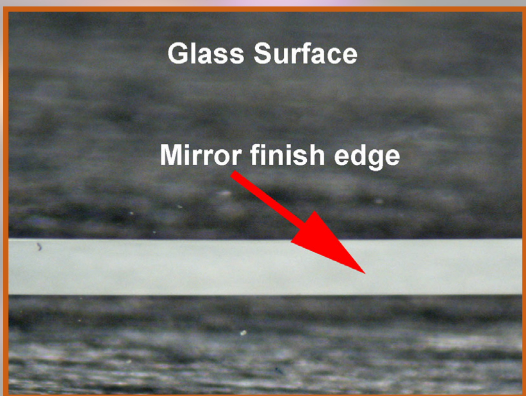
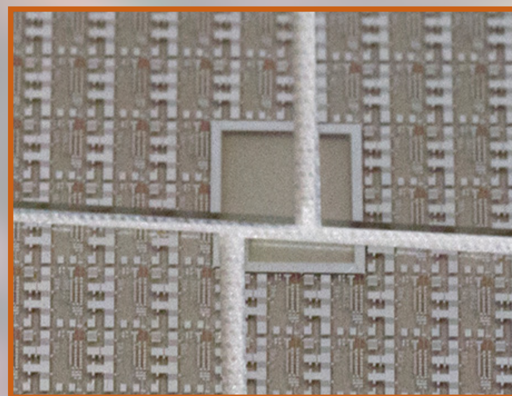
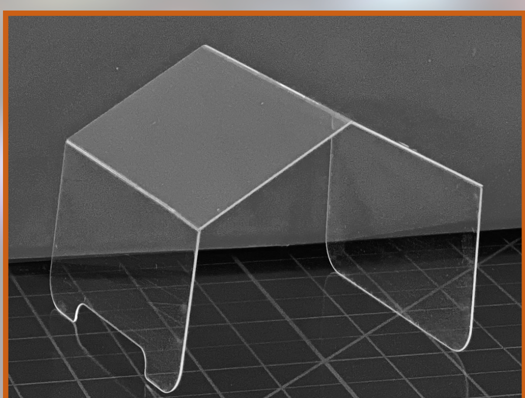
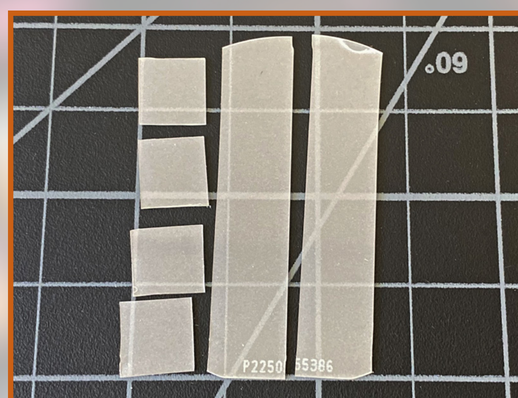
Cleaving Substrates for Photonics Technologies

