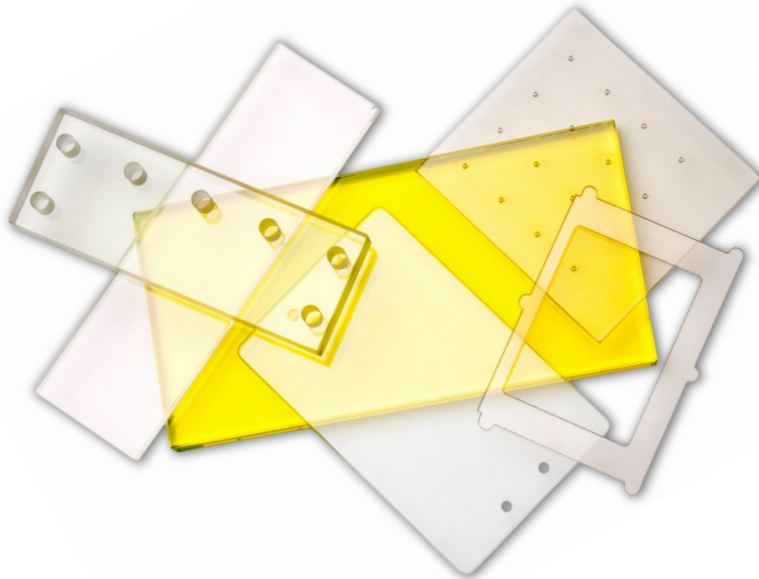
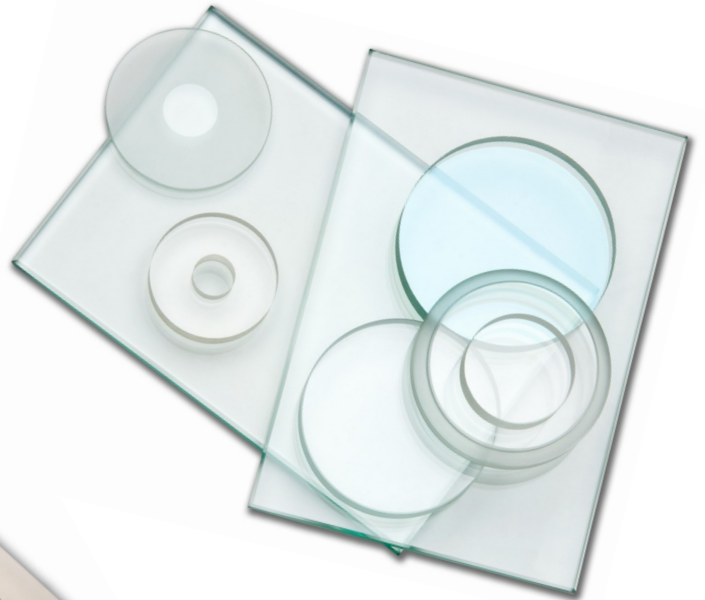


**Custom Glass Fabrication Capabilities
Technical Capabilities Brochure**

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- **Cutting**
- **Machining**
- **Edge Finishing**
- **Special Options**

