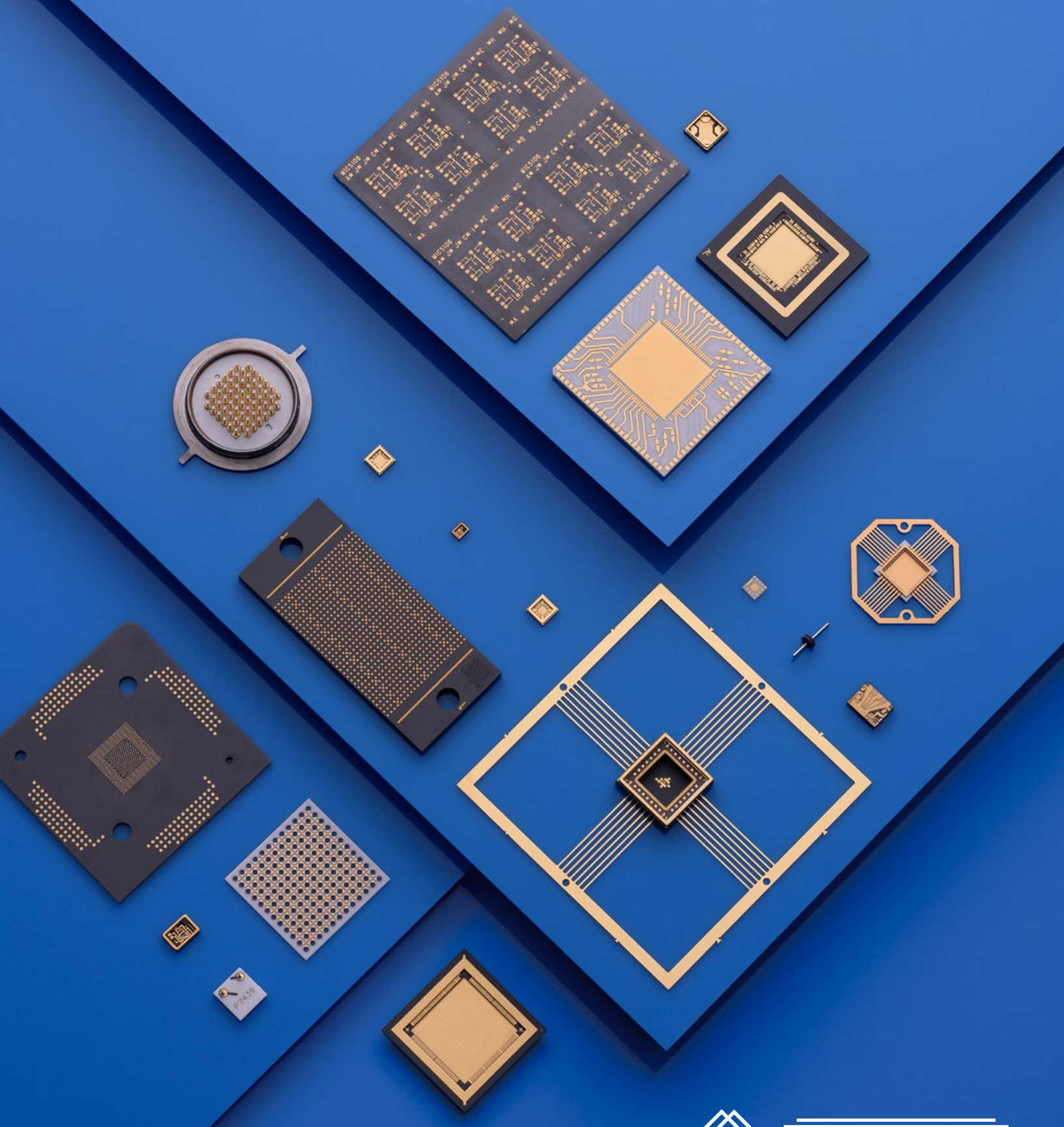
DESIGN GUIDELINES



AdTech Ceramics

ABOUT ADTECH CERAMICS

AdTech Ceramics is the leading US manufacturer of co-fired, multilayer ceramics, ideally positioned to assist with your critical custom packaging requirements. Manufacturing is based in Chattanooga, Tennessee where there is more than 120 years of continuous ceramic manufacturing history including some of the original multilayer patents conceived over 50 years ago. The ownership continues to invest in technology and equipment to meet today's requirements.

COMPANY OVERVIEW

AdTech Ceramics offers a full line of multilayer co-fired ceramic packages for electronic applications and is positioned to take on your challenging package designs. Additionally, in-house metal machining, plating and brazing operations allow for the economical prototype and production of complex ceramic packages and assemblies.

- A US based manufacturer of advanced ceramic packages.
- Fully integrated manufacturing with prototype to high volume capabilities.
- Experienced engineering and application guidance to facilitate package design.
- AS9100D and ISO9001:2015 Certified.
- NADCAP Certified.

