or Fibers)”, and “Preparing Epoxy Cross-Sectional Discs (Powders)”
601.07080 656.01400	Slotted Specimen Mount Centering Ring (located under insert)		“Cutting a Cylindrical Specimen Stack”
623.01100	Wax Rods (set of 12, in canister)		“Cutting a Cylindrical Specimen Stack”
601.03033	2.3 mm Cutting Tool		“Cutting a Cylindrical Specimen Stack”
601.07140	Teflon Mold		“Reinforcing the Cylindrical Specimen Stack”
601.07110	Brass Tubes (set of 10, in canister)		“Reinforcing the Cylindrical Specimen Stack”, and “Slicing and Polishing Specimen Discs”

2.4.2 Preparing Cross-Sectional Specimens

The basic procedure for preparing cross-sectional TEM specimens includes the following steps.

1. **Cut rectangular dummy wafers from bulk material.**
2. **Coat dummy wafers with epoxy and stack in Teflon mold.**
3. **Cure the glued stack on a hot plate at 130 °C.**
4. **Cut a cylinder from the stack using the Tuned Piezo Cutting Tool.**
5. **Glue the cylinder inside a metal tube.**
6. **Slice through the metal tube to cut specimen discs.**

Each step is illustrated and described in more detail in the following sections.

2.4.2.1 Cutting Rectangular Dummy Wafers

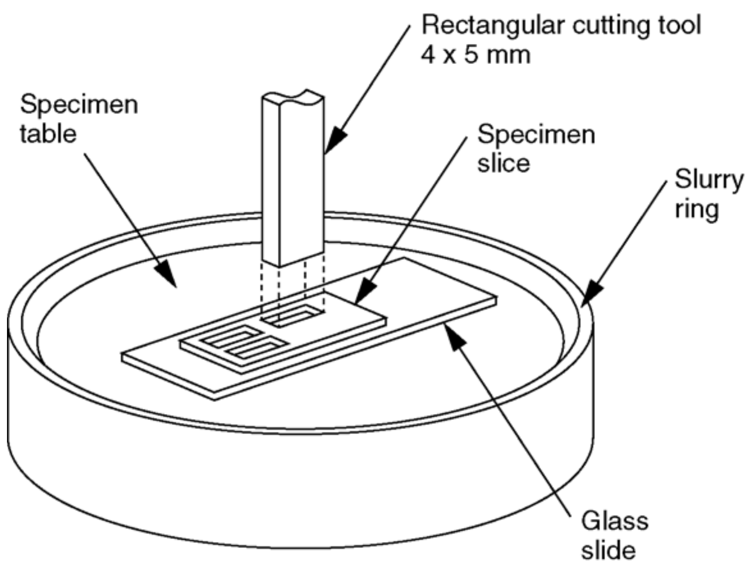
To cut rectangular wafers

Use the procedures in the following sections to prepare and cut a number of rectangular specimen slices from bulk material using the Tuned Piezo Cutting Tool.

- Section 2.3, “Working with Specimens,” on page 20
- Section 2.3.2, “Positioning a Specimen,” on page 21
- Section 2.3.3, “Cutting Thin Specimens,” on page 22

NOTE: Use the 4 x 5-mm rectangular cutting tool to cut the dummy wafers (see Figure 2-3).

Figure 2-3 Preparing Cross-Sectional Specimens, Step 1



2.4.2.2 Coating and Stacking Wafers

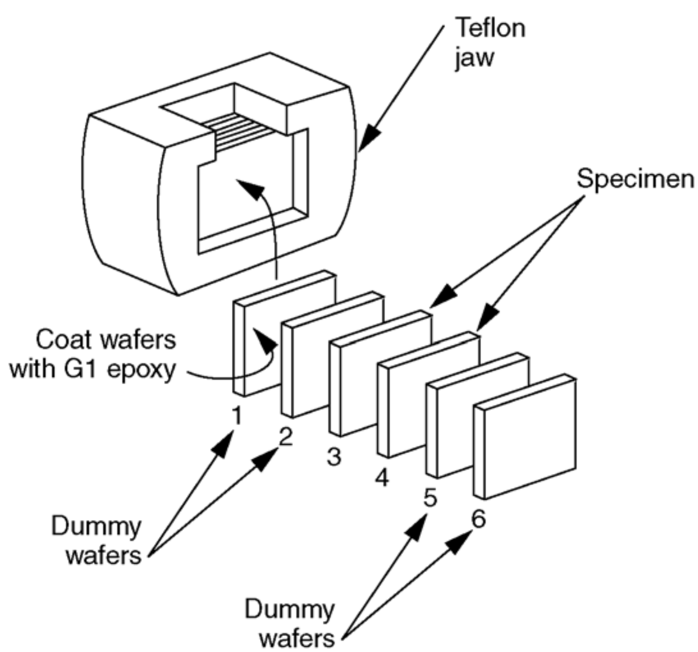
To create a cross-sectional wafer stack

1. **Create an epoxy mixture in the Epoxy Mixing Cup using a 10:1 ratio of epoxy resin to epoxy hardener, by weight.**
2. **Coat two specimen wafers with a thin layer of the G1 Epoxy, as shown in Figure 2-4. Stack them face-to-face.**
3. **Coat four pure silicon dummy wafers with the epoxy and stack at either end of the two specimen wafers.**

NOTE: One advantage of using silicon for the dummy wafers is that their transparency colors and interference fringes can be used to accurately gauge the specimen thickness at the 2-5 μm level during dimpling.

