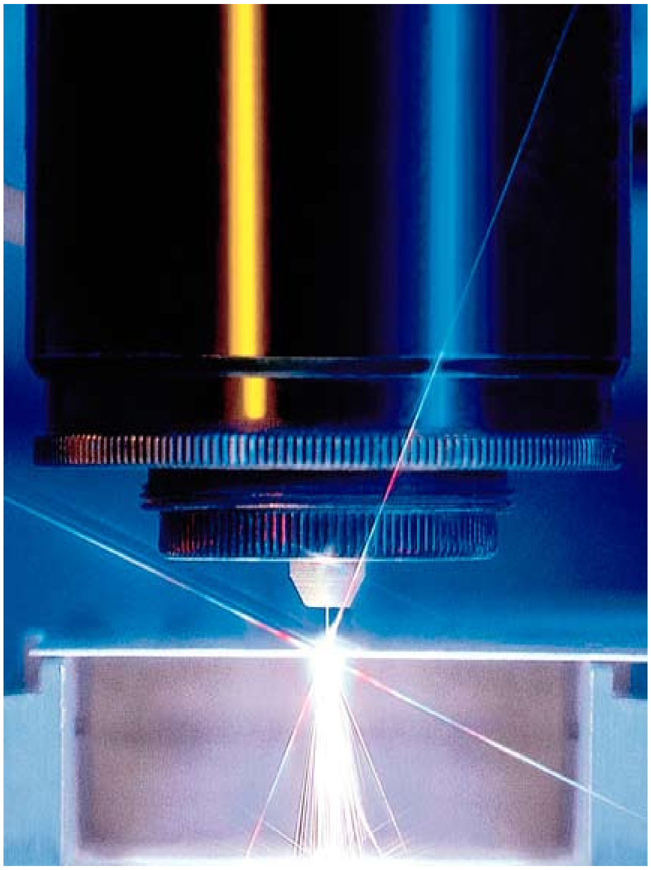
CoorsTek
Amazing Solutions.®

THICK-FILM CERAMIC SUBSTRATES DESIGN GUIDE

www.coorstek.com

Table of Contents



CoorsTek is the largest independent ceramics company in the United States and a world leader in the development and manufacture of advanced technical ceramics and other engineered materials. Recognized worldwide for technical expertise and nearly a century of production experience, CoorsTek is uniquely positioned to supply amazing manufacturing solutions.

CoorsTek is committed to providing the service and quality that customers have come to expect. CoorsTek is ISO 9001 and TS 16949 Certified to ensure product quality and traceability. Customer satisfaction is our goal.

CoorsTek has a highly qualified staff to assist with material selection and product design. Please contact us as noted below for more information.

I. Scope and Intent

This publication is designed to provide engineers with design guidelines, material property information, inspection methods and quality standards for CoorsTek thick-film alumina substrates. These guidelines will aid in optimizing substrate design and material selection in order to meet technical requirements cost-effectively.

If a substrate design does not comply with these guidelines, CoorsTek may still be able to offer options to specific design requirements. It is our practice to indicate exceptions to customer prints and specifications should they differ from these guidelines, for the purpose of offering alternatives and possible cost reduction.

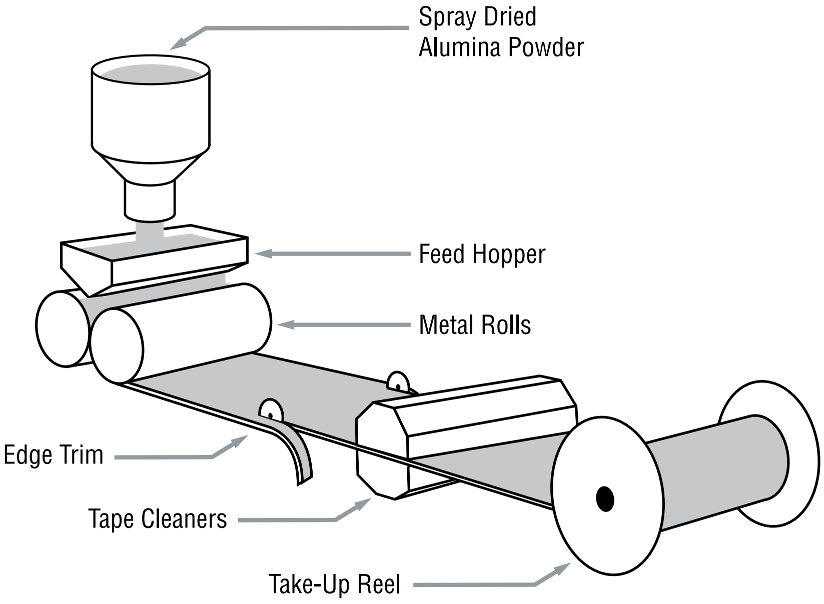
II. Technology Overview

Roll compaction is a method of fabricating continuous thin sheets of ceramic materials by compacting flowable ceramic powders in a rolling mill. This fabrication technology allows parts to be manufactured to precise dimensional specifications, yields two identical working surfaces and tighter thickness control. CoorsTek roll compaction substrate technology incorporates three basic steps: spray dried powder preparation, tape fabrication by roll compaction and sintering.

Initially, the raw materials (which consist of high purity ceramic powders) are ball-milled with dispersants, organic binders and plasticizers to achieve proper particle size distribution and slurry rheology. The slurry is then spray dried to form a flowable powder that can be fabricated into a tape when roll compacted.

The roll compaction process is related to dry pressing in that it uses spray dried alumina powders as feedstock. However, the process differs in the type and amount of binders and plasticizers used in order to fabricate a flexible, continuous sheet of tape.

The process consists of a powder-feed system, which continuously replenishes a reservoir above the metal rolls. The powder is controllably presented to the rolls where it is subsequently compacted to form a continuous sheet of tape. This tape is then edge trimmed, cleaned and collected on a take-up reel.