New Downsizing Methods for Glass and Sapphire



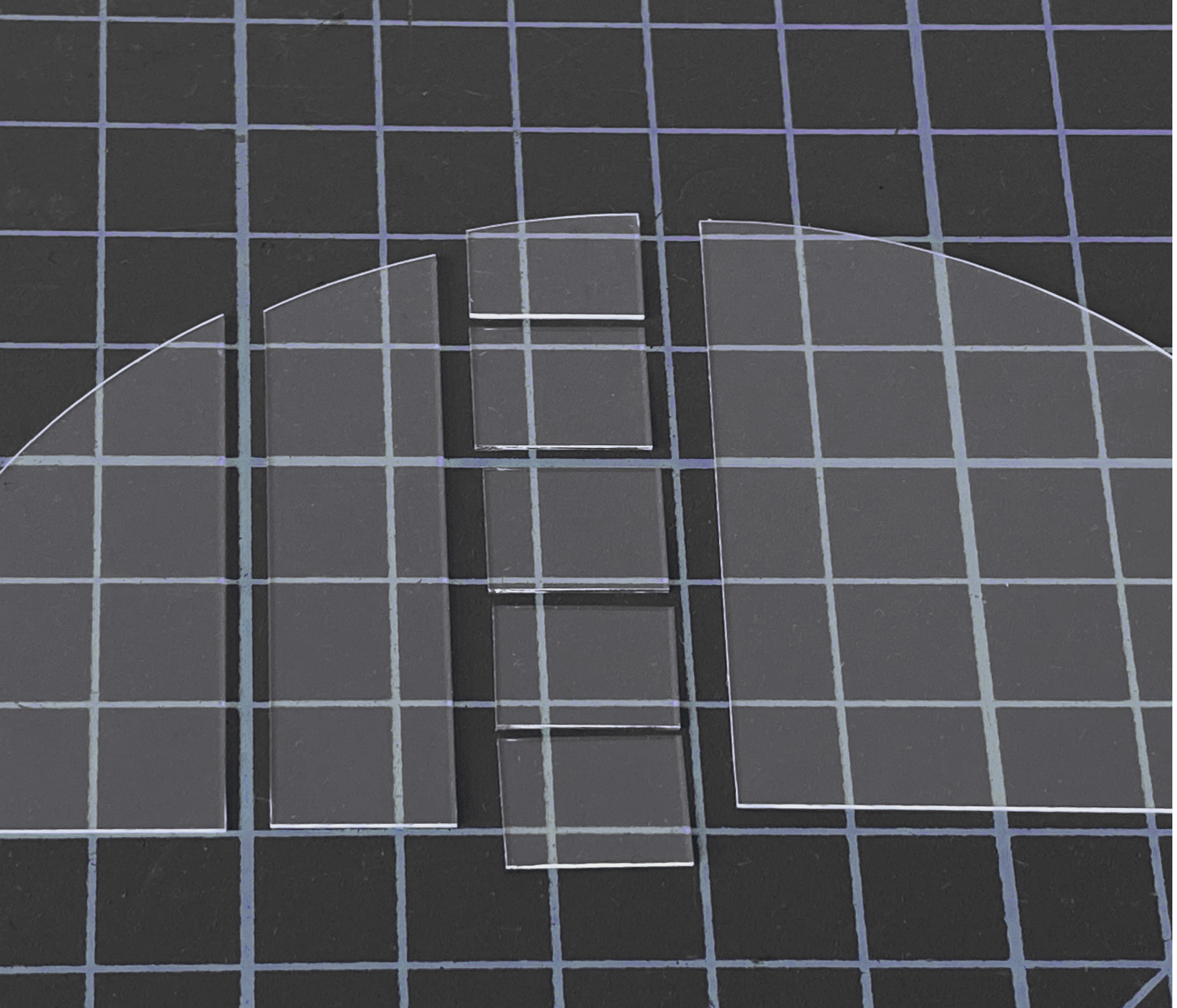






LatticeGear

New Dimensions in Scribing and Cleaving



INTRODUCTION

LatticeGear designs, manufactures, and sells cleanroom compatible benchtop tools for cleaving a wide variety of substrates, both crystalline and amorphous, including silicon, GaAs, InP, sapphire, and glass. When developing tools and processes, we learned that scribing parameters such as scribe angle and depth are critical to the quality of the cleave.

For glass, stray cracks will occur if the scribing conditions are not optimized. This results in unwanted lateral crack propagation that changes with angle of the scribe wheel or scribe tip, scribing force and other variables.

Crystal Class and Hardness

Material	Crystal Class	mohs Hardness
Perovskite	Orthorhombic	5.0–5.5
GaSb	Cubic, hextetrahedral	4.5
AlN	Hexagonal	5.0–7.0
GaN	Hexagonal	5.0–6.0
InP	Cubic (Zincblende)	5.0
Sapphire	Hexagonal	9.0
SiC	Hexagonal	9.0–9.5
GaAs	Cubic (Zincblende)	4.5
Silicon	Cubic	6.5
Hard glass (borosilicate)	Amorphous	7.5
Soft glass (soda-lime)	Amorphous	5.5
Gorilla glass/tempered glass	Amorphous	7.0–9.0

For crystalline materials, one must understand the crystal structure to predict the cleaving behavior. For all materials, substrate thickness, and hardness will influence the method chosen for scribing and cleaving. It can't be emphasized enough that the cleaving method is just as important as scribing parameters.

With this knowledge, LatticeGear developed a suite of scribing and cleaving tools that are flexible, yet also enable repeatable processes. Solutions are customized for the wide variety of materials and desired outcomes. To develop these solutions, scribing parameters such as length and depth, and cleaving method are varied during the optimization process.

In this technical note we present examples of our best practices for scribing and cleaving glass and sapphire substrates.

The following describes our learning to date on thick glass, thin glass, fused quartz glass, tempered glass and sapphire.

GLASS

Thick Glass

Thick glass can be cleaved with LatticeGear's LatticeAx®, FlipScribe® or the FlexScribe. Tool choice(s) will depend on the substrate type and desired outcome.

As an example, the borosilicate glass slide in Figure 1 was cleaved with the patented LatticeAx 120. The LatticeAx produces clean edges and a mirror finish without creating fractures. The LatticeAx method uses an edge indent followed by a 3-point cleaving process. Indent and cleaving are integrated into the single LatticeAx tool.

The LatticeAx is a good option for those needing to cleave in nanofabrication facilities. Information about this application can be found online at Cleanroom Technology magazine.

Figure 1. Scientific glass, 1 mm thick cut with the LatticeAx.