4. **Stack the coated wafers in the Teflon jaw, in the order shown in Figure 2-4.**

Figure 2-4 Preparing Cross-Sectional Specimens, Step 2

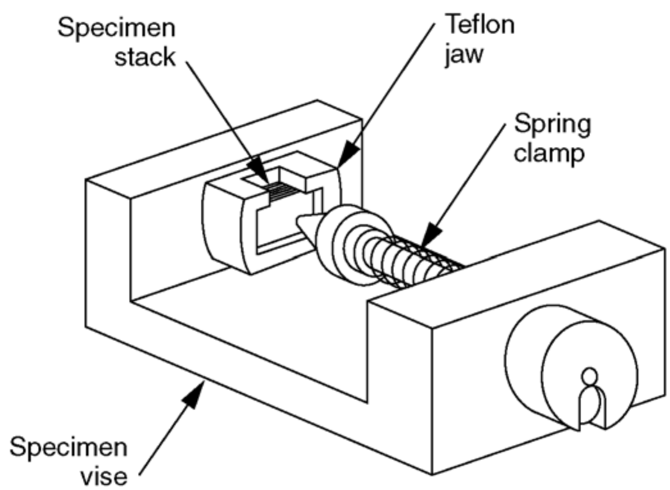


2.4.2.3 Pressure Bonding the Specimen Stack

To pressure bond the cross-sectional stack

1. **Insert the Teflon jaw in the spring-loaded vise.**
2. **Apply pressure using the spring-loaded vise to bond the specimen stack together in the Teflon jaw.**
3. **Place the entire vise on a hot plate and cure the stack under pressure for 10 min at 130 °C to obtain a strong bond with minimum glue thickness.**
4. **Remove the assembly when the curing process is complete, and allow it to cool to room temperature.**

Figure 2-5 Preparing Cross-Sectional Specimens, Step 3

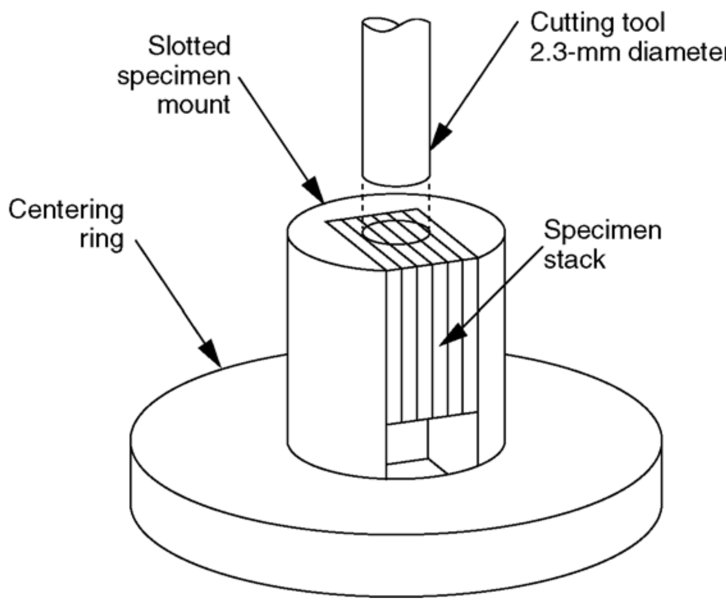


2.4.2.4 Cutting a Cylindrical Specimen Stack

To cut a cylindrical stack

1. **Remove the specimen stack from the Teflon jaw.**
2. **Using mounting wax, glue the cured specimen stack in the slotted specimen mount.**
3. **Place the slotted specimen mount in a centering ring.**
4. **Place the centering ring containing the specimen stack onto the magnetic base plate and slide into position on the TPC Tool.**
5. **Use a 2.3-mm diameter cutting tool to cut a cylinder from the middle of the stack (see Figure 2-6).**