Roll Compaction Process

II. Technology Overview (cont'd)

Tungsten carbide tooling is used to mechanically punch the tape, producing parts of the desired green size and shape. Following the tape punching process, the parts are sintered by passing them through a high-temperature tunnel kiln. The sintering process brings about several significant changes in the ceramic part: total surface area is reduced, bulk volume is reduced and strength is increased. The process produces polycrystalline, homogeneous parts having the desired physical and electrical properties.

Green scored substrates are produced in the same tape manufacturing process with reliance on specialized tooling to form the score lines in the unfired substrate. As the tool produces the substrate shape, score blades in the tooling penetrate the part surface to a controlled depth. The substrate can then be singulated by the customer at the appropriate time. Dimensional and design criteria discussed in this specification generally apply for green scoring with some exceptions. It is suggested that the customer's design department discuss specific requirements during the design phase to minimize costs. Green scoring can be an economical alternative to laser scribing. However, there is usually a tolerance trade-off due to shrinkage of the tape.

III. As-Fired Substrates Design Guidelines

The following design standards represent factors that should be considered to ensure optimal substrate design and material selection. Material samples are available on request so that the design or process engineer can determine, by proof test, the product specifications that best fit the process needs.

A. Materials

1. ADS-96R Thick-Film substrates are engineered to minimize as-fired resistor variations and maximize aged adhesion values. Superior resistor stability is achieved by controlling the substrates' effects on the temperature coefficient of resistance. ADS-96R is particularly well suited for small geometry, high resistor value circuitry.

2. ADSR-96R Thick-Film DuraStrate™ substrates are a fine-grained material which offers over a 20% increase in strength over the standard ADS-96R. DuraStrate material is primarily used in applications requiring substrates 0.020" thick or less.

3. ADOS-90R (opaque) is the alumina substrate material of choice for light-sensitive semiconductor device applications.

4. ADS-995R Mid-Film™ substrates are compatible with etchable ink and photo-formed systems, have higher flexural strength, higher thermal conductivity, higher dielectric constant with lower loss, uniform density and grain size.

B. Dimensional Criteria

1. <u>Length/Width Tolerances</u>

Economy	± 1½ % NLT ± 0.010" (±0.254 mm)
Standard	± 1% NLT ± 0.004" (± 0.102 mm)
Premium	± 0.5% NLT ± 0.003" (± 0.076 mm)

2. <u>Thickness Tolerances</u>

Applies to thicknesses from 0.010" (0.254 mm) to 0.140" (3.556 mm)

Standard	± 10% NLT ± 0.002" (± 0.0508 mm)

Lapping services are available for tighter tolerances.

Note: NLT=not less than

3. Camber Tolerances

Standard	≤ 0.003 in./in. (≤ 0.003 mm/mm)
Premium	≤ 0.002 in./in. (≤ 0.002 mm/mm)

Tighter tolerances available upon request. Lapping services are also available.

4. Hole Diameter Tolerances

Hole Diameter	Tolerance
0.015" (0.381 mm) - 0.029" (1.737 mm)	± 0.002" (± 0.051 mm)
0.030" (0.762 mm) - 0.099" (2.515 mm)	± 0.003" (± 0.076 mm)
≥ 0.100" (2.540 mm)	± 0.005" (± 0.127 mm) or ± 1%, whichever is greater

5. Hole-to-Hole Tolerance

Standard	± 1% NLT ± 0.004" (± 0.102 mm)
Premium	± 0.5% NLT ± 0.003" (± 0.076 mm)

C. Design Criteria

1. Hole-to-hole and Hole-to-edge spacing

Under no circumstances should the resulting wall between two holes be less than 1.5 times the thickness of the substrate.

2. Minimum Hole Diameters

Substrate Thickness	Minimum Hole Diameter
0.025" (0.635 mm) - 0.035" (0.889 mm)	0.015" (0.381 mm)
0.036" (0.914 mm) - 0.060" (1.524 mm)	0.020" (0.508 mm)
0.061" (1.549 mm) - 0.080" (2.032 mm)	0.025" (0.635 mm)

3. Tooled Corner Radius

Minimum 0.125" (3.175 mm) Radius recommended to maximize yields.

D. Thicknesses and Standard Sizes

CoorsTek offers thicknesses from 0.010" (0.254 mm) to 0.140" (3.556 mm). The most economical thickness range is 0.025" (0.635 mm) to 0.040" (1.016 mm).