PRODUCTS AVAILABLE INCLUDE

- Custom HTCC (high temperature co-fired ceramics) with alumina (Al_2O_3) or aluminum nitride (AlN)
  - Ceramic-to-Metal assemblies
  - Chemically and CNC milled metal components
  - QFN and LCC packages
  - Power dissipation designs
  - Microwave designs
  - Optical and photonic packages
  - Custom PGA and BGA packages
  - Feedthroughs
  - Multichip double-sided motherboards

Note: These general guidelines should be used for typical designs. If exceptions or special requirements are needed, they should be reviewed with AdTech Ceramics.

PROCESS OVERVIEW

AdTech Ceramics is the leading US manufacturer of custom hermetic ceramic and metal packages. Ceramic and metal powders are sourced to precise specifications to produce HTCC packages in Al_2O_3 or AlN. The processes have been documented to AS9100D standards to meet the most rigorous industry standards. Capabilities include tape casting, co-fired metallization, multilayer ceramic processing, chemical milling, metal machined components, brazed assemblies, and electrolytic/electroless plating.

MATERIALS PREPARATION

Ceramic materials are prepared by milling precise amounts of raw materials into a homogeneous slurry. This mixture is principally ceramic powders of controlled particle sizes with fluxes and small amounts of organic binders and solvents. This slurry is poured onto a carrier and then passed under a blade to produce a uniform strip of specific thickness. When dried, this strip becomes a ceramic-filled "tape" which is easily handled for unfired processing.

Metal powders of exact compositions and particle sizes are prepared as "pastes" for subsequent screen printing on the green ceramic tape, or in some cases, on the fired ceramic. Likewise, ceramic powders can be prepared as pastes to be used as screen printed dielectric layers.

GREEN PROCESSING

Individual products are arranged in arrays for sheet processing. Via holes, edge castellations and cavities are then punched in the tape. Because of the abrasive nature of ceramics, special tooling must be used for these operations. Green processing of ceramic is sensitive to particulates and is performed in a clean, controlled environment.

Via holes are filled with a refractory metal paste, or bore coated, to become the vertical electrical interconnections between the layers. Conductive circuit patterns are printed onto the ceramic tape with refractory metal pastes using precision screen printing.

The layers are then stacked and laminated together. At this point the array may be scored to allow post-fire operations in the array, or individual products may be cut or punched out of the array prior to sintering.

SINTERING (FIRING)

The ceramic-refractory metal composite structure is sintered, or "co-fired," at temperatures as high as 1600°C in a carefully controlled atmosphere. During the firing process most ceramics shrink approximately 20% in the X, Y and Z dimensions. Hot pressed AlN is physically constrained in the X and Y dimensions so that all shrinkage occurs in the Z dimension.

POST-FIRE PROCESSING

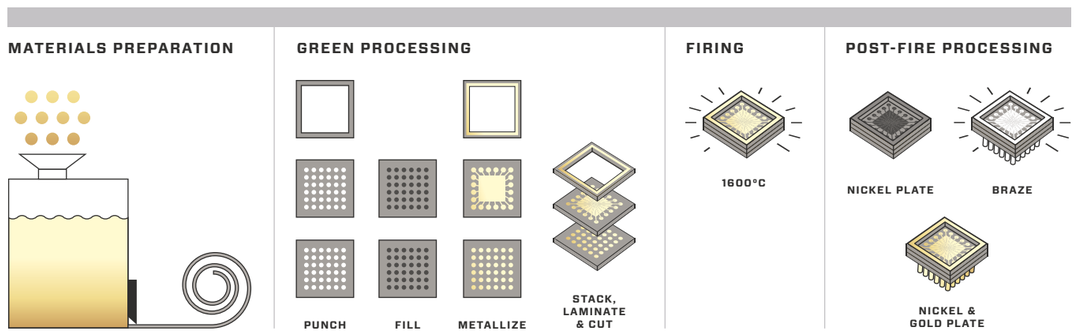
Ceramic packages are typically supplied with gold over nickel plating on the metallized areas, and can have metal components attached by brazing or soldering.

Nickel is plated on all exposed metal surfaces to allow brazing and to provide solderability. Metal leads, pins, seal rings and heat sinks are attached by brazing with silver or a silver-copper eutectic alloy to form a strong hermetic joint. Gold-tin and gold-germanium solders are also commonly used to hermetically bond gold plated components.

Final plating may be either electroless or electrolytic nickel and gold. Electrolytic plating requires that all exposed circuits be temporarily, electrically connected through a lead frame, internal tie bar, or a combination of the two.

A combination of electrolytic and electroless plating can be used if designs require. (Note: Metal components must be electrolytic.)

Post-fire metallizations can be used for applications requiring special flatness or precision tolerances. Ceramic dicing, lapping, polishing, laser or ultrasonic machining are available for applications requiring precise tolerances.