Figure 2-6 Preparing Cross-Sectional Specimens, Step 4



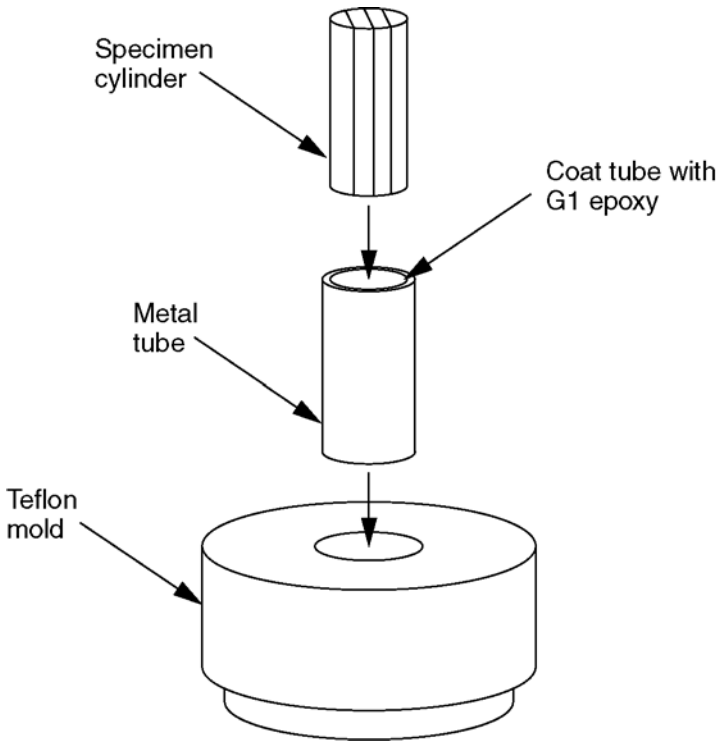
2.4.2.5 Reinforcing the Cylindrical Specimen Stack

The 2.3-mm cut cylinder is rather fragile and needs to be reinforced so it will not separate during grinding, dimpling, and ion milling.

To reinforce the cross-sectional cylinder

1. **Using G1 Epoxy, coat the inside of a 3-mm diameter metal reinforcing tube.**
2. **Insert the cut specimen cylinder into the metal tube.**
3. **Insert the tube and specimen into the circular Teflon mold.**
4. **Cure this assembly on a hot plate for 10 min at 130 °C.**
5. **When the curing process is complete, remove the assembly and allow it to cool to room temperature.**

Figure 2-7 Preparing Cross-Sectional Specimens, Step 5

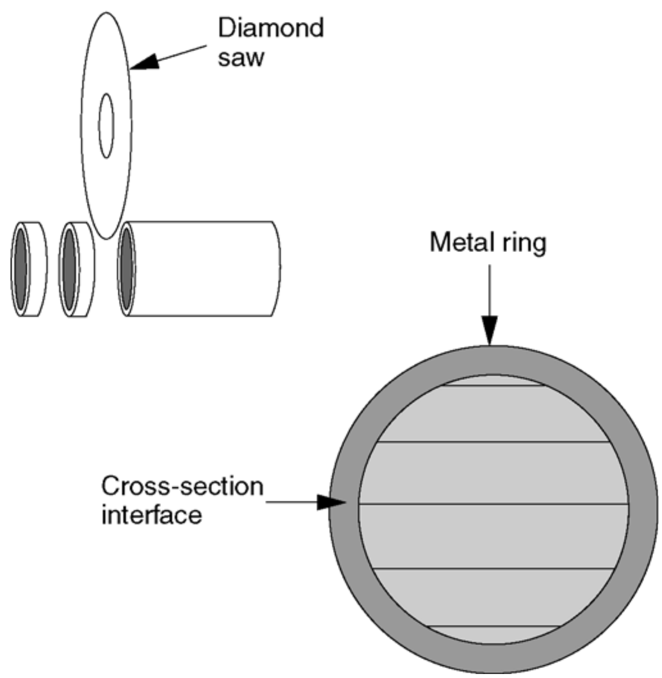


2.4.2.6 Slicing and Polishing Specimen Discs

To slice and polish cross-sectional specimen discs

1. **Slice the metal reinforcing tube containing the specimen cylinder into a series of 250-400 µm thick discs, using a thin blade diamond saw (see Figure 2-8).**
2. **Using the Gatan Precision Disc Grinder, grind each disc flat on both sides, to a thickness of approximately 80 µm.**
3. **Use felt polishing wheels on the dimple grinder to dimple one side of the sliced specimen disc.**

Figure 2-8 Preparing Cross-Sectional Specimens, Step 6



2.4.3 Preparing Metals and Hard Material Cross-Sections

When working with metals and hard materials, perform the steps in the following sections:

- Section 2.4.2.1, “Cutting Rectangular Dummy Wafers,” on page 28

NOTE: Instead of two specimens mounted face to face in the center of the wafer stack, use only one specimen of the metal or hard material desired. Use silicone dummy wafers for the other 5 layers.