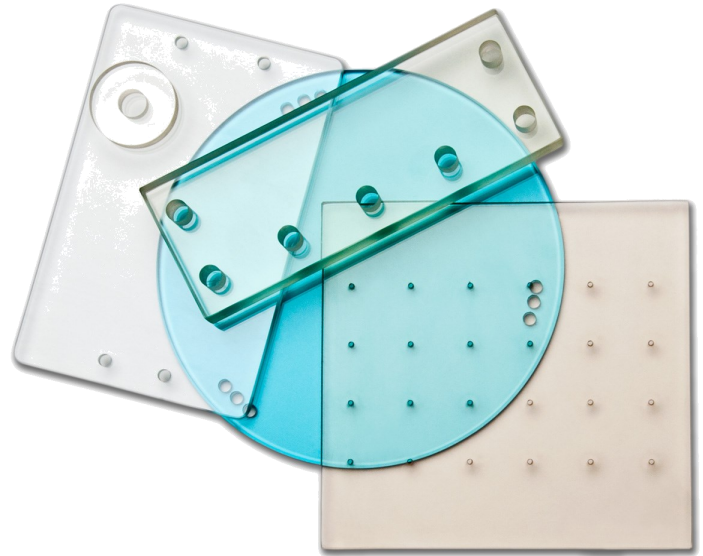
Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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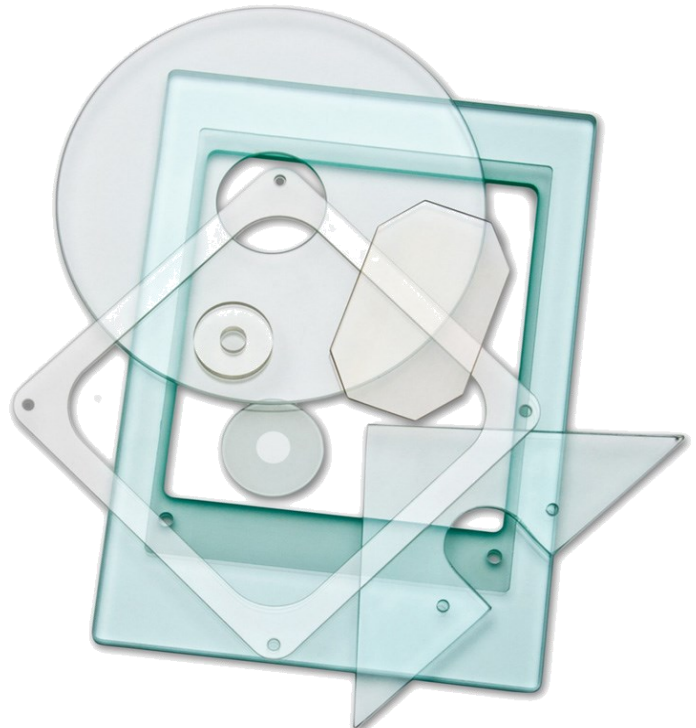
Abrisa Technologies provides precision custom machined optical components from prototype to high volume and OEM production. We can apply a variety of precision processes, individually or in combination, to any glass substrate. 90% of Glass Fabrication requirements are unique, consequently when you require a specific transmission, size, edge, polish, cleanliness standard or more for your product, turn to Abrisa Technologies to produce your fabricated glass components.

Capabilities

- **Cutting (Pages 3 & 4)**
 - Waterjet
 - Scribe Cutting
 - Hand Cutting
 - Precision XY Sawing (Slicer)
 - Tube & Rod Cutting
- **Edging (Page 7)**
 - Angled & Multi-Level Bevels
 - Seams
 - Corner Dubbing
 - Circle & Flat Ground
 - Pencil & Polished
- **Screen Printing (Pages 5 & 6)**
 - Machine & Custom Press
 - Ink Types (Epoxy/Polyester & Frit)
 - Etching & Bus Bars
 - Edge Printing
- **Strengthening (Pages 8 - 10)**
 - Chemical
 - Chemical (HIE™) - High Ion-Exchange
 - Heat
- **Machining (11 & 12)**
 - CNC Processing
 - Shapes
 - Notching
 - Slotting
 - Grooving
 - Step Surface
 - Drilling (Holes & Tapers)
 - Countersink & Inside Dimensional Seaming
 - Circle Grinding
 - Grinding & Polishing (Buffing & Lapping)
 - Sandblasting (Surface Patterns & Logos)



- **Cleaning (Page 13)**
 - Flat Glass Washers
 - Ultrasonic Tanks
 - Automated Dryers
 - Class 100 Clean Room
- **Metrology (Page 14)**
- **Specialty Packaging (Page 14)**



Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Cutting

- **Water Jet** - Provides relatively quick set-up and cutting of large glass sheets with curves, holes, and other shapes.

Cut Tolerances*: 0.50 mm [0.020"]
Maximum Thickness: 38.1 mm [1.500"]
Minimum Thickness : 1.00 mm [0.040"]
Maximum Material Size: 2,286 mm x 1,168 mm [90" x 46"]
Minimum Material Size: 51 mm x 51 mm [2" x 2"]

*Cut tolerance established for substrates \leq 3 mm [0.118"] thick. Cut tolerances are 1.00 mm [0.040"] for thicker substrates

- **Scribe Cutting**

Excalibur (scribe cutting):

Cut Tolerances:* 0.64 mm [0.025"]
Maximum Thickness: 25.40 mm [1.000"]
Minimum Thickness: 0.55 mm [0.022"]
Maximum Material Size: 3,556 mm x 2,438 mm [140" x 96"]
Minimum Material Size: 254 mm x 254 mm [10" x 10"]

*Cut tolerance established for substrates \leq 3 mm [0.118"] thick. Cut tolerances are up to 1.14 mm [0.045"] for substrates up to 6.40 mm [0.250"] thick, up to 1.78 mm [0.070"] for substrates up to 13 mm [0.500"] thick, and up to 2.80 mm [0.110"] for substrates up to 25.4 mm [1.00"] thick.