CERAMIC MATERIAL SELECTION

Custom ceramic packages are manufactured with materials to achieve our customer's specific thermal, geometric and quality goals.

CERAMIC MATERIALS

- Alumina (Al_2O_3)
- Aluminum Nitride (AlN)

METALLIZATION MATERIALS

- Tungsten (W)
- Molybdenum (Mo)
- Platinum (Pt)

Custom materials may be considered to meet special volume requirements

ALUMINA (92% Al_2O_3)

Alumina is the most commonly used ceramic material for multilayer packages. The material is readily available, the processing and adaptation in the industry is mature, and the performance is well characterized. Alumina offers high strength, good thermal conductivity, hermeticity, and excellent electrical properties. It is the lowest cost high density interconnect for high reliability applications. Alumina is available in both white and dark.

ALUMINUM NITRIDE (AlN)

Due to its high thermal conductivity and excellent coefficient of thermal expansion (CTE) match to silicon, aluminum nitride is the ceramic material of choice for high heat dissipation and/or large chip applications. AdTech's aluminum nitride is produced using hot press technology.

Ideal for applications requiring high thermal conductivity (160 W/mK). The patented hot press process allows precision tolerances (±0.15%).

Aluminum nitride's primary application is for MCMs requiring multiple internal metal patterns (30+ layers possible) with vias only terminating on the top and bottom surfaces. The external metal patterns are applied using thin film processing on a precision surface finish having a standard flatness better than .001" / inch.

TYPICAL CERAMIC PROPERTIES

MATERIAL	UNITS	92% ALUMINA (Al_2O_3)	ALUMINUM NITRIDE (AlN)
Color		Dark or White	Translucent Gray
Density	g/cc	3.62 (0.131)	3.26 (0.118)
Flexural Strength	MPa (psi x 10^3)	443 (64)	280 (40)
Youngs Modulus	GPa (psi x 10^6)	275 (40)	340 (49)
Shear Modulus	GPa (psi x 10^6)	112 (16)	140 (20)
Surface Finish	µm (µ")	<1.14 (<45)	<0.76 (<30)
Thermal Expansion (25-300°C)	10^{-6}/°C (10^{-6}/°F)	6.57 (3.64)	4.00 (2.2)
Thermal Conductivity (25°C)	W/mK (BTU-in/ft^2-h-°F)	20.3 (141)	160 (1174)
Dielectric Strength	kv/mm (volts/mil)	11.6 (295)	13.0 (330)
Volume Resistivity	ohm-cm^2/cm	$>10^{14}$	$>10^{14}$
Dielectric Constant (1MHz)		9.2	8.6
Dielectric Constant (10 GHz)		9.2	8.2
Dissipation Factor (1 MHz)		0.0003	0.0001
Loss Factor (10 GHz)		0.003	0.0010

Note: Values are typical and should not be considered as specifications.

MATERIAL PROCESS SELECTION

Custom ceramic and metal packages are tailored using a wide variety of fabrication methods and materials to achieve our customer's specific thermal, geometric and cost objectives. Material and process selections defined with well-established design rules, material properties and continuous process improvement evolves with a foundation of over 50 years in multilayer microelectronics.

METALLIZATIONS

Co-fire metallization is largely dictated by the ceramic base material. Alumina and aluminum nitride require refractory metals such as tungsten (W) and molybdenum (Mo) for high temperature sintering in protective atmospheres. Platinum can be used for ultra-high temperature applications. A variety of thin film surface metal options are available.

BRAZED COMPONENTS

Kovar and Alloy 42 are materials of choice for brazed components due to the thermal expansion match with ceramics. However, other materials such as molybdenum, AlSiC, copper alloys, copper moly, and copper tungsten, BeO, and diamond composite materials can be brazed to metallized ceramic.

PLATING

AdTech offers electrolytic and electroless nickel in thicknesses typically from 50µ" to 300µ" and electrolytic and electroless gold in thicknesses typically from 30µ" to 100µ". Thicknesses outside these ranges may be possible. A combination of plating types can be realized. ENIG, ENEPIG and selective plating options are also available.

