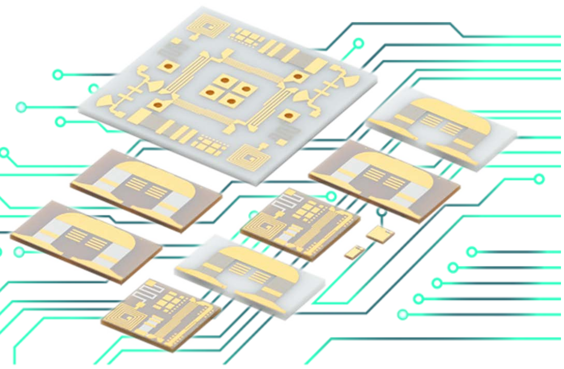
Thin Film Substrates
Product Introduction



✿ Product Overview

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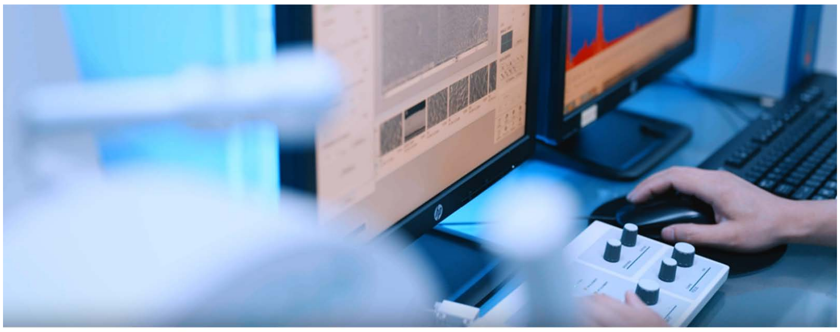
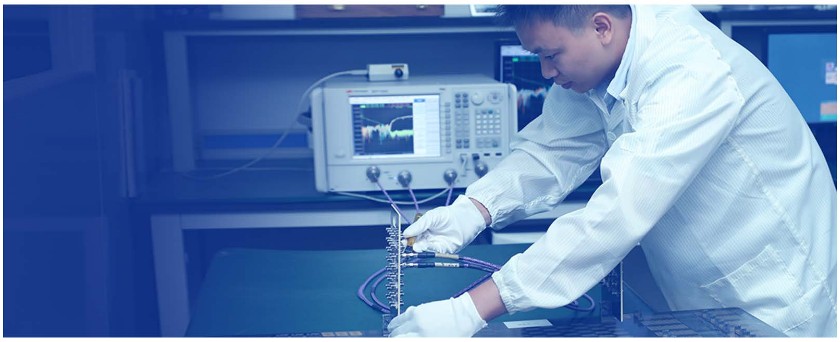
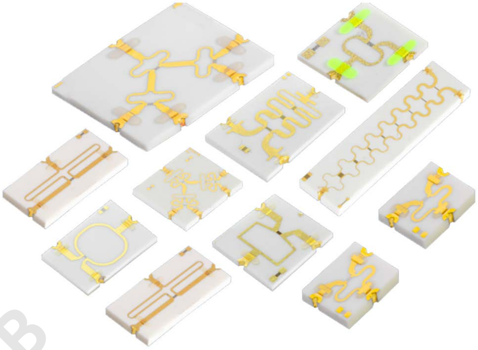




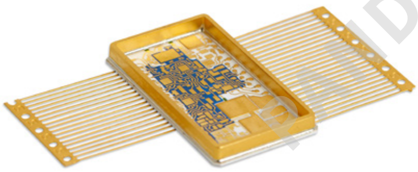
✿ Product Overview

What are Thin Film Substrates ?

Thin Film Substrates, are advanced materials used to deposit metal thin films, typically copper, onto ceramic substrates through techniques such as physical vapor deposition (PVD), chemical vapor deposition (CVD), direct bonding copper (DBC), direct plate copper (DPC), and active metal brazing (AMB), which utilize vapor-phase deposition to form a uniform and controlled metal layer on the ceramic surface, resulting in a composite material that combines the mechanical robustness of ceramics with the excellent electrical performance of metals.



Thin Film Substrates offer precise, uniform metal layers, essential for manufacturing accurate electronic components and circuits. The ceramic substrate provides excellent thermal conductivity and mechanical strength, enabling high-temperature performance and efficient heat dissipation. With a low coefficient of thermal expansion, they remain stable under temperature fluctuations, making them ideal for miniaturized, high-density integrated circuits.



What are Thin Film Deposition Technologies ?

Thin Film Deposition Technologies involve depositing thin material layers onto substrates. The processes transform materials into vapor or gas phases, which are then deposited onto the substrates using physical or chemical methods, creating films with specific properties.

- **Chemical Vapor Deposition (CVD):** Gaseous precursors react to form a solid film, used in semiconductors and solar cells. Variants include Low-Pressure, High-Pressure, and Metal-Organic CVD.
- **Physical Vapor Deposition (PVD):** Solid material is evaporated or sputtered into gas and deposited as a thin film. Common techniques are evaporation deposition and magnetron sputtering.
- **Direct Plasma CVD (DPC):** Plasma enhances CVD reactions, improving film quality and deposition rate, widely used in semiconductor and display manufacturing.
- **Direct Bonded Copper (DBC):** Copper is bonded to a ceramic substrate for high thermal conductivity and mechanical strength, ideal for power modules.
- **Active Metal Brazing (AMB):** High-temperature metal bonding forms strong films, used for connecting microelectronic components.