Bystronic (scribe cutting):

Cut Tolerances:* 0.38 mm [0.015"]
Maximum Thickness: 9.65 mm [0.380"]
Minimum Thickness: 0.055 mm [0.022"]
Maximum Material Size: 3,556 mm x 2,438 mm [140" x 96"]
Minimum Material Size: 610 mm x 813 mm [24" x 32"]

*Cut tolerance established for substrates \leq 3 mm [0.118"] thick. Cut tolerances are up to 0.50 mm [0.020"] for substrates up to 6.40 mm [0.250"] thick and up to 0.64 mm [0.025"] for substrates up to 9.50 mm [0.380"] thick.

TLC (scribe cutting):

Cut Tolerances:* 0.13 mm [0.005"]
Maximum Thickness: 6.35 mm [0.250"]
Minimum Thickness: 0.15 mm [0.006"]
Maximum Material Size: 635 mm x 635 mm [25" x 25"]
Minimum Material Size: 51 mm x 51 mm [2" x 2"]

*Cut tolerance established for substrates \leq 2.5 [0.100"] mm thick. Cut tolerances are up to 0.25 mm [0.010"] for substrates up to 6.40 mm [0.250"] thick.

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- **Scribe Cutting (cont.)**
- **Hand Cutting**

Cut Tolerances:	0.76 mm [0.030"]
Maximum Thickness:	6.35 mm [0.250"]
Minimum Thickness:	0.50 mm [0.020"]
Maximum Material Size:	1,828 mm x 1,524 mm [72" x 60"]
Minimum Material Size:	51 mm x 51 mm [2" x 2"]
Maximum Part Size:	762 mm x 305 mm [30" x 12"]
Minimum Part Size:	19 mm x 19 mm [0.75" x 0.75"]

- **Precision XY Sawing (Slicer)**

Cut Tolerances:*	0.03 mm [0.001"]
Maximum Thickness:	4.00 mm [0.157"]
Minimum Thickness:	0.50 mm [0.020"]
Maximum Material Size:	165 mm x 165 mm [6.5" x 6.5"]
Minimum Material Size:	51 mm x 51 mm [2" x 2"]

*Cut tolerance established for substrates ≤ 2.5 [0.100"] mm thick. Cut tolerances are 0.05 mm [0.002"] for thicker substrates.

- **Tube & Rod Cutting** - Provides cutting of glass tubes or rods to required length. The precision saw provides ground edges while the diamond cutter provides cut edges.

Precision Saw (tube & rod cutting):

Cut Tolerances:	0.25 mm [0.010"]
Maximum Diameter:	114.3 mm [4.50"]
Minimum Diameter:	3.18 mm [0.125"]
Maximum Material Length:	1524 mm [60"]
Minimum Material Length:	102 mm [4.00"]
Maximum Part Length:	635 mm [25"]
Minimum Part Length:	38.1 mm [1.50"]

Diamond Cutter (tube & rod cutting):

Cut Tolerances:	0.76 mm [0.030"]
Maximum Diameter:	177.8 mm [7.00"]
Minimum Diameter:	3.18 mm [0.125"]
Maximum Material Length:	1270 mm [50"]
Minimum Material Length:	02 mm [4.00"]
Maximum Part Length:	406.4 mm [16"]
Minimum Part Length:	38.1 mm [1.50"]

Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Screen Printing:

Screen Printing at Abrisa Technologies' Santa Paula facility is performed on either a semi-automatic printer or automated printer within a Class 1000 or 10,000 cleanroom. The platform selected is dependent upon need and spec requirements. Inks are available in multiple colors including metallics and range from low temperature epoxies to high temperature frits. Abrisa Technologies generally stocks black and silver epoxies and black frit. Other inks are available for custom requirements including multiple colors and metallics.