TYPICAL COMPONENT PROPERTIES

MATERIAL	MOLYBDENUM	(15-85) COPPER TUNGSTEN	ALLOY 42	KOVAR	ALLOY 194	BeO	TUNGSTEN
Thermal Conductivity @25°C (W/mK)	138	170	10.5	16.7	260	200-250	173
Coefficient of Thermal Expansion @25°C-100°C (x 10^{-6}/°C)	5.1	7.1	5.0	5.9	9.8	6.9	4.5
Electrical Resistance @25°C (x 10^{-6} ohm-cm)	5.2	6.1	72	49	1.7	n/a	5.5
Specific Gravity (g/cc)	10.2	16.8	8.1	8.4	8.9	2.9	19.3

METALLIZATION RESISTANCE (TYPICAL)

CERAMIC	92% ALUMINA (Al_2O_3)	ALUMINUM NITRIDE (AlN)
Metallization	Tungsten	Tungsten or Tungsten-Moly
Buried	.012 ohm/sq (Standard)	.015-.020 ohm/sq
	.008 ohm /sq (High Conductivity)	—
Surface	.005 ohm/sq (Gold Plated)	.005 ohm/sq (Gold Plated)
Vias	.003 ohm (0.25mm (.010") DIA x 0.25mm (.010") length)	—

PLATING SPECIFICATIONS

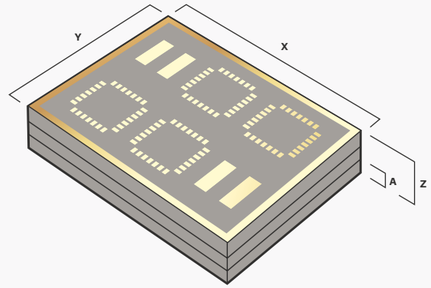
FINISH	PROCESS	SPECIFICATION
Gold	Electroless	MIL-G-45204 or AMS2422
	Electrolytic	MIL-G-45204 or AMS2422 or ASTM-B488
Nickel	Electroless - CVD	Meets the requirements of SAE AMS2404
	Electroless – NiP	SAE AMS2404
	Electrolytic	SAE AMS-QQ-N-290
ENEPIG	Electroless	n/a

STRUCTURAL & INTERCONNECT DESIGN GUIDELINES

Design considerations for multilayer ceramic packages can be grouped into these categories: Structural Parameters and Interconnect Layout. Customers create product designs following AdTech Ceramics manufacturing capabilities listed below.

STRUCTURAL PARAMETERS

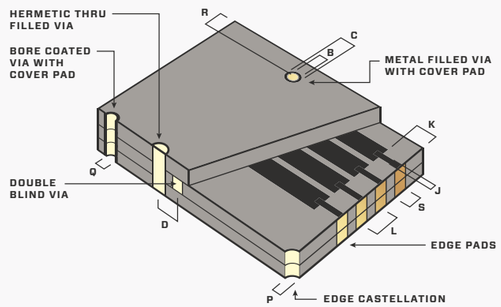
Each ceramic material has specific design and tolerance limitations due to its physical properties and processing technologies. These include size, number of layers and flatness.



FEATURES		UNITS	92% ALUMINA (Al_2O_2)	ALUMINUM NITRIDE (AlN)
Length/Width	(X/Y)	Standard Tolerances	± 1% NLT 0.13mm (.005")	± 0.13mm (.005")
		Special Tolerances	+/- 0.50%	± 0.05mm (.002")
Layer Thickness	(A)	Standard	0.18mm (.007") to 0.64mm (.025")	0.13mm (.005")
		Special	0.10mm (.004") to 0.76mm (.030")	0.09mm (.0035") to 0.25mm (.010")
		Standard Tolerances	± 10%	± 10%
		Special Tolerances	± 5%	n/a
Package Thickness	(Z)	Range	0.15mm (.006") - 5.08mm (.200")	0.51mm (.020") - 5.08mm (.200")
		Standard Tolerances	± 10%	± 0.08mm (.003")
		Special Tolerances	± 5%	± 0.03mm (.001")
Overall Flatness		Standard	0.08mm/mm (.003"/inch)	0.03mm/mm (.001")/inch
		Special (Machined)	0.03mm/mm (.001"/inch)	n/a
Surface Finish		As Fired	<1.14µm (45µ")	n/a
		Lapped	<0.51µm (20µ")	<0.64µm (25µ")
		Polished	<0.13µm (5µ")	<0.13µm (5µ")

VERTICAL INTERCONNECTS

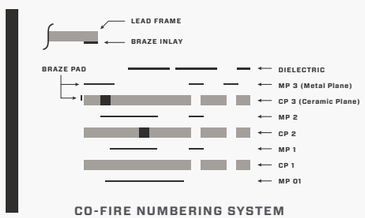
The basic interconnect between layers is the metal-filled via. Also used are bore coated (metallized side wall) vias, metallized edge castellations and flat edge metallization. Generally, via diameters should be at least the thickness of the ceramic layer and via pitch 2.5 times the layer thickness. Vias may require a cover pad to be printed with the metal interconnect pattern to assure optimal electrical connection between layers. Straight through vias are hermetic and staggering is not required.