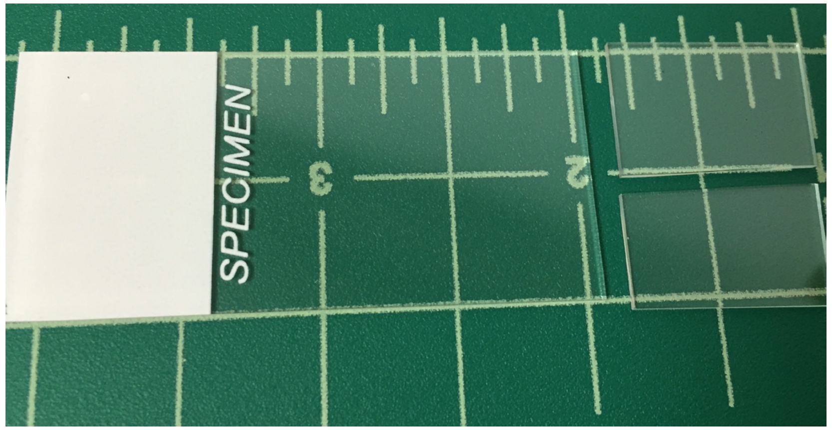
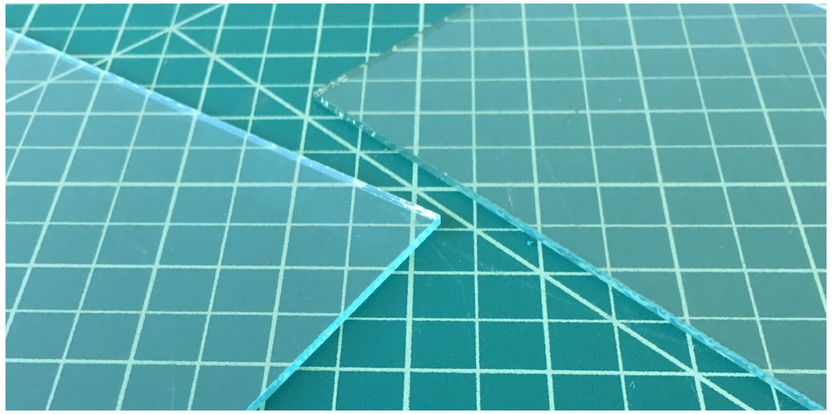


Figure 2. Thick glass, 2.5 mm thick, cut with the FlexScribe.



The cleaving mat has 12.7 mm squares. These can be used to measure the samples.

In situations where the top surface cannot be touched, the FlipScribe is used. The FlipScribe scribes the backside of the sample leaving the surface untouched.

When scribing the surface is acceptable, for example if cutting large plates of glass, the FlexScribe is the best and fastest method.

Thin Glass

Samples such as cells, biofilms, metal and oxide thin blanket and patterned films are frequently grown or deposited on glass substrates. Breaking or cleaving the glass substrate is necessary when creating splits for further experiments or to observe the sample in a microscope or other analytical instruments.

A repeatable process has been developed to downsize thin 22 mm^2 glass coverslips using the FlexScribe. Key to the success of the process was the cutting wheel selection and the downward force applied during the scribing. The thickness of the glass ranged from 120–160 microns.

Figure 3. Glass coverslips cleaved using the FlexScribe.

Eagle XG glass substrate

Eagle XG glass substrates used in the LCD industry were purchased to see whether the cleaving process could be modified to downsize larger samples. Using the FlexScribe and a diamond cutting wheel, followed by 3 point cleaving with the LatticeAx, the wafer can be cut cleanly without particulate contamination or fractures in unwanted directions. Figure 5 shows the cleanliness of the cut and mark made by the scribe on the top surface of the glass.

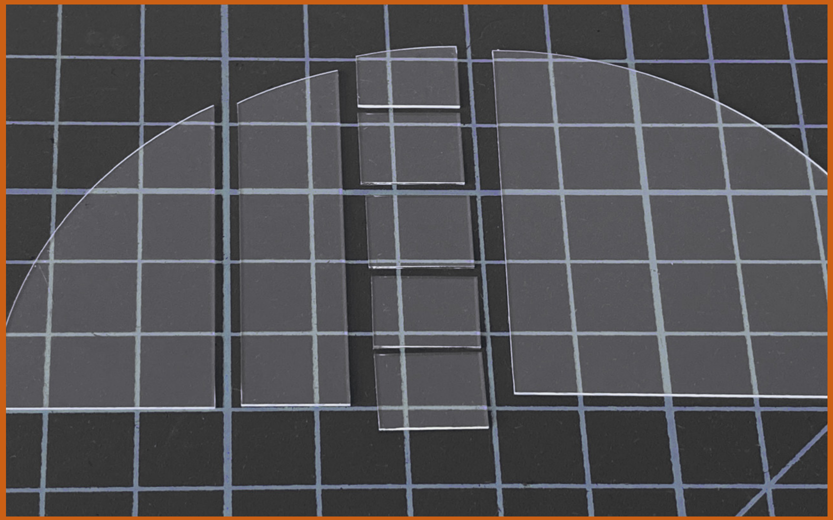


Figure 4. Downsized 100 mm diameter, 0.5 mm.