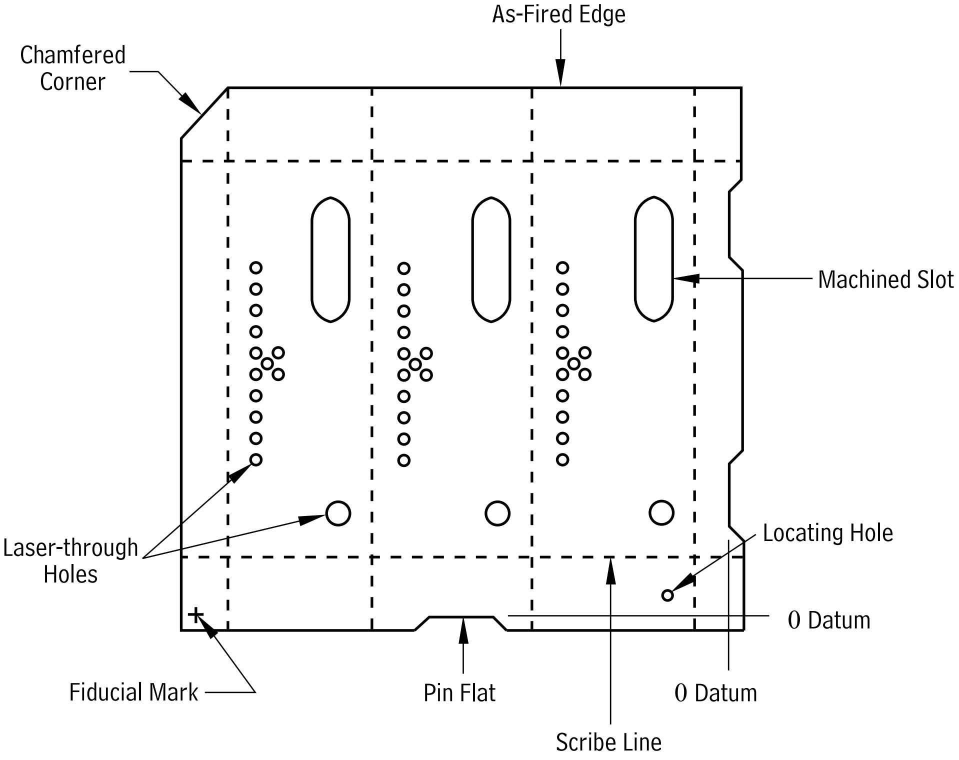
Standard Sizes:
3.5" x 3.5" (88.9mm x 88.9mm)
4.5" x 4.5" (114.3mm x 114.3mm)
4.5" x 6.5" (114.3mm x 165.2mm)
5.0" x 7.0" (127.0mm x 177.8mm)
5.5" x 6.5" (139.7mm x 165.2mm)

For complex geometries and sizes other than those listed above, please contact your CoorsTek sales representative.

IV. Laser Services

The following are designed to provide engineers with design guidelines, inspection methods, and quality standards for laser machining/profiling, drilling, and scribing of CoorsTek thick-film alumina substrates. These guidelines will aid in optimizing lasered substrate design in order to meet your technical requirements cost-effectively. The illustration below depicts some of our laser capabilities.

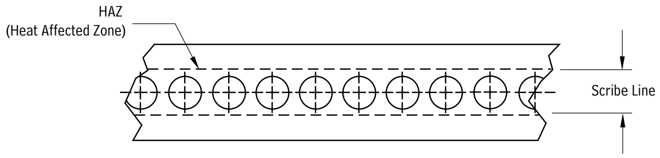
If a lasered substrate design does not comply with these guidelines, we may still be able to offer options to your specific design requirements. CoorsTek will indicate exceptions to customer drawings and specifications should they differ from these guidelines, for the purpose of offering alternatives and possible cost reduction. We offer services in design consultation, rapid prototyping and expedited deliveries for laser scribing, machining and annealing.



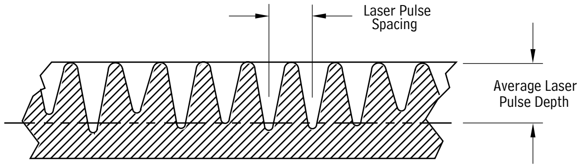
A. Laser Scribing

CoorsTek offers special differential scribing to enhance preferential singulation. By varying the laser pulse spacing and depth in the (x) and (y) scribe directions, the sequence of singulation may be controlled more precisely. Enhanced laser scribing helps to prevent hooking, chipping and premature breakage, which improves process yields. The following illustrations and tables show typical scribe line configurations and tolerances.

Top View of Lasered Scribed Line



Cross Section of Laser Scribed Line



CoorsTek Recommended Laser Scribing Parameters. These parameters can be adjusted to specific customer requirements.

Laser Scribed Tolerances

Nominal Substrate Thickness		Resultant Segment Tolerance From Two Broken Edges		Laser Scribed Edge To First Scribe Line	
(English)	(Metric)	(English)	(Metric)	(English)	(Metric)
0.010"	0.254 mm	+0.006" -0.002"	+0.15 mm -0.05 mm	+0.004" -0.002"	+0.10 mm -0.05 mm
0.015"	0.381 mm	+0.006" -0.002"	+0.15 mm -0.05 mm	+0.004" -0.002"	+0.10 mm -0.05 mm
0.020"	0.508 mm	+0.006" -0.002"	+0.15 mm -0.05 mm	+0.005" -0.002"	+0.13 mm -0.05 mm
0.025"	0.635 mm	+0.006" -0.002"	+0.15 mm -0.05 mm	+0.005" -0.002"	+0.13 mm -0.05 mm
0.030"	0.762 mm	+0.008" -0.002"	+0.20 mm -0.05 mm	+0.006" -0.002"	+0.15 mm -0.05 mm
0.035"	0.889 mm	+0.008" -0.002"	+0.20 mm -0.05 mm	+0.007" -0.002"	+0.18 mm -0.05 mm
0.040"	1.02 mm	+0.008" -0.002"	+0.20 mm -0.05 mm	+0.007" -0.002"	+0.18 mm -0.05 mm
0.050"	1.27 mm	+0.008" -0.002"	+0.20 mm -0.05 mm	+0.007" -0.002"	+0.18 mm -0.05 mm
0.060"	1.52 mm	+0.014" -0.002"	+0.36 mm -0.05 mm	+0.010" -0.002"	+0.25 mm -0.05 mm
0.080"	2.03 mm	+0.020" -0.004"	+0.51 mm -0.10 mm	+0.012" -0.003"	+0.30 mm -0.08 mm
0.100"	2.54 mm	+0.025" -0.004"	+0.64 mm -0.10 mm	+0.014" -0.003"	+0.36 mm -0.08 mm
0.120"	3.05 mm	+0.025" -0.004"	+0.64 mm -0.10 mm	+0.014" -0.003"	+0.36 mm -0.08 mm

Notes:
1. Laser machined edges to first scribe line tolerance is ± 0.002" (± 0.051 mm) for all substrate thicknesses.
2. Scribe line to scribe line tolerance prior to breaking is ± 0.002" (± 0.051 mm).
3. Perpendicularity and parallelism of scribe lines and/or scribed and broken edges will not exceed 0.0005 in/in (0.0005 mm/mm) when measured at the average laser pulse centers.