- Section 2.4.2.2, “Coating and Stacking Wafers,” on page 29
- Section 2.4.2.3, “Pressure Bonding the Specimen Stack,” on page 30

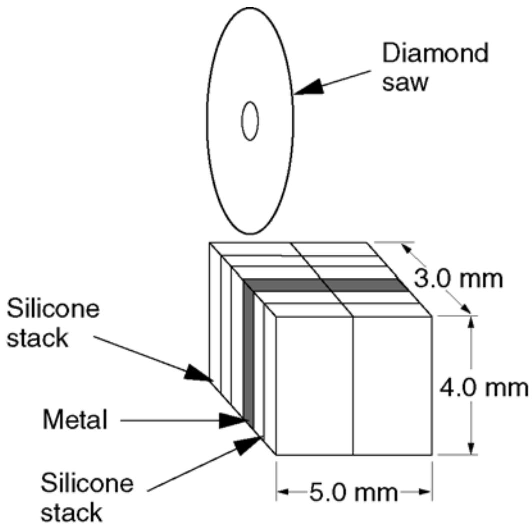
Then use a diamond saw to cut the wafer stack in half, and cut a cylinder from a half stack, as shown in Figure 2-9.

2.4.3.1 Cutting Hard Material Specimen Stacks

To cut hard material specimen stacks

1. **Remove the specimen stack from the Teflon jaw.**
2. **Use a diamond saw to cut the stack in half, creating two stacks, each less than 2.3 mm wide.**

Figure 2-9 Cutting Stacks of Hard Materials



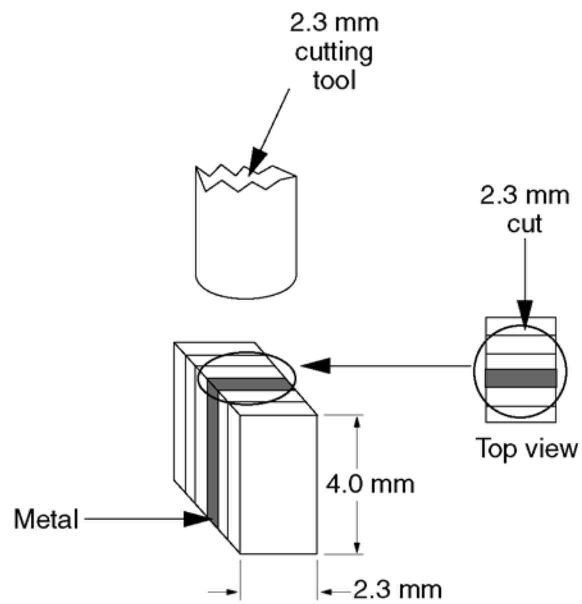
2.4.3.2 Cutting Cylinders from Hard Material Stacks

To cut hard material specimen cylinders

Use a 2.3-mm diameter cutting tool to cut a cylinder from each stack, as shown in Figure 2-10.

NOTE: There is no need for the slotted specimen mount when working with metals or hard materials.

Figure 2-10 Cutting Cylinders from Hard Material Stacks



2.4.3.3 Completing Hard Material Specimen Preparation

Complete the preparation of metals and hard material specimens by performing the steps in the following sections:

- Section 2.4.2.5, “Reinforcing the Cylindrical Specimen Stack,” on page 32
- Section 2.4.2.6, “Slicing and Polishing Specimen Discs,” on page 33

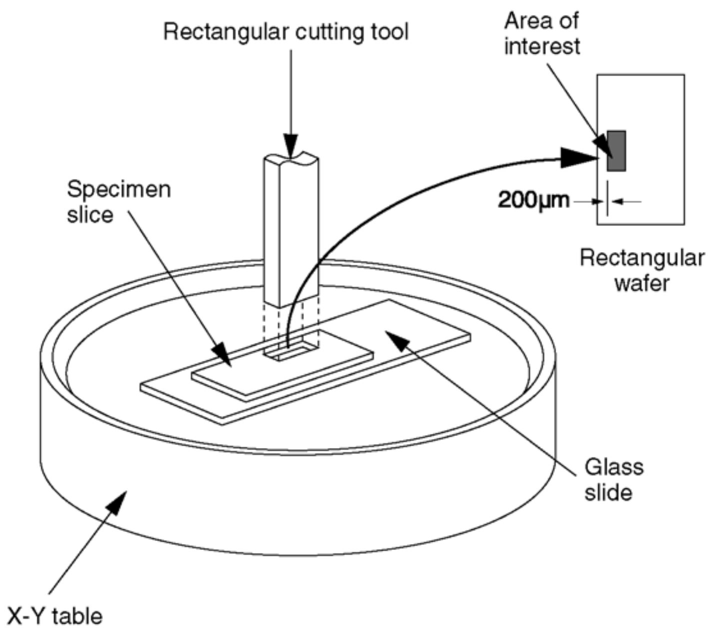
2.4.4 Preparing Precise Cross-Sections

2.4.4.1 Cutting Precise Rectangular Wafers

To cut a wafer with a precise area of interest

To prepare a cross-sectional specimen containing an area of specific interest, cut a rectangular wafer using the 4 x 5 mm rectangular cutting tool, such that the area of interest is less than 200 µm from a long edge of the wafer, as shown in Figure 2-11.