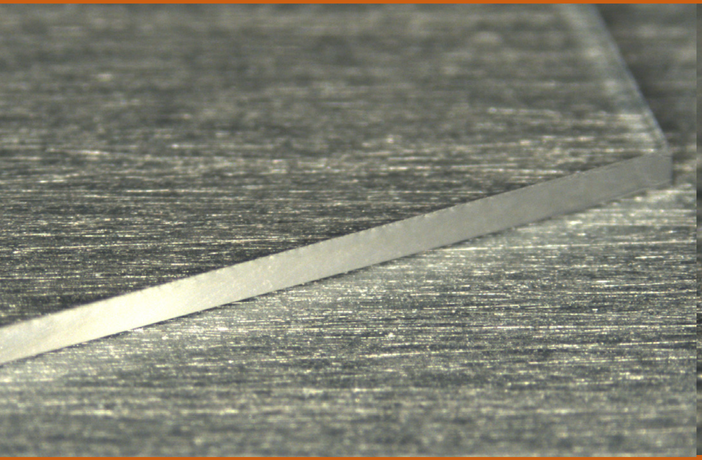


Figure 5. Optical image, view of wafer edge.

Figure 6. Optical image of 0.7 mm thick Eagle glass.

FUSED QUARTZ

LatticeGear's FlipScribe was used to downsize fused quartz.

The patented FlipScribe scribes without any touch to the top of the sample. It integrates a robust diamond scribe into a sample platform with a fence guide design (Figure 7). It allows users to accurately position the scribe mark relative to features on the front side, visualized either by eye or with a user-supplied high magnification microscope. FlipScribe is a compact, stable, accurate, fast cleaving solution suitable for any lab; no utilities required.

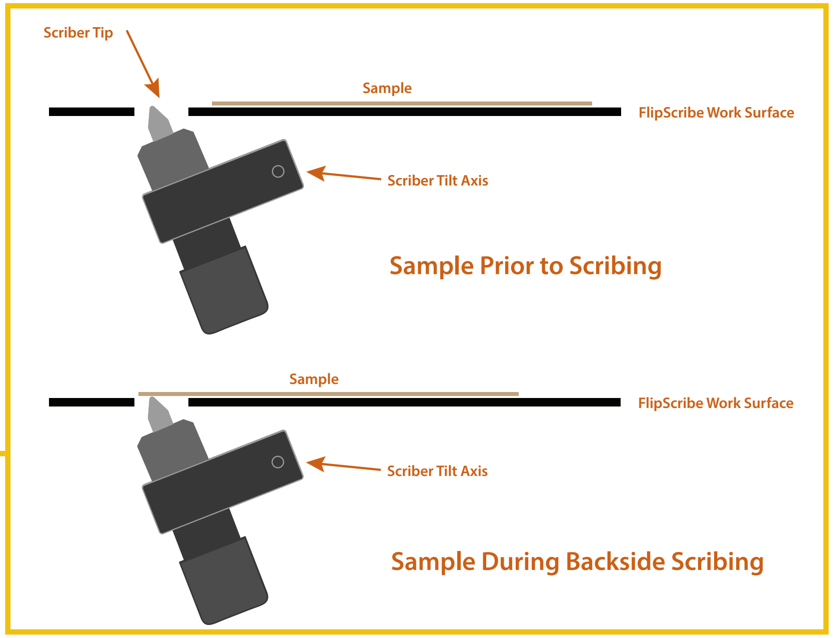


Figure 7. The FlipScribe backside scriber scribes the backside of the sample without touching the surface.

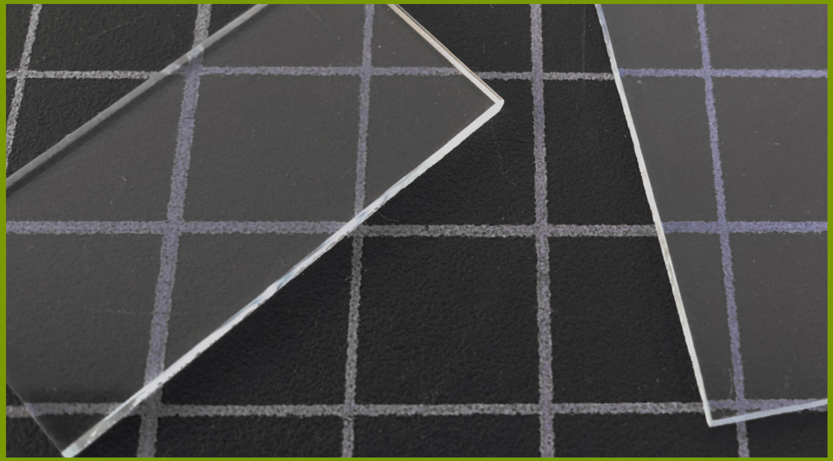


Figure 8. Fused quartz glass (50 mm x 50 mm) cut in half using the FlipScribe.

TEMPERED GLASS

LatticeGear had several customers looking for a way to downsize tempered glass. Downsizing tempered glass has seemed an impossible task using standard tungsten carbide (TC) or diamond scribing tools. Handheld and more sophisticated bench top scribing tools performed poorly, with the glass splintering into pieces during the scribing process.

The bench top FlexScribe scriber was developed to address glass cutting, including tempered glass. Because FlexScribe can be configured with custom cutting wheels, it makes sample preparation for quality control and failure analysis of these materials possible in any laboratory, without the need for lasers or dicing saws.

The following images show the types of samples that can be prepared from off the shelf mobile phone screens made of tempered glass. Each type of glass requires its own cutting recipe. With the right tool, it is simple to downsize glass with high success rates.