Standard Laser Scribed Pulse Depth & Spacing - Non Annealed

Substrate Thickness Range		Pulse Spacing		Pulse Depth	
0.010" - 0.012"	0.254 mm - 0.304 mm	0.004" ± 0.0005"	0.1016 mm ± .0127 mm	0.0045" ± 0.0015"	0.1143 mm ± 0.0381 mm
0.0125" - 0.017"	0.317 mm - 0.431 mm	0.005" ± 0.0005"	0.1270 mm ± .0127 mm	0.006" ± 0.003"	0.1524 mm ± 0.0762 mm
0.0175" - 0.022"	0.444 mm - 0.558 mm	0.006" ± 0.0005"	0.1524 mm ± .0127 mm	0.009" ± 0.003"	0.2286 mm ± 0.0762 mm
0.0225" - 0.027"	0.571 mm - 0.685 mm	0.006" ± 0.0005"	0.1524 mm ± .0127 mm	0.012" ± 0.003"	0.3048 mm ± 0.0762 mm
0.0275" - 0.032"	0.698 mm - 0.812 mm	0.006" ± 0.0005"	0.1524 mm ± .0127 mm	0.013" ± 0.003"	0.3302 mm ± 0.0762 mm
0.0325" - 0.037"	0.825 mm - 0.939 mm	0.006" ± 0.0005"	0.1524 mm ± .0127 mm	0.015" ± 0.003"	0.381 mm ± 0.0762 mm
0.0375" - 0.045"	0.952 mm - 1.143 mm	0.006" ± 0.0005"	0.1524 mm ± .0127 mm	0.018" ± 0.003"	0.4572 mm ± 0.0762 mm
0.0455" - 0.055"	1.155 mm - 1.397 mm	0.007" ± 0.001"	0.1778 mm ± .0254 mm	0.024" ± 0.005"	0.6096 mm ± 0.127 mm
0.0555" - 0.065"	1.409 mm - 1.651 mm	0.007" ± 0.001"	0.1778 mm ± .0254 mm	0.030" ± 0.005"	0.7620 mm ± 0.127 mm
0.0655" - 0.075"	1.663 mm - 1.905 mm	0.008" ± 0.001"	0.2032 mm ± .0254 mm	0.035" ± 0.005"	0.8890 mm ± 0.127 mm
0.0755" - 0.085"	1.917 mm - 2.159 mm	0.008" ± 0.001"	0.2032 mm ± .0254 mm	0.040" ± 0.005"	1.016 mm ± 0.127 mm
0.0855" - 0.095"	2.171 mm - 2.413 mm	0.009" ± 0.001"	0.2286 mm ± .0254 mm	0.045" ± 0.005"	1.143 mm ± 0.127 mm
0.0955" - 0.110"	2.425 mm - 2.794 mm	0.009" ± 0.001"	0.2286 mm ± .0254 mm	0.050" ± 0.005"	1.270 mm ± 0.127 mm
0.1105" - 0.125"	2.806 mm - 3.175 mm	0.009" ± 0.001"	0.2286 mm ± .0254 mm	0.060" ± 0.010"	1.524 mm ± 0.127 mm

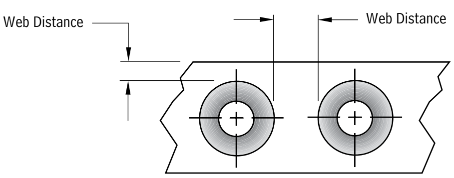
Standard Laser Scribed Pulse Depth & Spacing - Annealed

Substrate Thickness Range		Pulse Spacing		Pulse Depth	
0.010" - 0.012"	0.254 mm - 0.304 mm	0.004" ± 0.0005"	0.1016 mm ± .0127 mm	0.0055" ± 0.0015"	0.1397 mm ± 0.0381 mm
0.0125" - 0.017"	0.317 mm - 0.431 mm	0.004" ± 0.0005"	0.1016 mm ± .0127 mm	0.007" ± 0.003"	0.1778 mm ± 0.0762 mm
0.0175" - 0.022"	0.444 mm - 0.558 mm	0.005" ± 0.0005"	0.1270 mm ± .0127 mm	0.010" ± 0.003"	0.254 mm ± 0.0762 mm
0.0225" - 0.027"	0.571 mm - 0.685 mm	0.005" ± 0.0005"	0.1270 mm ± .0127 mm	0.013" ± 0.003"	0.3302 mm ± 0.0762 mm
0.0275" - 0.032"	0.698 mm - 0.812 mm	0.005" ± 0.0005"	0.1270 mm ± .0127 mm	0.014" ± 0.003"	0.3556 mm ± 0.0762 mm
0.0325" - 0.037"	0.825 mm - 0.939 mm	0.005" ± 0.0005"	0.1270 mm ± .0127 mm	0.016" ± 0.003"	0.4064 mm ± 0.0762 mm
0.0375" - 0.045"	0.952 mm - 1.143 mm	0.005" ± 0.0005"	0.1270 mm ± .0127 mm	0.019" ± 0.003"	0.4826 mm ± 0.0762 mm
0.0455" - 0.055"	1.155 mm - 1.397 mm	0.006" ± 0.0005"	0.1524 mm ± .0127 mm	0.025" ± 0.005"	0.635 mm ± 0.127 mm
0.0555" - 0.065"	1.409 mm - 1.651 mm	0.0065" ± 0.0005"	0.1651 mm ± .0127 mm	0.033" ± 0.005"	0.828 mm ± 0.127 mm
0.0655" - 0.075"	1.663 mm - 1.905 mm	0.0075" ± 0.0005"	0.1905 mm ± .0127 mm	0.038" ± 0.005"	0.965 mm ± 0.127 mm
0.0755" - 0.085"	1.917 mm - 2.159 mm	0.0075" ± 0.0005"	0.1905 mm ± .0127 mm	0.043" ± 0.005"	1.092 mm ± 0.127 mm
0.0855" - 0.095"	2.171 mm - 2.413 mm	0.009" ± 0.001"	0.2286 mm ± .0254 mm	0.045" ± 0.005"	1.143 mm ± 0.127 mm
0.0955" - 0.110"	2.425 mm - 2.794 mm	0.009" ± 0.001"	0.2286 mm ± .0254 mm	0.050" ± 0.005"	1.127 mm ± 0.127 mm
0.1105" - 0.125"	2.806 mm - 3.175 mm	0.009" ± 0.001"	0.2286 mm ± .0254 mm	0.060" ± 0.010"	1.524 mm ± 0.254 mm