Figure 2-11 Preparing Precise Cross-Sectional Specimens, Step 1



2.4.4.2 Coating and Stacking Precision Cut Wafers

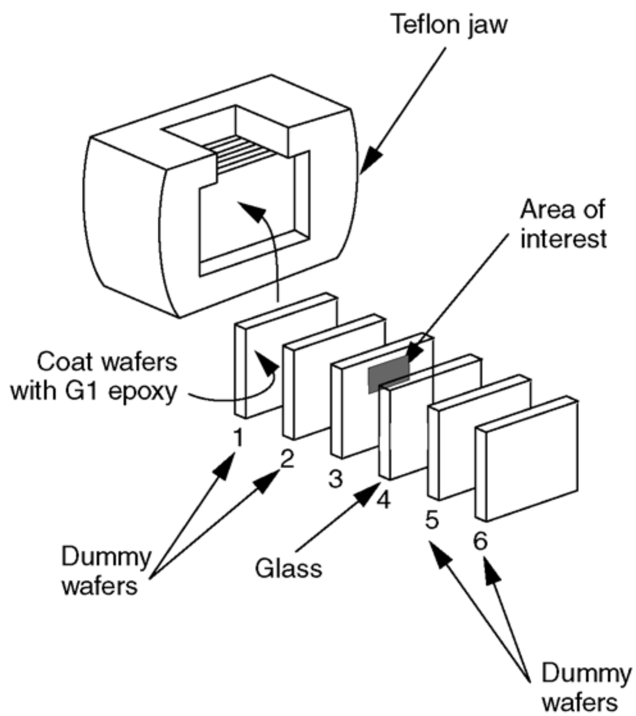
To create a cross-sectional stack

1. **Create an epoxy mixture in the Epoxy Mixing Cup using a 10:1 ratio of epoxy resin to epoxy hardener, by weight.**
2. **Coat the specimen wafer with a thin layer of the G1 Epoxy.**
3. **Coat a glass wafer with epoxy and stack it facing the wafer containing the area of interest.**
4. **Stack the precision cut wafer and the glass wafer in the middle of a stack of epoxy-coated dummy wafers, as shown in Figure 2-12.**

NOTE: One advantage of using silicon for the dummy wafers is that their transparency colors and interference fringes can be used to accurately gauge the specimen thickness at the 2-5 µm level during dimpling.

5. **Stack the coated wafers in the Teflon jaw, as shown in Figure 2-12.**

Figure 2-12   Preparing Precise Cross-Sectional Specimens, Step 2



2.4.4.3 Completing the Preparation of Precision Cut Specimens

Complete the preparation of precision cut specimens by performing the steps in the following sections:

- Section 2.4.2.3, "Pressure Bonding the Specimen Stack," on page 30
- Section 2.4.2.4, "Cutting a Cylindrical Specimen Stack," on page 31
- Section 2.4.2.5, "Reinforcing the Cylindrical Specimen Stack," on page 32
- Section 2.4.2.6, "Slicing and Polishing Specimen Discs," on page 33

2.4.5 Preparing Powders and Fibers

There are two methods that can be used to prepare specimens of powders or fibers using the Tuned Piezo Cutting Tool.

2.4.5.1 Preparing Epoxy Mixture Discs (Powders or Fibers)

To prepare epoxy mixtures for powders or fibers

1. **Create an epoxy mixture in the Epoxy Mixing Cup using a 10:1 ratio of epoxy resin to epoxy hardener, by weight.**
2. **Mix the powder or fibers into the epoxy mixture.**
3. **Transfer the mixture into a brass tube.**

Fibers should run the length of the tube.

4. **Cure the epoxy mixture in the brass tube on a hot plate at 130 °C for 10 minutes.**
5. **When the curing process is finished, remove the brass tube and allow it to cool.**
6. **Cut the brass tube into thin discs, using a diamond saw.**
7. **Disc grind, dimple grind, and ion mill each disc to perforation.**

2.4.5.2 Preparing Epoxy Cross-Sectional Discs (Powders)

To prepare epoxy cross-sectional specimens for powders

1. **Create an epoxy mixture in the Epoxy Mixing Cup using a 10:1 ratio of epoxy resin to epoxy hardener, by weight.**
2. **Mix the powder into the epoxy mixture.**
3. **Coat the inner surfaces of 6 stacked silicon dummy wafers with G1 epoxy.**
4. **Apply the G1 epoxy and powder mixture between wafers 3 and 4 in the stack.**
5. **Complete the preparation of the cross-sectional powder specimen using the steps in the following sections:**
   - Section 2.4.2.3, “Pressure Bonding the Specimen Stack,” on page 30
   - Section 2.4.2.4, “Cutting a Cylindrical Specimen Stack,” on page 31
   - Section 2.4.2.5, “Reinforcing the Cylindrical Specimen Stack,” on page 32
   - Section 2.4.2.6, “Slicing and Polishing Specimen Discs,” on page 33