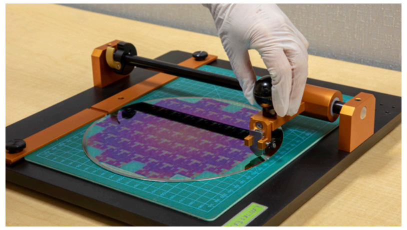


Figure 9. LatticeGear's FlexScribe.

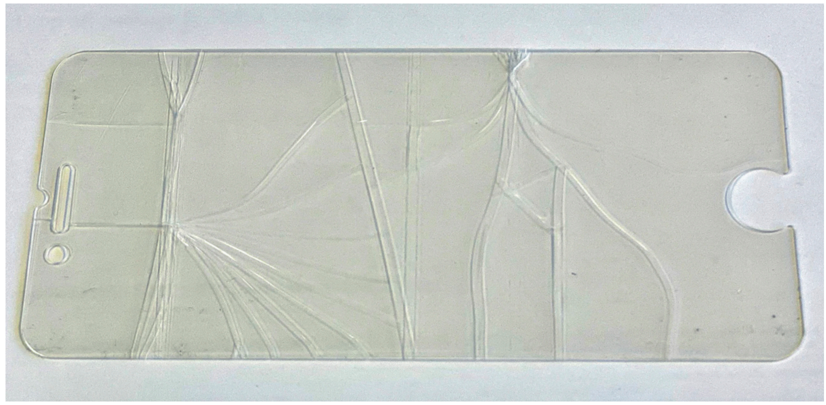


Figure 10. Cutting with a standard tungsten carbide scribing wheel resulted in a splintered sample.

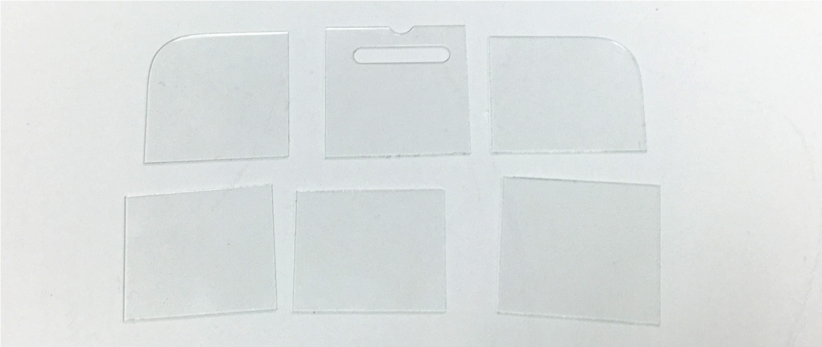


Figure 11. A new approach using the FlexScribe customized for cutting tempered glass yielded clean samples about 1 cm^2.

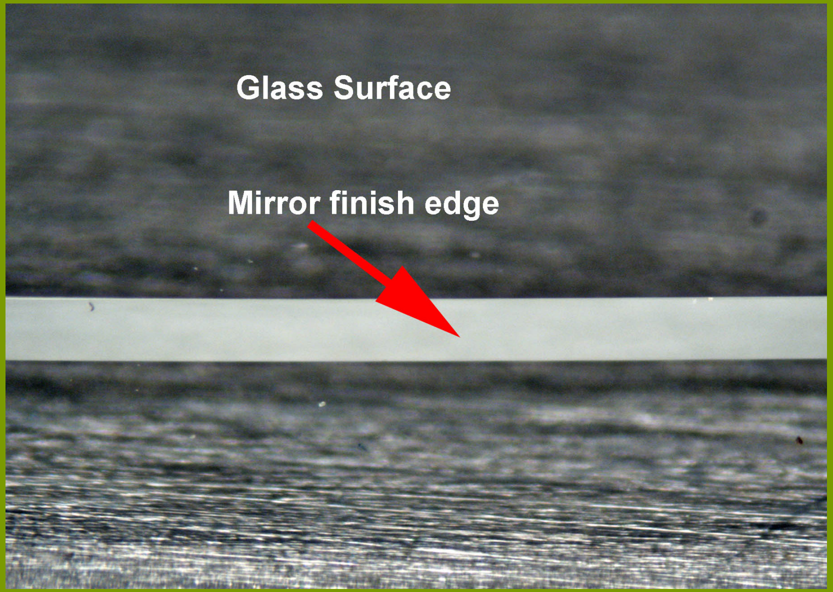


Figure 12. Cleaved edge of Corning Gorilla glass shows a mirror-finish image edge (red arrow).