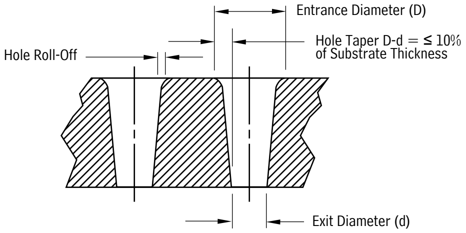
B. Laser Machining

Coorstek offers machining surface for precise hole location edge definition, and to produce custom shapes and sizes. The following illustrations and tables show typical configurations, design guidelines, and tolerances.

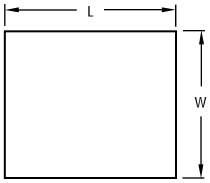
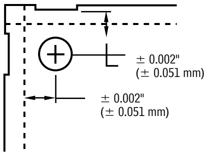
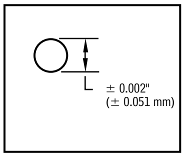
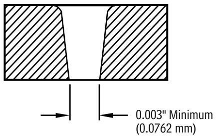
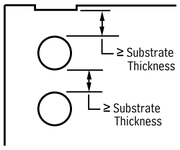
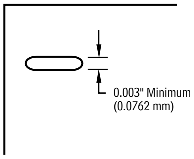
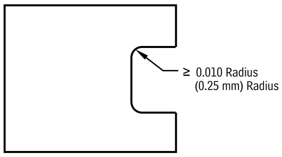
Top View of Laser Drilled Holes



Cross Section of Laser Drilled Holes

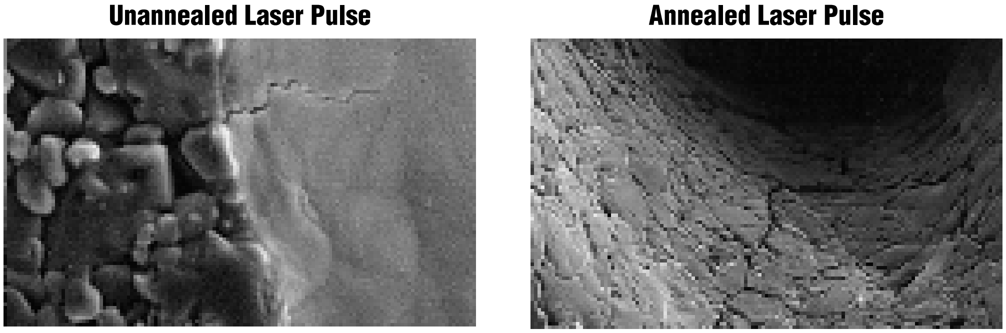


Laser Machining

Length and Width	± 0.002" (±0.051 mm)	
Hole Location	± 0.002" (± 0.051 mm) from any laser cut flat to hole centerline ± 0.002" (± 0.051 mm) from center of scribe lines to hole centerline ± 0.001" (± 0.026 mm) available upon request	
Hole Diameter	± 0.002" (± 0.051 mm)	
Minimum Hole Diameter	Minimum hole diameter typically = 0.003" (0.0762 mm)	
Minimum Web Thickness	Hole edge to another edge or between adjacent holes substrate thickness	
Minimum Slot Width	Minimum slot width typically = 0.003" (0.076 mm)	
Corner Radius	0.010" (0.254 mm) Radius Note: Specify internal corner radii rather than sharp corners (90°) to help reduce microcracking and chipping.	

C. Annealing

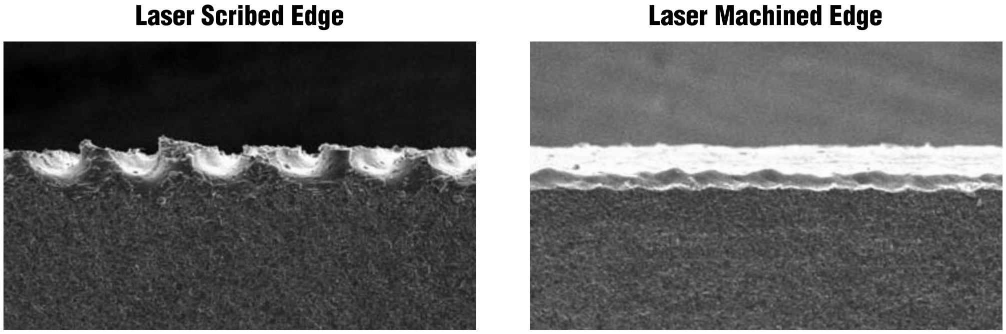
Annealing treatments are also available. CoorsTek offers annealing treatments to modify the microstructure of the heat affected zone (HAZ) in a laser drilled hole (reference photos immediately below) and/or to relieve any residual substrate stresses. The annealed microstructure provides an enhanced surface for metallization, thus improving via metal adhesion. The annealing process also increases the breaking force required for singulation of laser scribed substrates. Laser scribing parameters will be adjusted to result in desired singulation (as shown in the table on page 8).