Appendix A
Spares and Consumables

Table A-1 Spare Parts

PART NUMBER	DESCRIPTION
03368	Microscope illuminator bulb
06445	Viton O-ring for slurry-retaining ring
601.01100	Slurry-retaining ring (includes O-ring)
601.03590	Copper washers (set of 5)
601.05070	Specimen table (X-Y positioning)
601.05082	Magnetic base (X-Y table)
601.06200	Syringe kit
601.06300	Cutting tool wrench

Table A-2 Consumables

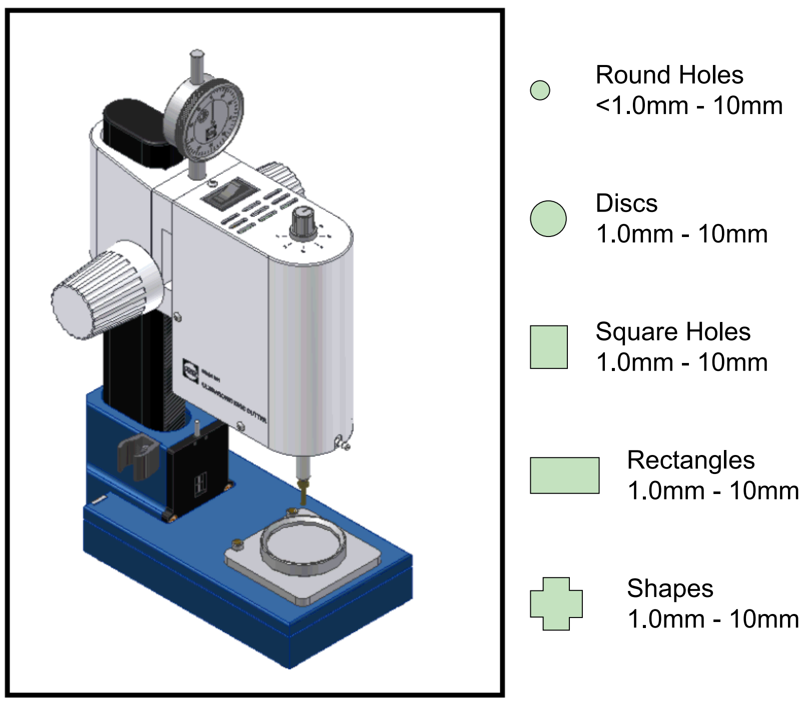
PART NUMBER	DESCRIPTION
601.00700	Container of 320 cutting grit (0.5 kg)
601.00710	Container of 600 cutting grit (0.5 kg)
601.00720	Container of 800 cutting grit (0.5 kg)
601.07110	Brass tubes (set of 10)
601.07230	G-1 epoxy with hardener (20 grams resin, 2 grams hardener)
601.07270	G-2 epoxy with hardener (20 grams resin, 2 grams hardener)
601.07580	Slotted specimen mount (set of 4)
623.01100	Mounting wax (12 rods, 3.5 mm x 32 mm)

Table A-3 Cutting Tools

Part Number	Description
601.03034	Circular cutting tool 0.25 mm hole diameter
601.03200	Circular cutting tool 0.4 mm hole diameter
601.03035	Circular cutting tool 0.5 mm hole diameter
601.03201	Circular cutting tool 0.6 mm hole diameter or 0.3 mm diameter disc
601.03210	Circular cutting tool 0.8 mm hole diameter or 0.5 mm diameter disc
601.03038	Circular cutting tool 1.0 mm hole diameter
601.03039	Circular cutting tool 1.1 mm hole diameter
601.03212	Circular cutting tool 1.3 mm hole diameter
601.03336	Circular cutting tool 1.8 mm hole diameter
601.03036	Circular cutting tool 2.0 mm hole diameter
601.03037	Circular cutting tool 4.0 mm hole diameter
601.03211	Circular cutting tool 8.0 mm hole diameter
601.03331	Circular cutting tool 1.5 mm disc diameter
601.03334	Circular cutting tool 1.8 mm disc diameter
601.03335	Circular cutting tool 2.0 mm disc diameter
601.03209	Circular cutting tool 2.5 mm disc diameter
601.03031	Circular cutting tool 3.0 mm disc diameter
601.03032	Circular cutting tool 2.7 mm disc diameter
601.03033	Circular cutting tool 2.3 mm disc diameter
601.03339	Circular cutting tool 7.0 mm disc diameter
601.03340	Circular cutting tool 10.0 mm disc diameter
601.03168	Rectangular cutting tool 0.8 mm x 4.5 mm
601.03151	Rectangular cutting tool 1.0 mm x 2.0 mm
601.03301	Rectangular cutting tool 1.0 mm x 3.0 mm
601.03152	Rectangular cutting tool 1.0 mm x 4.0 mm
601.03153	Rectangular cutting tool 1.4 mm x 2.16 mm
601.03302	Rectangular cutting tool 1.5 mm x 4 mm
601.07150	Rectangular cutting tool 2.0 mm x 3.0 mm
601.03154	Rectangular cutting tool 2.0 mm x 15 mm
601.03161	Rectangular cutting tool 2.1 mm x 8.0 mm
601.07180	Rectangular cutting tool 2.5 mm x 3 mm