- Ekra X4**

Minimum Thickness:	0.76 mm [0.030"]
Maximum Thickness:	12.7 mm [0.5"]
Tolerance:	±0.13 mm [±0.005"]
Minimum Size:	76.2 x 50.8 mm [3" x 2"]
Maximum Size:	380 mm x 380 mm [15" x 15"]

- Argon - Large Format**

Minimum Thickness:	~1 mm [0.040"]
Maximum Thickness:	19 mm [0.75"]
Tolerance:	±1.016 mm [±0.040"] up to ±0.4 mm [±0.015"]
Minimum Size:	460 mm x 460 mm [16" x 16"]
Maximum Size:	1828 mm x 1371 mm [72" x 54"]

- Cameo/Saturn**

Minimum Thickness:	0.76 mm [0.030"]
Maximum Thickness:	25.4 mm [1.0"]
Tolerance:	±1.016 mm [±0.040"] up to ±0.25mm [±0.010"]
Minimum Size:	7.6 mm x 7.6 mm [0.3" x 0.3"]
Maximum Size:	457 mm x 609 [30" x 24"]

- Saturn**

Minimum Thickness:	0.76 mm [0.030"]
Maximum Thickness:	25.4 mm [1.0"]
Tolerance:	±1.016 mm [±0.040"] up to ±0.25 mm [±0.010"]
Minimum Size:	7.6 mm x 7.6 mm [0.3" x 0.3"]
Maximum Size:	457 mm x 355 mm [18" x 14"]

- Abrisa Technologies Custom Press**

Minimum Thickness:	0.76 mm [0.030"]
Maximum Thickness:	25.4 mm [1.0"]
Tolerance:	±1.016 mm [±0.040"] up to ±0.25 mm [±0.010"]
Minimum Size:	7.6 mm x 7.6 mm [0.3" x 0.3"]
Maximum Size:	914 mm x 609 mm [36" x 24"]

Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Screen Printing *(cont.)*

- Ink Types:**

- Epoxy/Polyester:**

- Color: Black & silver (standard, custom available)
- Resolution: Can print as fine as 0.127 mm [0.005"] minimum
- Thickness Requirements:
 - Single Pass: 10 - 12 μm
 - Double Pass: 25 - 60 μm

- Frit:**

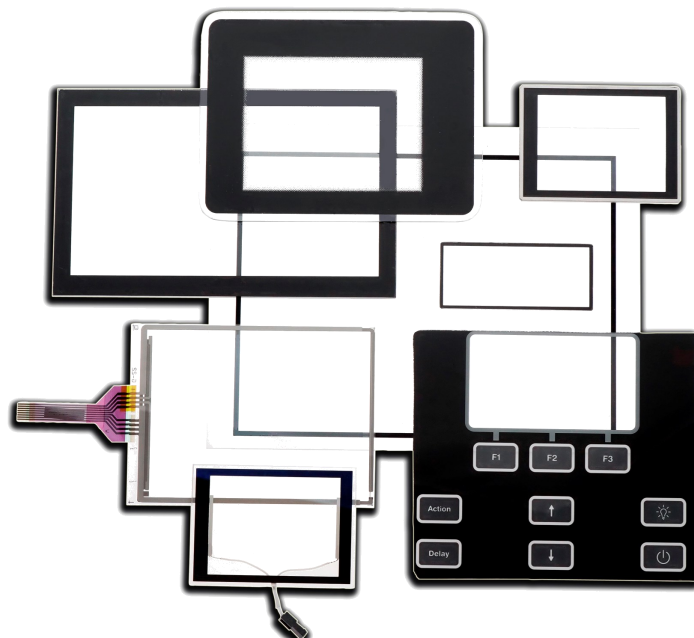
- Color: Black & silver (standard, custom available)
- Durability: Higher durability than epoxy/polyester—more scratch resistant
- Resolution: Can print as fine as 0.305 mm [0.012"]
- Thickness Requirements:
 - Single Pass: < 0.051 mm [< 0.002"]
 - 35 - 60 μm

Etching & Bus Bars:

Abrisa provides etching and busbar applications per project specifications such as silver epoxy or conductive ink printed on an ITO or IMITO. The etching and busbar process is available on the Ekra X4, Cameo 18, Cameo 30, and Saturn. L-shaped and U-shaped bus bars are also available through edge printing. The size and tolerance limitations are the same as standard screen printing.

Edge Printing:

Edge printing for small to medium sized parts is available for any application with ceramic frit ink. Generally there are no limitations on part size or material thickness. However, for epoxy ink the largest part with edge printing is typically 72" x 54". Tolerances are up to $\pm 0.010"$.



Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Edging - Finishing the sharp edges of cut glass is applied for safe handling, chip reduction, or aesthetics. At Abrisa Technologies, we provide angled and multilevel bevels, seams, corner dubbing, circle or flat ground, pencil, and polished edging.



Flat Ground Edges - Diamond embedded grinding wheels put a satin finish on the edge.



Flat Polish Edges - Taking a ground edge another step, polishing the edges to give the glass a nice sheen finish.



Flat Polish Edges with Arris - This is a flat polished edge with polished chamfers (Arris).



Pencil Ground Edges - Diamond embedded grinding wheels put a satin finish on the edge, with an edge radius similar to pencil or C-shape.



Pencil Polished Edges - Edges are polished to a sheen finish, with radius similar to pencil or C-shape.



Safety Seamed Edge - (Swiped Edge, chamfered edge)
A sanding belt is used to lightly sand off the sharp edge of the glass.



Dubbed Corners - The sharp edge of each corner can be nubbed or broken as required (chamfered or radius corner).



Stepped and Route Surfaces - Glass is ground away to leave a step or lip.

Beveled Edges - (3) styles - Ground or polished bevels on glass or mirror, circles, rectangles to any degree can be provided

Bullnose Edges (Half & Full) - These are typically polished edges (can be ground if required) that are similar to pencil edges, the difference being that the bullnose edge is a full radius curve where the diameter matches the thickness of the glass substrate. There are specific profiles where the relief angles can be different, typically where aesthetics are important or for critical applications where the edge of the glass could affect functionality.

General specifications for edging glass substrates are:

- Minimum Substrate Thickness:** 0.020" (0.5 mm)
- Maximum Substrate Thickness:** 1" (25.4 mm) – will have overall size limitations
- Tolerances:** ±0.001" to ±0.010" dependent upon size and shape of glass parts
- Maximum Substrate Size:** 110" x 60" (2794 mm x 1524 mm) up to 6 mm thick at this size. Can provide edge treatments for thicker substrates in smaller sizes, consult factory.

Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Chemical Strengthening (Standard Soda Lime):

The Chemical Strengthening process toughens soda lime through a sodium and potassium ion exchange in a salt bath. Glass can be strengthened from 8 to 16 hours and is often requested for toughened thin display applications. Chemical strengthening is best suited for thin soda lime sheets (under 3mm) and applications where optical distortion must be kept to a minimum. Chemically strengthened glass does not “dice” like fully heat tempered glass when broken.

Minimum Thickness:	0.30 mm [0.012”]
Maximum Thickness:	19 mm [0.75”]
Minimum Size:	25.4 mm x 25.4 mm [1” x 1”]
Maximum Size:	1,168.4 mm x 736.6 mm [46” x 29”]* Contact factory for larger sizes
Cosmetics:	Up to 60/40
Modulus of Rupture (MOR):	
8 hours	Avg 350 - 550 MPa and Avg 15 - 25 DOL
16 hours	Avg 500 - 700 MPa and 25 - 35 DOL



Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Chemical Strengthening (HIE™ Glass):

Abrisa Technologies' High Ion Exchange or HIE™ glass is chemically strengthened glass that has increased strength as a result of a post-product chemical process. This process typically increases the strength of the glass by 6 to 8X that of float glass. The ion-exchange process creates a deep compression layer on the surface of the glass structure, reducing the introduction of flaws once incorporated into the end product and put into service.

Typically used for electronic display screens such as smartphones, laptop and tablet computers, mobile devices, touch screens, and more, HIE glass provides outstanding resistance to breakage, scratches and temperature fluctuations.

HIE chemically strengthened glass advantages:

- **Improved impact resistance**
- **Improved flexibility strength**
- **Improved scratch resistance**
- **Improved resistance to temperature changes**

By using a thin glass such raw material such as Corning® Gorilla® Glass, SCHOTT Xensation™ Cover glass, or AGC Dragontrail™, the end product will have improved transmission, reduced weight, and reduced mounting costs as just some of the significant advantages.

Abrisa Technologies can provide customized fabrication solutions for their HIE™ glass that include the application of thin film coatings, various edge treatments, custom cutting and drilling, screen printing, Bus Bars and more."