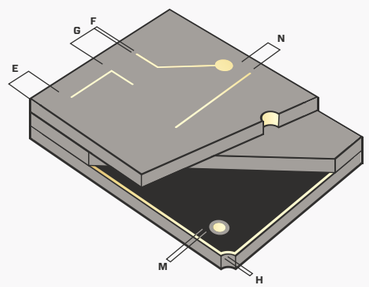
FEATURE		DESCRIPTION	92% ALUMINA (Al_2O_2)	ALUMINUM NITRIDE (AlN)
Filled Via	(B)	Diameter Range	0.10mm (.004") - 0.51mm (.020")	0.13mm (.005") - 0.51mm (.020")
	(C)	Cover Pad dia (Internal)	(B) + 0.05mm (.002")	(B) +0.05mm (.002")
	(C)	Cover Pad dia (External)	(B) + 0.13mm (.005")	(B) +0.38mm (.015")*
	(D)	Via-to-Via Centerline	0.30mm (.012") Min. [2.5x(B)]	0.38mm (.015") Min. [2.5x(B)]
	(R)	Via-to-Edge (Standard)	centerline = A+B (centerline = layer thickness + via diameter)	n/a
		Via-to-Edge (Sawed Edge)	(B/2) + 0.20mm (.008") Internal Via	B/2 + 0.20mm (.008") Internal Via
Bore Coated Via	(Q)	Diameter Range	0.30mm (.012") Min.	n/a
	(P)	Castellation Radius (Typical)	0.20mm (.008")	n/a
Edge Metallization	(L)	Centerline	0.46mm (.018")Min.	n/a
	(J)	Circuit Neckdown (Range)	0.10mm (.004") Min. to [S - 0.08mm (.003")]	n/a
	(K)	Pullback From Edge	0.51mm (.020") (TYP) 0.25mm (.010") Min.	n/a
	(S)	Minimum Pad Width	0.18mm (.007")	n/a

HORIZONTAL INTERCONNECTS

Circuit layout is usually a compromise between maximizing conductor trace width to minimize resistance, and maximizing the space between conductors and other metal features such as vias. It is desirable to pull back buried metal features from the ceramic edge, and neck down conductors that terminate with edge metallization.



CO-FIRE NUMBERING SYSTEM

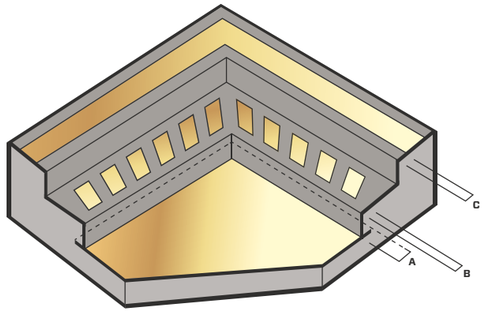


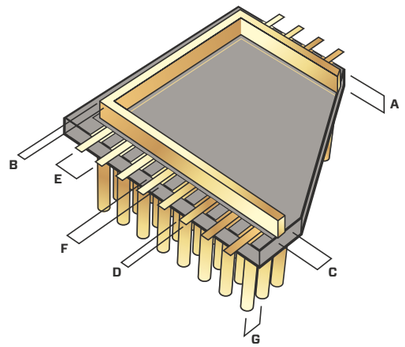
FEATURE		DESCRIPTION	92% ALUMINA (Al_2O_2)	ALUMINUM NITRIDE (AlN)
Internal Metal Circuit	(F)	Typical Width	0.13mm (.005") - 0.25mm (.010")	0.13mm (.005") - 0.25mm (.010")
		Custom Width	0.10mm (.004")	0.10mm (.004")
	(G)	Typical Space	0.13mm (.005") - 0.25mm (.010")	0.13mm (.005") - 0.25mm (.010")
		Custom Space	0.10mm (.004")	0.10mm (.004")
		Maximum Coverage	100% (see "H")	75%
		Recommended Grid	N/A	Equal lines and spaces
	(H)	Preferred Space from Edge	0.76mm (.030")	0.254mm (.010")
		Custom Space from Edge (Sawed)	0.25mm (.010")	n/a
Surface Metal Circuit	(F)	Typical Width	0.13mm (.005") - 0.25mm (.010")	0.13mm (.005")*
		Custom Width	0.10mm (.004")	0.05mm (.002")*
	(G)	Typical Space	0.15mm (.006")	0.13mm (.005")*
		Custom Space	0.10mm (.004")	0.05mm (.002")*
		Maximum Coverage	100%	See "E"
	(E)	Preferred Space from Edge	0.25mm (.010")	0.254mm (.010")*
		Custom Space from Edge	0.00mm (.000")	0.18mm (.007")*
Relation to Vias	(M)	Preferred Isolation Ring Around Cover Pad	0.25mm (.010")	0.10mm (.004")*
		Custom Isolation Ring (External)	0.15mm (.006")	0.05mm (.002")*
		Custom Isolation Ring (Internal)	0.20mm (.008")	0.20mm (.008")*
	(N)	Preferred Circuit to Cover Pad	0.20mm (.008")	0.10mm (.004")*
		Custom Space (External)	0.13mm (.005")	0.05mm (.002")*
		Custom Space (Internal)	0.15mm (.006")	0.15mm (.006")*

*External Thin Film Process (Internal guidelines same as HTCC Alumina)

SPECIAL FEATURE DESIGN GUIDELINES

Special consideration should be given to the following features:
Cavities, Metal Components, Wire Bond Pads, and Special Enhancements or Finishes.