Unannealed Laser Pulse
Annealed Laser Pulse

Scanning Electron Photomicrographs of ADS-96R (1,000x and 30° Tilt)

D. Lasered Edge Treatments

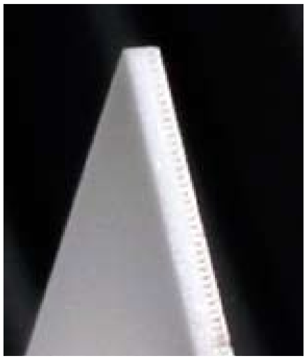
CoorsTek offers a variety of edge finishing treatments: laser scribed, laser scribed and brushed, SilkEdge™ substrates, SmoothEdge™ substrates, and laser-machined substrates. Contact your CoorsTek sales representative for availability of specific edge finishing treatments. Note: Laser edge treatment availability is geometry dependent.


Laser Scribed Edge
Laser Machined Edge

Scanning Electron Photomicrographs of ADS-96R (100x)

Laser Scribed Edge

SmoothEdge™ Substrates



SilkEdge™ Substrates

E. Tolerances

These specifications are based on the application of statistical process control methods to determine multibeam equipment capability to a Cpk of ≥ 1.33. Dimensional tolerances should be specified as close as necessary to facilitate process requirements and minimize cost.

V. Inspection

A. Requirement

CoorsTek uses ANSI standards for our in process and final inspection. The following is a list of our typical requirements.

Sampling Plan: ANSI Z1.4 Single Sampling Plan for Normal Inspection

Characteristics	Inspection Level	Measurement Device
External Sizes	General Inspection Level 1 AQL 1.0	Calipers, Micrometers
Internal Feature Location and Size	Special Inspection Level S-2 AQL 1.5	Optical Measurement Equipment, Pin Gages
Dye Check	Special Inspection Level S-2 AQL 1.5	Dye Penetrant
Camber, Final Inspection Camber, In process	General Inspection Level 1 AQL 0.65 100%	See methods section
Visual, Final Inspection Visual, In process	General Inspection Level 1 AQL 1.5 100%	See methods section
All Other Specifications	General Inspection Level 1 AQL 1.5	See methods section

B. Methods

1. Visual Inspection Procedures (reference table on page 13):
   As-Fired, Lasered, and Lapped: Visual only using low angle light with unaided eye.

2. Length/Width: Length and width dimensions are inspected using calipers or optical measurement equipment as dictated by tolerances.

3. Thickness: Thickness is measured using an 0.125" (3.175 mm) diameter anvil micrometer.

4. Surface Finish: Surface finish is measured with a 0.0002" (0.005 mm) radius stylus profilometer using a 0.100" (2.54 mm) cutoff. Published values represent the substrate’s typical or average surface finish. CLA (Centerline Average), Ra (Roughness average) and AA (Arithmetic Average) are equivalent terms.

Verification of Surface Imperfections

Surface Imperfection	Verification Method
Burrs, Blisters, Fins and Ridges	0-1" (0-25.40 mm) Micrometer
Pits, Holes, Pocks, and Chips	Low angle light, unaided eye
Cracks	Dye penetrant
Surface Marks (Scratches and Score Marks)	Profilometer

5. Surface Porosity: Dye penetrant is used to determine surface porosity and verify cracks.

6. Camber Test Method: CoorsTek substrates are 100% inspected for camber using two ground, parallel plates spaced at a fixed distance by the following formula:

   Camber distance setting, D = T + [C x L], where:
   T = nominal substrate thickness
   C = camber (inches per inch or mm per mm)
   L = substrate length or longest outside dimension

English example:	Metric example:
For a 4.0” x 3.5” x 0.025” substrate:	For a 101.6 mm x 88.9 mm x 0.635 mm substrate:
Nominal substrate thickness, T = 0.025”	Nominal substrate thickness, T = 0.635 mm
Camber, C = 0.003” per inch	Camber, C = 0.003 mm per mm
Longest outside dimension, L = 4.0”	Longest outside dimension, L = 101.6 mm
Camber distance setting,	Camber distance setting,
D = 0.025” + [0.003” per inch x 4.0”] = 0.037”	D = 0.635 mm + [0.003 mm per mm x 101.6 mm] = 0.9398 mm

   To inspect for camber, parallel plates are set at a 45° angle with a gap equal to the D value determined in the formula. Substrates that pass through the gap under their own weight are acceptable. Camber bar sets are available for purchase from CoorsTek.

7. Hole Sizes and Shapes: Hole diameters and shapes are verified using computer-enhanced optical measuring with top or back light equipment or pin gauges. Method of hole verification will be chosen for best correlation on hole size between CoorsTek and customer.

8. Hole Locations: CoorsTek’s standard procedure for inspection of hole locations is computer-enhanced optical measuring equipment on the entry side using top light.

9. Scribe Lines:

   a. Before Break: Scribe line locations are inspected using computer-enhanced optical measuring equipment.

   b. After Break: The part segments are inspected with digital calipers.

10. Chips: Inspection for chips is done under a high-intensity, low-angle light using the unaided eye.

11. Part Features: Location and size of part features are inspected with computer-enhanced optical measuring equipment.

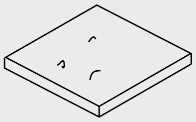
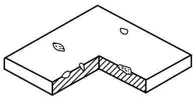
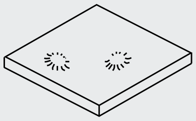
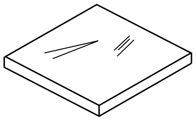
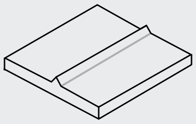
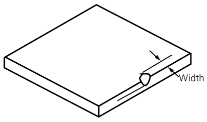
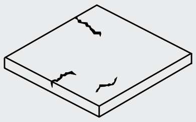
12. Pulse Depth: Average laser pulse depth is inspected on a substrate cross section using enhanced optical methods at a magnification of 30x. The average is determined over a minimum of 10 adjacent pulses.