Part Number	Description
601.03155	Rectangular cutting tool 2.8 mm x 7.6 mm
601.03156	Rectangular cutting tool 3.5 mm x 6.5 mm
601.03157	Rectangular cutting tool 4.0 mm x 8.0 mm
601.03158	Square cutting tool 5.0 mm
601.03159	Square cutting tool 10.0 mm

Figure A-1 Cutting Tool Head Shapes



Appendix B
Gatan G-1 and G-2 Epoxies

B.1 Features of G-1 and G-2 Epoxies

B.1.1 Uses

Gatan G-1 and G-2 epoxies are ideal for preparing SEM cross-sections and TEM specimens in general, including powders and fibers. They are particularly useful for bonding wafers prior to cross-sectioning, and as an embedding medium to support powders, fibers, flakes, thin wires, and other small objects.

B.1.2 Properties

Gatan G-1 and G-2 epoxies are two-component, 100% solid, heat curing epoxies designed for elevated temperature applications. When fully cured, they are strong and resistant to most solvents and chemicals used for cleaning operations, including acetone. Adhesion to metals, glasses, ceramics, and most plastics is exceptional. They have excellent wicking characteristics and can achieve both thin (< 1 µm) and thick bonds.

Because of their high temperature stability, they can be used in TEM hot stages for “in situ” studies. A color change indicates when curing is complete. These epoxies have a shelf life of about one year, at room temperature.

Optimum performance is obtained only by accurate weight measurement, at a ratio of 10:1 (Resin:Hardener).

B.1.2.1 Properties of G-1 Epoxy

- Operates continuously at 300 °C, endures 400 °C for several hours
- Exhibits a glass transition temperature of 100 °C with a degradation temperature at 500 °C
- Exhibits a color change from amber to dark red or brown upon cure
- Gatan studies show G-1 bound interfaces can be studied in a TEM hot stage at temperatures in excess of 1000 °C.

B.1.2.2 Properties of G-2 Epoxy

- Contains **no** hazardous ingredients (no carcinogens, solvents or thinners)
- Operates continuously at 200 °C, endures 300 °C for several hours
- Exhibits a glass transition temperature of 130 °C with a degradation temperature at 400 °C.
- Exhibits a color change from straw to amber or slight reddish upon cure.

B.2 Curing Characteristics

Figure B-1 Curing Time and Temperature

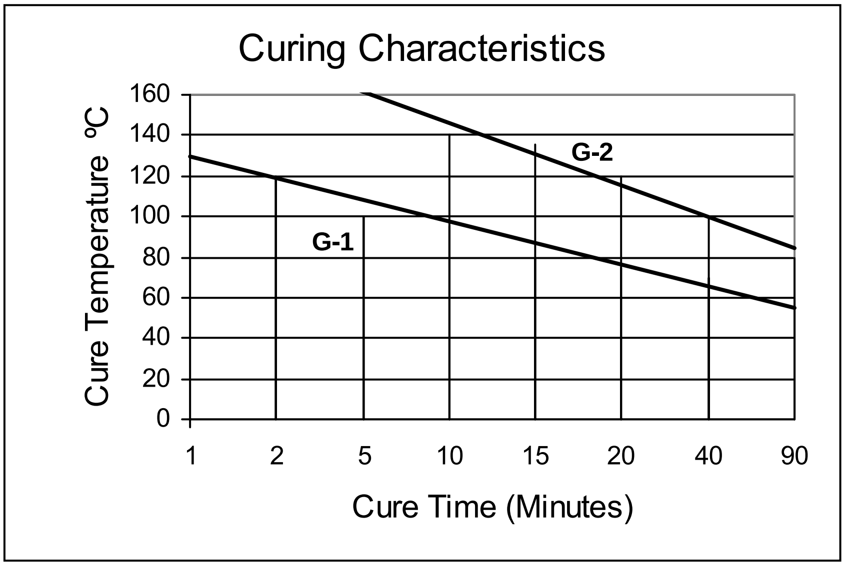


Table B-1 G-1 and G-2 Cure Schedule

TEMPERATURE	G-1 CURE TIME	G-2 CURE TIME
130 °C	90 seconds	15 minutes
120 °C	2 minutes	20 minutes
100 °C	5 minutes	40 minutes
80 °C	15 minutes	90 minutes
60 °C	90 minutes	--

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Gatan Product Warranty

Gatan warrants that products manufactured by Gatan shall be free of defects in materials and workmanship for the warranty period, which commences at date of shipment. Gatan tests the performance of a unit as part of its final test procedure, prior to shipment from its factory. Gatan warrants that the unit meets Gatan's published specifications at time of shipment from its factory. All product warranties provide, for a period of one year after shipment to customer, parts (excluding all normal consumable, wear, and maintenance items) and labor. For Specimen Preparation Equipment and Specimen Holders, Gatan will correct any defects in the instrument either by repair in our facility or replacing the defective part, with the shipping party responsible for shipping costs. For products which attach to the column (Cameras, DigiScan, GIF, and PEELS), travel of up to 100 miles from a Gatan authorized repair center (Pleasanton, CA; Warrendale, PA; Munich, GmbH; and Corby, UK) is included. Travel expenses for service beyond 100 miles will be charged for.