CAVITIES

Cavities are punched into the ceramic in its green state. Metallization should generally be pulled back from the edges of cavities. When cavity floors are metallized, the metallization should extend beyond the cavity wall to assure complete coverage.

METAL COMPONENTS

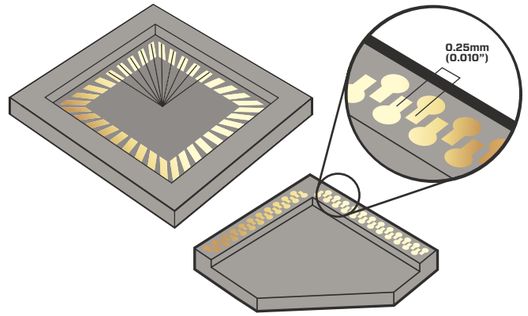
Metal components such as seal rings, heat sinks, lead frames and RF/Optical components may be attached to metallized patterns on the ceramic by high temperature brazing or soldering with AuSn or AuGe alloys. Leads may be necked down or formed in the braze pad area.

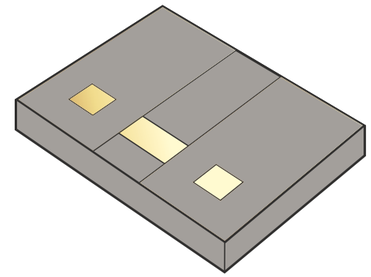
CAVITY DESIGN

FEATURE		DESCRIPTION	92% ALUMINA (Al_2O_3)	ALUMINUM NITRIDE* (AlN)
Die Attach Pad	(A)	Preferred Extension	0.51mm (.020")	n/a
		Minimum Extension	0.25mm (.010")	n/a
Circuit Pattern	(B)	Preferred Pull Back	0.13mm (.005")	n/a
		Minimum Pull Back	0.08mm (.003")	n/a
Metallized Seal Ring	(C)	Preferred Pull Back	0.25mm (.010")	n/a
		Minimum Pull Back	0.00mm (.000")	n/a
				* Post fired machining possible

METAL COMPONENTS

FEATURE		DESCRIPTION	SPECIFICATION
Seal Ring Height	(A)	Preferred	1.02mm (.040")
Seal Ring Width	(B)	Preferred	1.02mm (.040")
		Range	0.25mm (.010") (Minimum)
Metallized Seal Ring Width	(C)	Preferred	Seal Ring Width + 0.51mm (.020") Min.
Lead Frame Width	(D)	Preferred	0.20mm (.008")
Lead Frame Pitch	(E)		≥ 0.51mm (.020")
Metallized Lead Frame Pad	(F)	Minimum	D + 0.25mm (.010") (0.13mm (.005") minimum space between pads)
Metal Pin Pitch	(G)	Standard	2.54mm (.100")
		Custom	1.27mm (.050")





WIRE BOND PAD DESIGN

By designing wire bond pads in a radial pattern (from the center of the cavity) it is possible to compensate for variations in the co-fired shrinkage.

For very high density applications wire bond pads can be staggered in a double row around the die, achieving pads as small as 0.15mm (0.006") x 0.15mm (.006") on an effective 0.25mm (0.010") pitch.

SCREENED DIELECTRICS

Screen printed dielectrics are frequently used to cover exposed circuitry or form solder or braze dams. The composition of the screened dielectric is the same as that of the base ceramic and is generally applied in the green state for sintering during the co-fire process.

HTCC THERMAL ENHANCEMENTS

The thermal performance of co-fired alumina packages may be improved by adding a brazed heat sink such as molybdenum (Mo), copper tungsten (CuW), copper moly (CuMo), aluminum silicon (AlSi), copper moly copper (Cu/Mo/Cu), beryllium copper (BeO), or diamond composite materials.

POST-FIRE SPECIFICATIONS

The mechanical features and tolerances of a package may be realized using a variety of process options. Lapping and polishing can be used to achieve flatness and surface finish. Diamond sawing, laser, CNC and ultrasonic machining are available to achieve special requirements and tighter tolerances.

TOOLING ENGINEERING CAPABILITIES

AdTech's engineering staff can interface with and accept customer design data in a number of formats.

Design files can be accepted in: Autodesk® AutoCAD®, Autodesk® InventorTM, SolidWorks®, IGES, STEP and Gerber formats.

AdTech Ceramics can accept customer files sent to: sales@AdTechCeramics.com.

SINTERED AIN SOLUTIONS

Custom sintered AlN ceramics available.