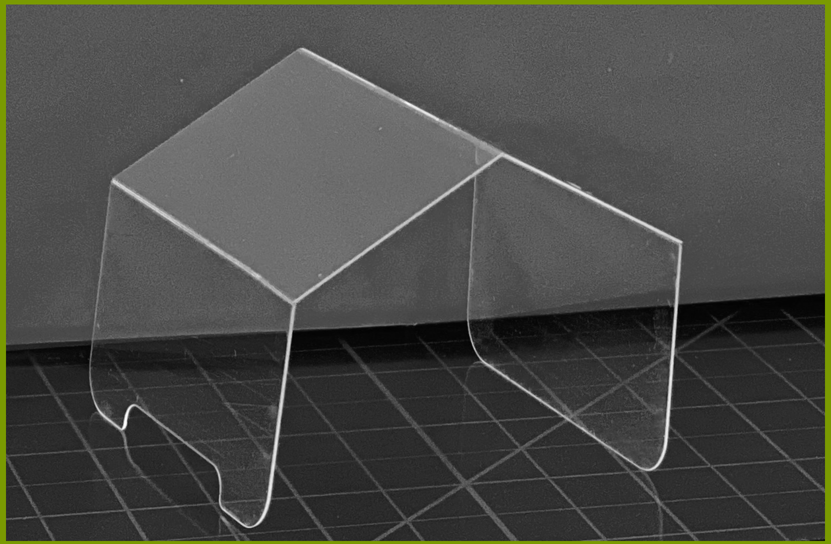


Figure 13. Glass protection screen, 9H hardness, cut into quarters, then folded after cutting.

SAPPHIRE

Cleaving is a fast and simple technique used to prepare samples of silicon and other semiconductor materials. Sapphire, however, does not always cleave well because of its hexagonal crystal structure. Current sapphire downsizing methods include sawing and handheld tool cleaving; however, yields can be unsatisfactory because fractures may propagate in undesirable directions and material is lost during the process. Laser scribing and cryogenic cooling are mentioned in literature as methods that can reduce unwanted fractures, delamination, chipping and loss of material, but these methods are costly, time consuming and can present other undesirable issues like poor edge quality and thermal damage due to temperature changes.

Because cleaving is fast and low cost with no loss of material, 2" and 3" sapphire wafers were acquired by LatticeGear in order to revisit cleaving of sapphire. Two methods are presented here. These methods are differentiated from handheld scribing and cleaving because they integrate new techniques into mechanical platforms: diamond microline indentation, topside scribing and backside scribing and cleaving. The "smart" mechanics (knobs, levers, dials) of these platforms enable repeatable processes and remove end result variations attributable to an operator's level of experience.

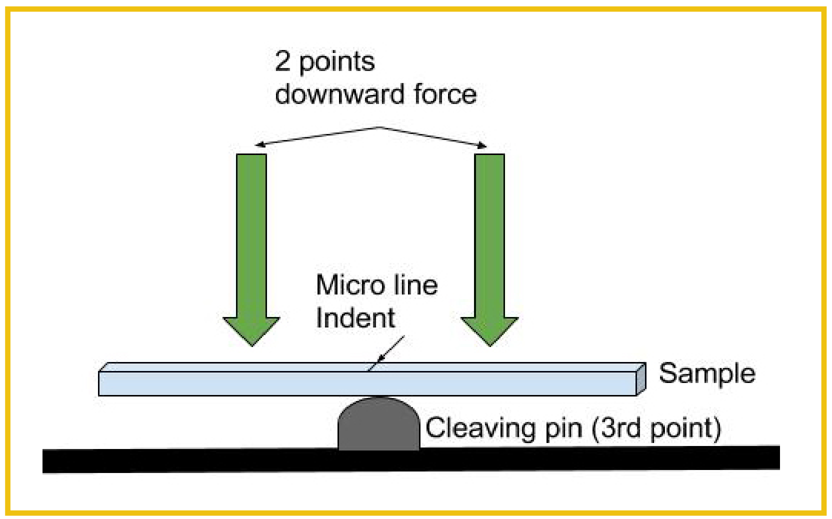


FIgure 14. This illustration shows the 3-point cleaving method, the mechanics of which are integrated into the LatticeAx design.

Method 1: Preparing 5 mm die with mirror-finish facets from sapphire wafers

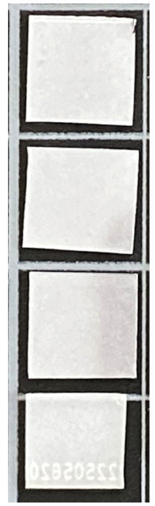


Figure 15. 5mm die cleaved from a 2" diameter sapphire wafer

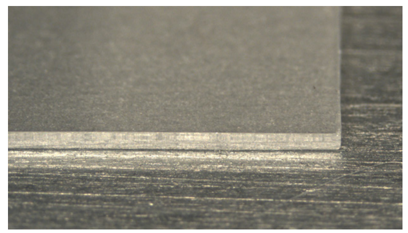


Figure 16. Mirror finish on edge of sapphire die; die cleaved with the LatticeAx.

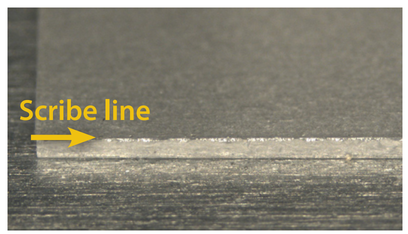


Figure 17: Mirror finish cleave below the scribe line created using the FlexScribe.