Abrisa Technologies HIE™ Glass offerings include:

- Thicknesses from 0.4 mm to 2.0 mm
- Sheet sizes* from 18.7" to 49.2" (475 mm to 1250 mm)

* These are the standard sizes that these raw materials are available in, and/or can be fabricated to. In terms of supplying a strengthened piece of glass with fabrication, screen print and coatings (value-added) manufacturing, the maximum size that Abrisa Technologies can offer is 36" x 29" (1,168.4 mm x 737 mm).

Custom thicknesses and sheet sizes may be available.
Consult factory.

Four Point Bending Test
with 9 lbf of pressure being applied
HIE™ glass thickness is 0.99 mm
Not performed in-house



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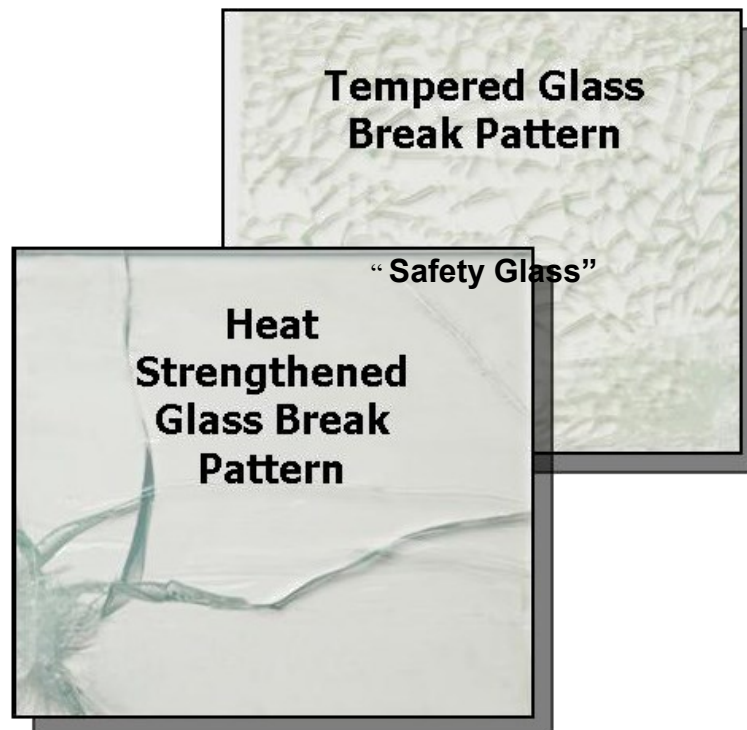
Heat Tempering: (Standard ASTM C-1048-04)

Heat Tempering toughens soda lime through the controlled heating and cooling of the glass to maintain a temperature differential between the core and outer surfaces. The stressed induced compress the outer surfaces, forming a substrate substantially tougher than standard soda lime. When broken, tempered glass “dices” into many small pieces. This is typically referred to as “Safety Tempering” for it’s reduced likelihood of cutting a person in the event of a fracture.

- **Horizontal Heat Tempering Furnace:**

Minimum Thickness:	3 mm [0.118”]
Maximum Thickness:	19 mm [0.75”]
Minimum Size:	76.2 mm x 76.2 mm [3” x 3”]
Maximum Size:	838.2 mm x 736.6 mm [29” x 33”]
Maximum Size:	(Diagonal) 1056.8 mm x 736.6 mm [42” x 29”]*
	Approx. 51” Diagonal
Treatment:	Temper Kind Full Temper (FT) or Heat Strengthened (HS)

* Contact factory for sizes beyond these dimensions.

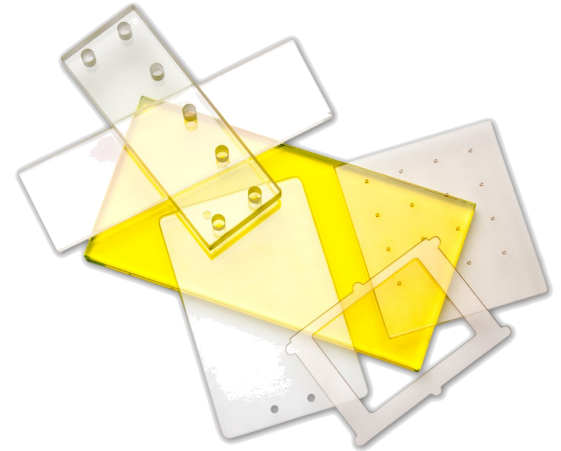


Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Machining

Abrisa Technologies provides multiple technologies/processes to support your glass/optics shapes, surfaces, edging, and hole drilling requirements. Depending on glass types, thicknesses, hole diameter, and edge quality; Abrisa Technologies can choose between CNC machining, opposed edge drilling, or abrasive material removal or sandblasting to meet your specific glass fabrication requirements.