DESIGN SERVICES

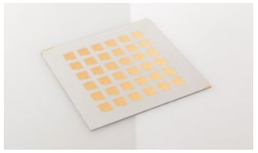
Microwave, electrical, routing, and thermal analysis needs can be considered if required

SPECIAL CAPABILITIES

AdTech Ceramics continues to lead the industry of Ceramic Multilayer Co-Fired Packages. Special Capabilities include Ceramic Metal Packages, Microwave and High Frequency Applications, Split Via/Edge Metallization, Pt Co-Fire, and various specialized plating processes. Co-fired ceramic technology was invented in our Chattanooga facility over 50 years ago, and today the company continues to lead the industry in innovative uses and technologies.

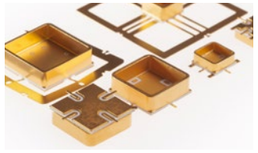
Pt CO-FIRE HTCC

AdTech's line of Pt co-fire packages combines the Al_2O_3 material system with platinum metal conductors. Screen printing Pt with hermetic vias using multilayer capability addresses harsh environmental and bio-compatible applications.



NON-MAGNETIC PACKAGING

AdTech's plating engineering team has developed a non-magnetic finishing option that is wire-bondable and solderable for special application requirements.

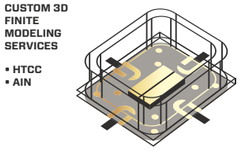


CERAMIC METAL PACKAGING

Co-fire ceramics provide superior high frequency performance and I/O capability, along with the electrical functionality and mechanical robustness of ceramic/metal braze joints. AdTech's extensive experience with multilayer co-fire combined with metal machining and brazing technology provides an avenue for new solutions in packaging technology.

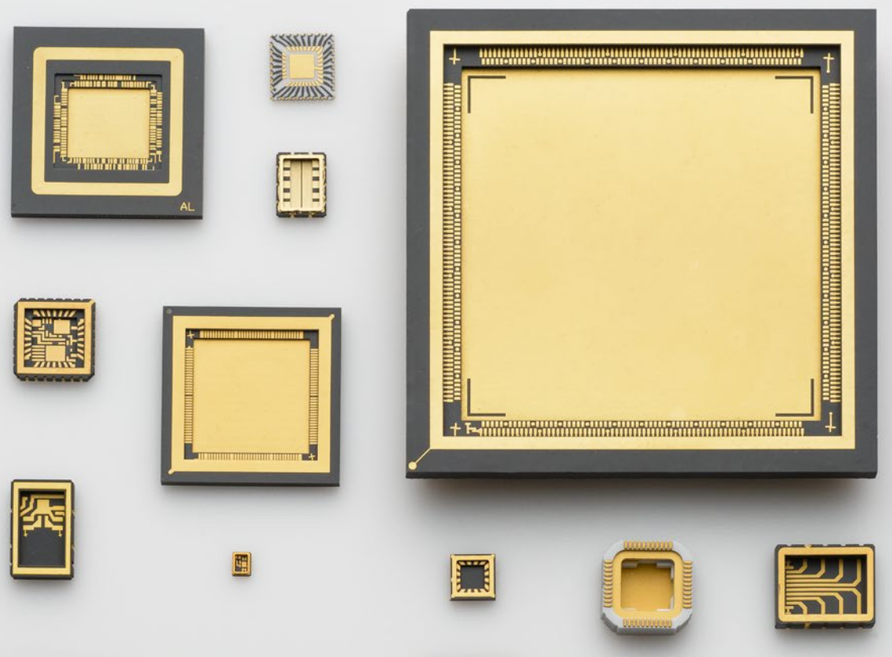
CUSTOM 3D FINITE MODELING SERVICES

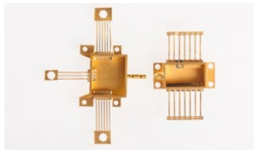
- HTCC
- AIN



MICROWAVE DESIGN ASSISTANCE

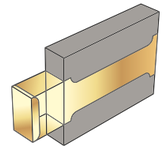
AdTech produces Al_2O_3 and AIN packages for microwave applications in the X through K band frequency ranges. Our partner's design process uses state of the art 3-D Finite Element Method (FEM) simulators and proprietary numerical simulators. This process can yield market-differentiating performance while maintaining cost effective solutions.





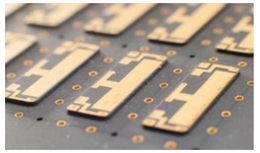
HIGH FREQUENCY APPLICATIONS

AdTech's ceramic packages are able to support high frequency applications with demonstrated performance up to 95 GHz.



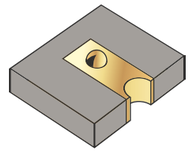
SPLIT VIA EDGE METALLIZATION

AdTech's patented "split-via" concept provides an exceptionally reliable method of edge metallization without concern for processing damage at the point where metallization wraps around the edges. Traditional screened edge metallization is also available.