The 5 mm die shown in Figure 15 were cleaved using a two-step process from a 2" wafer. In the first step, the LatticeAx was used to cleave perpendicular to the wafer flat, coinciding with a crystal plane. A weak point, called a microline indent on the LatticeAx, is made by using a wedge-shaped diamond indenter on the top surface of the sample. The short microline indent is about 0.7–1.0 mm in length. The sample is then cleaved using 3-point cleaving. This creates a cleave plane that follows the crystal plane and propagates from the weak point. Figure 14 shows a how the 3-point cleaving mechanism works. This resulted in very clean cross section faces such as those required for photonics applications (Figure 16, top photo).

In step 2 the sample is cleaved pependicular to the first cleave to make a square die. For sapphire, this cleaving direction does not coincide with a crystal plane. To cleave counter to the crystal plane, a long scribe must be made across the entire length of the sample. In this example we used the FlexScribe. This technique forces the sample to cleave at 90 degrees to the first cleave, resulting in the die shown in Figure 15.

Figure 17 shows the scribe line made by the FlexScribe during the topdown scribe. The sample is clean and mirror finish below the scribe line.

For photonic applications it is important to plan the cleaving process based on the desired use case. A similar approach to cleaving can be taken to prepare samples from AlN, GaN, SiC and other non-cubic substrates.

For more details on this process download our applications note New Methods for Cleaving Sapphire Wafers Reduce Material Loss and Increase Yield.

Method 2: Separating die from a sapphire wafer

The FlipScribe is a scribing machine that scribes the backside of the sample while the operator views targets on the frontside of the sample. Samples are guided over the scriber tip either manually or with the aid of sample holders (Figure 18). Figure 19 shows the position of the scriber contacting the backside of the sample during scribing. The scriber tilt and height are adjustable; this was found to be key when optimizing a process for preparing samples along lithography versus crystal planes, or for amorphous material.

In Figure 20, the left image shows a sample cleaved after manual scribing with a pen-style diamond scriber. A weak point (long scribe line in this case) made with a hand scriber is commonly too deep, large and destructive. If it is "too weak", the cleave naturally propagates through the strong, natural crystal plane. The cleave will always follow "the path of least resistance". Note that the sample cleaves along a crystal plane which is not parallel to the lithography.

The right side image in FIgure 20 shows a sample cleaved using the FlipScribe. This preparation resulted in a sample with its sides following the lithography. A holder can be used to secure the sample, assuring a shallow, thin and straight scribe line that creates a "strong weak point" to initiate the cleave.

This work shows that even though sapphire it is a difficult material, it can be successfully cleaved.

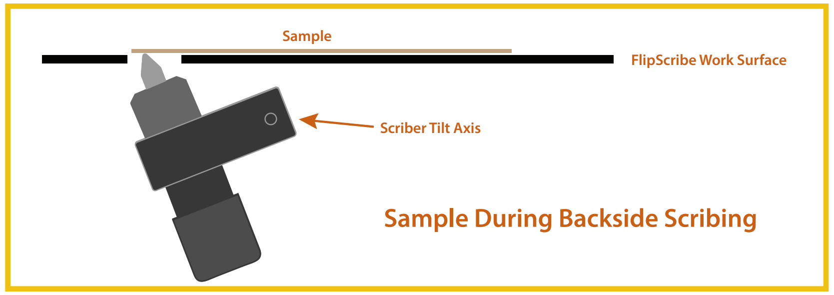


Figure 19. Diagram showing the sample on the FlipScribe work surface and position of the scriber. Note that the scribing process does to touch the surface of the sample.

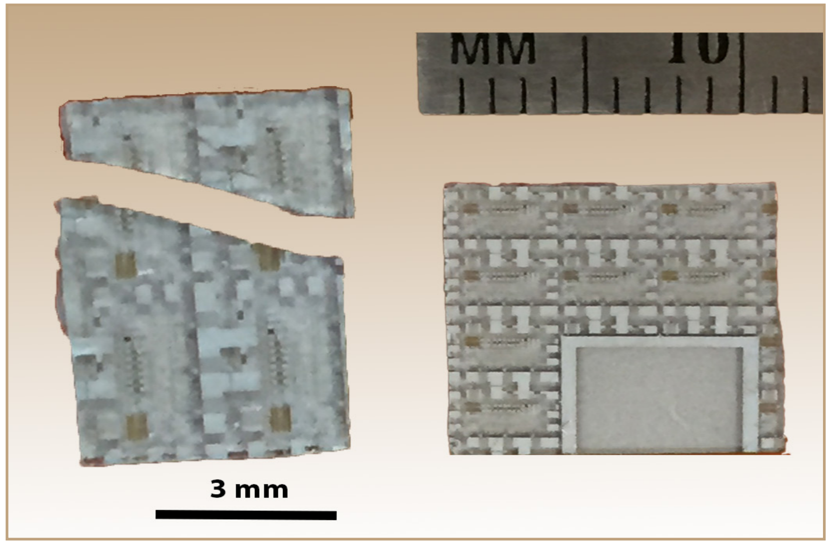


Figure 20. Comparison of sapphire scribed and cleaved with handheld scribers versus using the FlipScribe. Left: Sapphire after manual scribe and cleave. Right: Sapphire scribed using the FlipScribe, then cleaved with LatticeGear's Small Sample Pliers.