- **CNC Processing (Shapes, Notching, Slotting, Grooving, Step Surface):**

CNC machining can provide any custom shape with any type of ground or polished edging, including parts with holes, tapers, notches, slots, grooves, or stepped surfaces.

Minimum Thickness:	0.76 mm [0.030"]
Maximum Thickness:	>25.4 mm [1.0"]
Tolerance:	±0.508 mm [±0.020"] up to ±0.127 mm [±0.005"]
Minimum Size:	76.2 x 76.2 mm [3" x 3"]
Maximum Size:	3,048 mm x 1,524 mm [120" x 60"]
Minimum Hole Size (Diameter):	0.76 mm [0.030"]

- **Drilling (Holes & Tapers):**

Abrisa Technologies provides multiple avenues to drill holes:

- Through holes
- Blind holes
- Step holes,
- Countersink holes

Hole parameters are only limited by the CNC machining capabilities stated above.

- **Countersink & Inside Dimension Seaming:**

Parts with holes, slots, or grooves can be tapered on both sides or seamed on the inside dimensions to improve inside edge quality. The only limitations are from the CNC machining capabilities stated above.

- **Circle Grinding:**

High volumes of circular parts can be quickly ground to precise diameters.

Minimum Thickness:	0.508 mm [0.020"]
Maximum Thickness:	25.4 mm [1.0"]
Tolerance:	±0.254 mm [±0.010"] up to ±0.127 mm [±0.005"]
Minimum Diameter:	6.35 mm [0.250"]
Maximum Diameter:	304.8 mm [12"]

Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Machining (cont.)

- **Grinding & Polishing (Buffing and Lapping)**

Parts with special surface or edge polishing requirements can be ground to size, rough surface ground (lapping), or smooth polished (buffing).

Surface Grinding and Polishing:

Minimum Thickness (Finished Part):	0.254 mm [0.010"]
Maximum Thickness:	50.8 mm [2.0"]
Thickness Tolerance*:	±0.127 mm [±0.005"] up to ±0.025 mm [±0.001"]
Minimum Size:	25.4 x 25.4 mm [1" x 1"]
Maximum Size:	438.1 mm x 438.1mm [17" x 17"] or 609.6 mm [24"] diameter.

*Thickness tolerance of ±0.025 mm [±0.001"] applies to parts 127 x 127 mm [5" x 5"] or smaller.

Edge Grinding and Polishing:

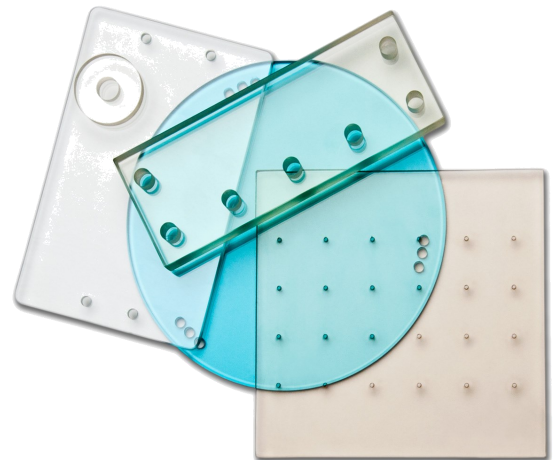
Minimum Thickness:	0.813 mm [0.032"]
Maximum Thickness:	50.8 mm [2.0"]
Thickness Tolerance*:	±0.254 mm [±0.010"] up to ±0.05 mm [±0.002"]
Minimum Size:	1.9 mm x 1.9 mm [0.75" x 0.75"]
Maximum Size:	533 mm x 533 mm [21" x 21"]

*Tolerance of ±0.05 mm [±0.002"] applies to parts 127 x 127 mm [5" x 5"] or smaller.

- **Sand Blasting (Surface Patterns and Logos):**

Portions of the part or the entire part can be sandblasted for a rough or cloudy surface finish or logos and patterns can be applied to the surface of the part. The inside or outside surfaces of tubing can also be sand blasted for a rough or cloudy surface finish. Sandblast grits available from 80-400.