13. Pulse Spacing: Average laser pulse spacing is inspected using enhanced optical methods at a magnification of 30x. The average is determined over 11 adjacent pulses.

14. Slag Height: Slag height is inspected with a micrometer and is not to exceed 0.001" (0.025 mm) in height.

15. Cracks: Inspection for cracks is performed using a dye penetrant or other appropriate techniques.

Surface Imperfections

Surface Imperfections		Acceptance Criteria
Burrs/Excess Body Fragment of excess material or foreign particle adhering to the surface		None > 0.001" (0.025 mm) High
Pits, Holes and Pocks A deep depression or void		None > 0.020" (0.508 mm) Diameter
Blisters Bubble or gaseous inclusion at the surface which, if broken, could form a pit, pock or hole		None > 0.001" (0.025 mm) High
Scratches Relatively long, narrow, shallow groove or cut in the surface		None > 0.0007" (0.017 mm) Deep
Bumps, Fins, Ridges Long, narrow protrusion on the surface		None > 0.001" (0.025 mm) High
Chips <u>Open:</u> Material broken off along an edge or corner <u>Closed:</u> Material has not broken off or separated		Print Face = None > 0.030" (0.762 mm) x 50% of thickness Waste Border = unlimited length x 100% of thickness
Cracks Line of fracture without complete separation		None

Note: The criteria in the table do not apply to substrates with surface areas greater than 35 square inches.
Please specify acceptance criteria for large area substrates when requesting quotation.

VI. Quality Assurance

A. Quality System

Our quality system is built around OpX™ – Operational Excellence, a practice that embraces Six Sigma Quality and Lean Manufacturing techniques. Quality is achieved by utilizing our customer's expectations to select target values and minimize variation around those values. The CoorsTek quality system is certified to ISO-9001 and TS 16949.

B. Acceptable Quality Level (AQL) Requirements

CoorsTek typically applies Z1.4 sampling by attributes, general inspection Level II, for visual and dimensional inspections. Level S2 sampling is implemented in applications where limited inspection is needed such as destructive test.

Typical Material Characteristics - This chart is intended to illustrate typical properties. Engineering data is representative. Property values vary somewhat with method of manufacture, size, and shape of part. This data is not to be construed as absolute and does not construe a warranty for which CoorsTek assumes legal responsibility.

Typical Material Characteristics

Characteristic	Unit	Test Method	ADOS-90R	ADS-96R	ADSR-96R DuraStrate™	ADS-995R MidFilm™
Alumina Content	Weight %	ASTM D2442	91	96	96	99.5
Color	–	–	Dark Brown	White	White	Ivory
Density	g/cm^3 (lb/ft^3)	ASTM C373	3.72 min. (0.134)	3.72 min. (0.134)	3.75 min. (0.135)	3.9 (0.141)
Hardness – Rockwell	–	ASTM E18, R45N	78	82	82	84
Surface Finish – CLA (as-fired)	Microinches (Micrometers)	Profilometer 0.0002" Radius Stylus 0.100" Cutoff ANSI/ASME B46.1	$\leq$ 45 ($\leq$ 1.14)	$\leq$ 35 ($\leq$ 0.89)	$\leq$ 35 ($\leq$ 0.89)	$\leq$ 35 ($\leq$ 0.89)
Average Grain Size	Micrometers	Intercept Method	5 - 7	4 - 7	1.5	2
Water Absorption	%	ASTM C373	NIL	NIL	NIL	NIL
Gas Permeability	–	*	NIL	NIL	NIL	NIL
Flexural Strength	Kpsi (MPa)	ASTM F394	53 (365)	58 (400)	70 (482)	64 (440)
Elastic Modulus	10^6 psi (GPa)	ASTM C623	45 (310)	44 (331)	44 (331)	55 (379)
Poisson's Ratio	–	ASTM C623	0.24	0.25	0.25	0.24
Coefficient of Linear Thermal Expansion	10^{-6}/°C (10^{-6}/°F)	ASTM C372				
25°-200°C			6.4 (3.6)	6.4 (3.6)	6.4 (3.6)	6.4 (3.6)
25°-500°C			7.3 (4.1)	7.2 (4.0)	7.2 (4.0)	7.2 (4.0)
25°-800°C			8.0 (4.4)	7.9 (4.4)	7.9 (4.4)	7.6 (4.2)
25°-1000°C			8.4 (4.7)	8.2 (4.6)	8.2 (4.6)	8.0 (4.4)
Thermal Conductivity	W/m°K (Btu • in/ft^2 • h • °F)	Various				
20°C			13 (90)	26 (180)	26 (180)	31 (215)
100°C			12 (83)	20 (139)	20 (139)	23 (160)
400°C			8 (56)	12 (83)	12 (83)	-
Dielectric Strength (60 cycles AC avg. RMS)	Volts/mil (Kv/mm)	ASTM D149				
0.025" thick			540 (21.3)	600 (23.6)	-	595 (23.4)
0.040" thick			-	490 (19.3)	470 (18.49)	-
Dielectric Constant (Relative Permittivity)	@ 25°C	ASTM D150				
1KHz			11.8	9.5	-	10
1MHz			10.3	9.5	9.55	10
Dissipation Factor (Loss Tangent)	@ 25°C	ASTM D150				
1KHz			0.1	0.0010	-	0.0003
1MHz			0.005	0.0004	0.0004	0.0003
Loss Index (Loss Factor)	@ 25°C	ASTM D150				
1KHz			1.2	0.009	0.009	0.003
1MHz			0.05	0.004	0.004	0.003
Volume Resistivity	ohm-cm or ohm-cm^2/cm	ASTM D1829				
25°C			$> 10^{14}$	$> 10^{14}$	$>4 \times 10^{14}$	$> 10^{13}$
300°C			4×10^{8}	1.0×10^{12}		$> 10^{9}$
500°C			–	1.0×10^{9}		$> 10^{8}$
700°C			7×10^{6}	1.0×10^{8}		$> 10^{7}$

*Helium leak through a plate 1" diameter by 0.010" thick measured at 3 x 10-7 torr vacuum versus approximately one atmosphere of helium pressure for 15 seconds at room temperature.