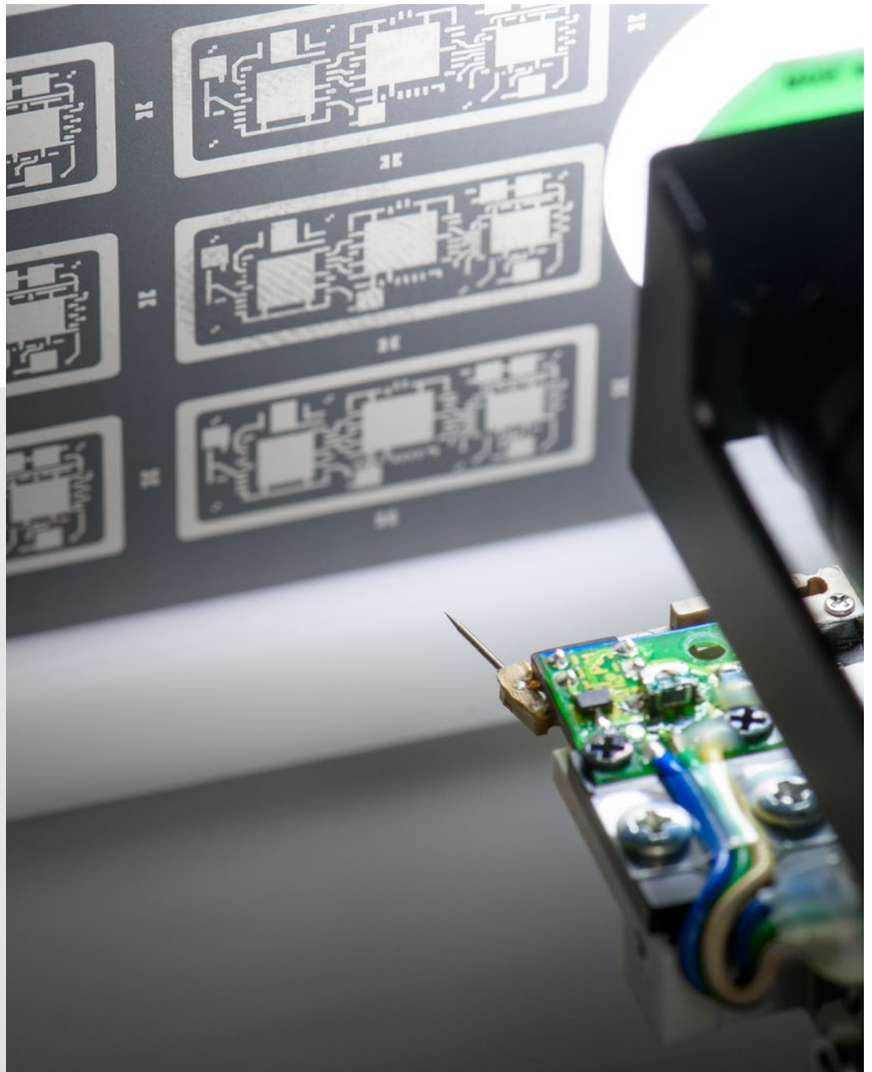
SELF-ALIGNING PEDESTALS & SEAL RINGS

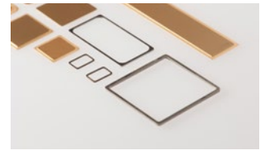
A ceramic pedestal may be used in the package design to allow for self-jigging of metal or ceramic lids, or as an isolated ceramic seal ring. Circuitry can be added to a pedestal that connects to the package base.



REFRACTORY METAL STANDOFFS

For the ultimate in standoffs, AdTech can co-fire refractory metal "bumps" on BGAs or substrates that will retain their shape through multiple solder reflow operations.





CHEMICAL MILLING

In addition to ceramic products, AdTech makes and supplies high quality chemically milled products in Kovar, alloy 42, stainless and spring steel. Products include step lids, lead frames, seal rings and other custom applications. Products can be supplied as etched, or with Ni/Au plating for seam welding and solder attach applications.

CNC MACHINING OF METAL COMPONENTS

AdTech fabricates, builds, and supplies precision machined alloys used in high reliability applications.

AdTech Ceramics

- Aerospace
- Medical
- Industrial
- Defense
- Commercial

ASSOCIATED COMPANIES

STATEK Est. 1970

Ultra-Miniature Quartz Crystals, Oscillators and Sensors

GREENRAY

Frequency Control Solutions

AS9100D &
ISO 9001:2015
Certified RoHS
Directive Compliant
REACH Compliant
NADCAP Certified

sales@AdTechCeramics.com
AdTechCeramics.com

511 Manufacturers Road
Chattanooga, Tennessee 37405, USA

(423) 755-5400
AdTechCeramics.com