Instruments, parts, and accessories not manufactured by Gatan will be warranted by Gatan for the specific items and periods in accordance with and provided by the warranty received by Gatan from the Original Equipment Manufacturer. All such accessory warranties extended by Gatan are limited in accordance with all the terms, conditions, and other provisions stated in this Original Equipment Manufacturer warranty. Gatan makes no warranty whatsoever concerning products or accessories not of its manufacture, except as noted above.

Customer Responsibilities

The customer bears the following responsibilities with regard to maintaining the warranty. The customer shall:

1. Perform the routine maintenance and cleaning procedures at the required intervals as specified in Gatan's operating manuals. Failure to perform specified maintenance will automatically void warranty.
2. Use Gatan replacement parts. Failure to use the specified replacement parts will automatically void warranty.
3. Use Gatan or Gatan-approved consumables.
4. Provide Gatan authorized service representatives access to the products during normal Gatan working hours during the coverage periods to perform service.
5. Provide adequate and safe working space around the products for servicing by Gatan authorized service representatives.
6. Provide access to, and use of, all information and facilities determined necessary by Gatan to service and/or maintain the products. (Insofar as these items may contain proprietary or classified information, the customer shall assume full responsibility for safe-guarding and protecting them from wrongful use.

Repairs and Replacements

Gatan will, at its option, either repair or replace defective instruments or components with conforming goods. Repair or replacement of products or parts under warranty does not extend the original warranty period. With the exception of consumable and maintenance items, the replacement parts or products used on instruments out of warranty are themselves warranted to be free of defects in materials and workmanship for 90 days.

Any products, part, or assembly returned to Gatan for examination or repair shall have Gatan's prior approval, with the customer requesting a Returned Goods Authorization (RGA) approval. This RGA and the associated RGA number may be obtained through Gatan Service or directly from Gatan's Warrendale facility at 724-776-5260. If the item is not under warranty, to obtain an RGA, the customer must provide a Purchase Order (PO) for the repair. If the item is under warranty and the customer is requesting an expedited exchange, as may be the case for a printed circuit board, a PO will be required. A credit against this PO will be issued by Gatan upon receipt of the item as returned in accordance with the RGA instructions. The returned item should be shipped prepaid by the customer with the RGA number clearly marked on the exterior of the shipping container and on the enclosed shipping documents. If the returned item is under warranty, return transportation will be prepaid by Gatan. If the returned item is not under warranty, return transportation will be charged to the customer.

Warranty Limitations

The warranty does not cover:

1. Parts and accessories which are expendable or consumable in the normal operation of the instrument.
2. Any loss, damage, and/or instrument malfunction resulting from shipping or storage, accident (fire, flood, or similar catastrophes normally covered by insurance), abuse, alteration, misuse, neglect, or breakage or abuse of parts by User.
3. Operation other than in accordance with correct operational procedures and environmental and electrical specifications.
4. Performance to specifications or safety of use (including X-ray emissions) if the unit is physically installed on, used in conjunction with, or used as part of a third party's equipment and is not installed by a Gatan service engineer.
5. Performance to specifications or safety of use (including X-ray emissions) as a result of the use of Gatan's equipment with that of a third party due to the third party's product design.
6. Modification of, or tampering with, the system.
7. Improper or inadequate care, maintenance, adjustment, or calibration by User.
8. User-induced contamination or leaks.
9. Any loss, damage, and/or instruments malfunction resulting from use of User-supplied software, hardware, interfaces, or consumables other than those specified by Gatan.

Warranty Exclusions

In the course of normal use and maintenance, certain parts have finite lifetimes. For this reason, the consumables, wear, and maintenance parts as specified in Gatan's operating manuals carry a 90-day warranty unless otherwise specified.

Post Warranty Period Support and Product Obsolescence

After the expiration of the warranty period described above, Gatan will provide service support for Gatan manufactured products at Gatan's service labor rates and parts pricing in effect at the time of the repair. Gatan will continue to provide billable service support for the products for a period of three years after discontinuance or design obsolescence by Gatan. After this three year period, service support will be offered at the sole discretion of Gatan.

Liability Limitations

This warranty is in lieu of and excludes all other expressed or implied warranties, including (but not limited to) warranties of merchantability of fitness for a particular purpose. Under no circumstances will Gatan Inc. or Gatan International be liable for any direct, indirect, special, incidental or consequential damages (including lost profit) or loss of any kind, whether based on warranty, contract, tort, or any other legal theory. The limits of Gatan liability in any dispute shall be the price received from the purchaser for the specific equipment at issue. The laws of the state of Pennsylvania apply to all aspects of this warranty.