IX. Glossary

The following design standards represent factors that should be considered to ensure optimal substrate design and material selection.

Annealing – Heat treatment of thick and thin film ceramic substrates to thermally modify the heat-affected zone (HAZ) allowing for improved via metal adhesion or, in some cases, to relieve residual stresses.

As-Fired Edge – The edge of a substrate produced by mechanical punching of unfired (green) ceramic tape.

Edge Treatment – The edge of a substrate produced by an abrasion process on a laser scribed or as-fired edge.

Chamfered Corner – A unique reference used to locate the datum point and/or the working surface ("A" side) for thin film substrates (reference illustration, page 6)

Cut Slot – Laser machined feature through thickness of substrate with length greater than width (reference illustration, page 6).

Datum – Reference point (0,0) from which all other ceramic substrate features are measured.

Drilling – Laser machining of round holes through the substrate thickness.

Fiducial – A marking used as a standard reference for substrate orientation and alignment (reference illustration, page 6).

HAZ – Acronym for Heat Affected Zone. Region of material adjacent to the laser scribe or cut.

Hole Roll-Off – In a cross-sectional view of a laser drilled hole, the radius at the intersection of the hole wall (tangent point) and the face of the substrate, on the beam entry side only (reference illustration 2, page 8).

Hooking – A small protrusion left along the edge after breaking. Hooks are considered acceptable if within overall specification limits.

LASER – Acronym for Light Amplification by Stimulated Emission of Radiation.

Laser Tick – An identifying reference mark typically found on the "B" face (non-working surface) of a thin film substrate, and "A" face of thick film substrates.

Locating Hole – Customer-specified optical and/or mechanical feature (reference illustration, page 6).

Machining/Profiling – Cutting through a ceramic substrate with a laser beam to produce a desired shape.

Multi-Up Design – A single substrate containing multiple laser scribed parts to allow for batch processing in the customer's process (reference illustration, page 6).

Pin Flat – Machined indentation, located on substrate edges, used for precise mechanical alignment of the substrate in the customer's process (reference illustration, page 6).

Pulse Depth – Average penetration distance of a laser pulse measured from the entrance side of the substrate (reference illustration 2, page 7).

Pulse Spacing – Separation distance between two adjacent laser pulses measured from centerline to centerline (reference illustration 2, page 7).

Scribing – To laser machine a line by perforating the material's surface. Separation of the material may then be done along the perforated line, thus achieving the desired part dimensions (reference illustration 1, page 7).

Singulation – Act of separating segments of the scribed substrate into the final part dimensions.

Slag – Resolidified ceramic material on the substrate's surface resulting from laser processing.

Tab – Ceramic material left inside a laser cut feature on the exit side of the substrate as the result of the start/stop point of the laser beam. Alternatives are available should this cause a problem to the function of the part.

Taper – Slope of the wall resulting from laser drilling and machining through the substrate thickness (reference illustration 2, page 8).

Web – Distance separating a hole from another substrate feature. This distance is measured from the hole entrance side (reference illustration 1, page 8).

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Thick-Film Ceramic Substrates Design Guide

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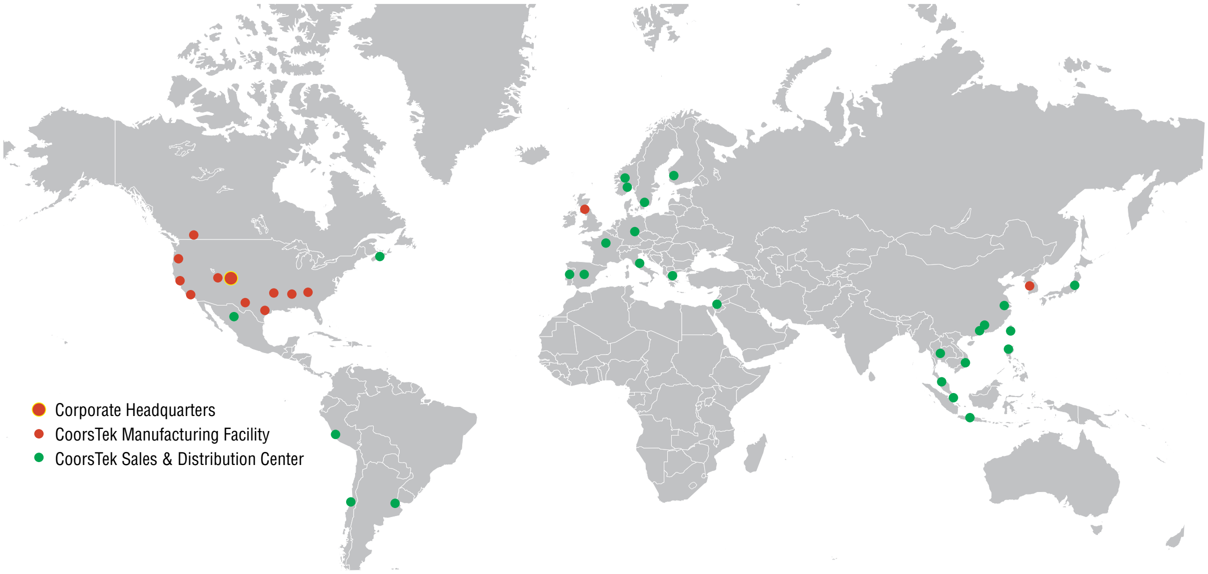

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