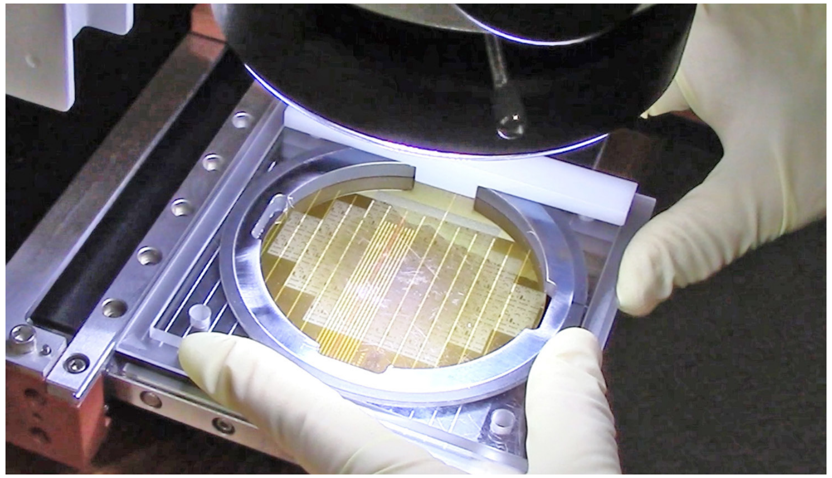
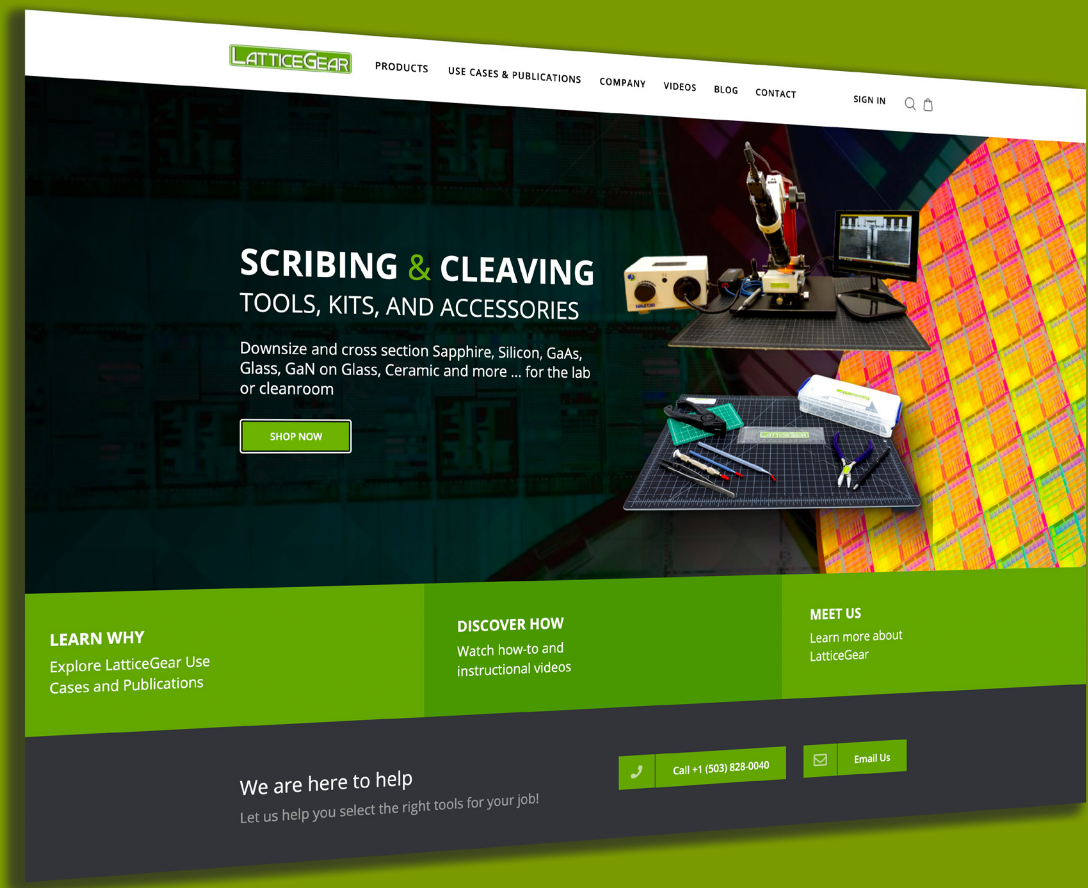


Figure 18. The FlipScribe is a scribing machine that makes the scribe on the backside of the sapphire.

CONCLUSION

This technical note demonstrates simple mechanical processes that can be used to downsize substrates and separate die from glass and sapphire. By knowing the material properties, including crystal structure and hardness. one can quickly develop methods based on scribing and cleaving. LatticeGear has developed a suite of tools that are flexible and enable repeatable processes. Cleaving and scribing accessories, FlipScribe, FlexScribe and LatticeAx are powerful tools that can be combined to create workflow for downsizing a wide range of materials.



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04.30.2020

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