Minimum Thickness:	1.1 mm [0.043"]
Maximum Thickness:	25.4 mm [1.0"]
Minimum Size:	25.4mm x 25.4 mm [1" x 1"]
Maximum Size:	2,032 mm x 1,118 mm [80" x 44"]
Maximum Tube Length:	812.8 mm [32"]



Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Cleaning

Abrisa Technologies' Santa Paula manufacturing facility has multiple high volume wash stations to remove dust, finger-prints, and other contamination. Wash stations use high pressure heated water and soft nylon brushes to clean surfaces. Glass exits completely dry and ready for inspection. Cleanliness levels exceed expectations of industrial or commercial customers. Cleanroom, medical, or other high-end applications must be evaluated on a case by case basis.

(Flat Glass Washers, Ultrasonic Tanks, Automated Dryers)

Cosmetic Requirements:

Typical	120/80
Enhanced	60/40

Substrate Thickness:

Typical	Up to 50.8 mm [2"] thick
Enhanced	Outside of range - "hand wash"

Substrate Size:

Typical Minimum	25.4 mm x 25.4 mm [1" x 1"]
Typical Maximum	1,168 mm x 1,168 mm [46" x 46"]
Enhanced	Outside of range - "hand wash"



Clean Rooms

Each Abrisa Technologies division's Quality Management System has based its foundation on the International Quality System Standard ISO 9001:2008. Abrisa Technologies strives for excellence through various SPC (statistical process controls) methods such as control charts, continuous improvement and design of experiments to name a few as well as the use of 5S's methodologies.



Certified to ISO 14644 - 1505 (at 5 microns)

Class 100 — 1,000

Size: (in. sq. ft.)

- Total	700
- Transfer Room	100
- Gown Room	100
- Main Clean Room	500+

Class 10,000 — 100,000

Soft wall clean rooms for dust & particle control (screen print)

- 500 +sq. ft
- 100+ sq. ft.



Custom Glass Fabrication Capabilities Technical Capabilities Brochure

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Metrology - At Abrisa Technologies, our metrology capabilities are an integral part of what we do. At various stages in the manufacturing process as well as before final packaging, all of our parts are thoroughly inspected to ensure compliance to customer requirements. Parts are both visually and dimensionally inspected using a wide range of industry standard measurement & inspection equipment as well as state-of-the-art machinery for compliance.

Typical metrology equipment utilized at Abrisa Technologies includes:

- Spectrophotometers
- Micro-VU Three Axes measurement machine
- Surface Testing Machines (Waviness and Roughness)
- Calipers and Micrometers,
- Micro-Flat Plates
- Optical Comparators
- MOR's and Surface Test Compression Equipment
- FSM 6000LE "New in 2012" to support Chemical Strengthening (HIE product line)

Specialty Packaging - Specialty packaging is available for parts with special surface requirements or packaging protection requirements for moisture, dust, and/or marking prevention.

Moisture, Dust, and Marking Reduction:

- PH Neutral Paper
- Silica Gel Packets
- Plastic Coverings Inside Crates
- Heat Shrinking
- Various Trays (Foam or Plastic)



Wafer Containers:

Plastic Wafer Containers are available for glass wafers with special surface requirements. Wafer containers allow parts to be packed and shipped in individual cells without paper.

- Maximum Part Thickness: 1.75 mm [0.069"]
- Maximum Part Diameter: 400 mm [15.748"]

Custom Glass Fabrication Capabilities

Glass Fabrication



Coating Deposition



CNC Machining



Strengthening - Chemical & Heat



Screen Printing of Graphics



Abrisa Technologies, a member of HEF Photonics, is a globally recognized technology glass fabrication and optical thin film coating company with expertise in high volume manufacturing and engineering capabilities, delivering Total Solutions that provide excellent performance, fitness-for-use and economies of scale.

Our US based, state-of-the-art ISO 9001:2015 and ITAR registered facilities include Abrisa Industrial Glass in Santa Paula, CA and ZC&R Coatings for Optics in Torrance CA. These two divisions produce solutions from cut-to-order coated glass components to custom complex and ready-to-install fabricated, strengthened, optically coated, electronically enabled and branded sub-assemblies.

Our Total Solutions serve a variety of markets including Micro-Electronics, Defense and Avionics, Display, Industrial Automation, Optical Sensors, Imaging, Photonics, Medical & Dental, Life Science and more.



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