Key Advantages of Thin Film Substrates :

- **Excellent Electrical Performance:** The conductive metal thin films provide excellent electrical performance, ideal for high-frequency circuits and precision devices. Their low resistance and inductance support high-speed signal transmission and efficient power management.
- **Controllable Size and Miniaturization:** Thin Film Substrates can be precisely sized for integrated circuits and small devices.
- **High Precision and Uniformity:** Using deposition techniques like PVD or CVD, thin-film substrates achieve uniform metal layers with high precision, ensuring stable, reliable performance in electronic components.
- **Excellent Thermal Management:** With ceramic as the base material, thin-film substrates offer excellent thermal conductivity for efficient heat dissipation, ideal for power amplifiers and RF modules.
- **High Mechanical Strength and Stability:** Ceramic substrates provide high mechanical strength and resistance to external forces, corrosion, and harsh environments, ensuring stability in demanding conditions.
- **Low Coefficient of Thermal Expansion:** The low thermal expansion of ceramic materials maintains dimensional stability under temperature changes, ensuring reliable performance in high-frequency or high-power applications.

✿ Product Overview

Appilcations of Thin Film Substrates :

1, High-Frequency & High-Power Devices:

- RF & Microwave Components: Ceramic substrates reduce signal loss and improve transmission stability, making them ideal for RF filters, amplifiers, and antennas.
- High-Power Devices: Ceramic substrates effectively dissipate heat in power amplifiers and lasers, ensuring stable performance.

2, Semiconductor Packaging:

- High-Density Packaging: Ceramic substrates provide strength and thermal stability for complex, high-density circuits and heat management in chips.
- Optoelectronic Device Packaging: Used in packaging LEDs and laser diodes due to their durability and heat resistance.

3, Automotive Electronics:

- Engine Control Units (ECUs): Ceramic substrates excel in high-temperature automotive environments, especially in ECUs.
- Electric Vehicle (EV) Systems: Essential in EV components like battery management and motor drives, ensuring stable operation under high power and heat.

4, Optics & Laser Technology:

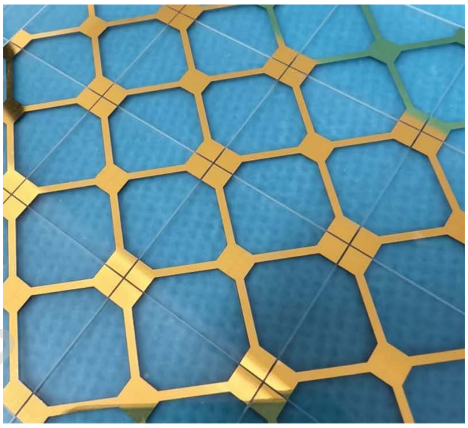
- Lasers & Systems: Ceramic substrates manage high power output without overheating, ideal for laser systems.
- Optical Devices: Used in sensors and interferometers for stability and precision.

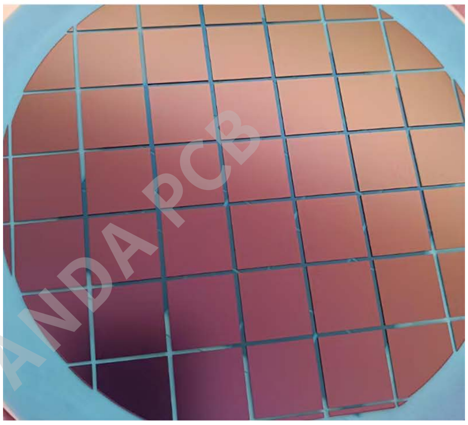
5, Military & Aerospace:

- Military Communication Devices: Ceramic substrates are crucial for radar and satellite communication systems, offering stability in extreme conditions.
- Aerospace: Used in flight control and navigation systems, ensuring reliability under temperature changes and vibrations.

6, Medical Electronics:

- Medical Imaging: Used in CT scanners and MRI machines for their precision and durability.
- Implantable Devices: Essential for pacemakers and neural stimulators, offering biocompatibility and long-term stability.





Differences Between Thick Film and Thin Film Substrates :

1, Manufacturing Process:

- Thick Film: Materials are deposited onto ceramic substrates via screen printing or inkjet printing, creating films from a few microns to hundreds of microns thick. It's a simple and cost-effective process suitable for mass production.
- Thin Film: Materials are deposited through techniques like CVD or PVD, producing films under a few microns thick.

2, Electrical Performance:

- Thick Film: Typically has lower electrical performance, with poorer conductivity and insulation. Environmental factors may affect the metal powders, causing degradation.
- Thin Film: Offers superior electrical characteristics like low capacitance and loss, making it ideal for high-frequency applications.

3, Thermal Performance:

- Thick Film: Has lower thermal stability and conductivity. While it can withstand high temperatures, its poor heat conduction may be a challenge in high-power applications.
- Thin Film: Offers better thermal stability and higher conductivity due to thinner layers, making it ideal for rapid heat dissipation in high-performance applications.

4, Mechanical Performance:

- Thick Film: With thicker layers, it has higher mechanical strength and impact resistance, suitable for applications where durability is key.
- Thin Film: Thinner layers result in weaker mechanical strength, making it more prone to damage and requiring careful design and handling.

5, Applications:

- Thick Film: Used in low to mid-frequency, high-power circuits, and applications needing less precision.
- Thin Film: Ideal for high-frequency, high-power, and precision electronics.

✿ Design Guidelines

Design Considerations of Thin Film Substrates:

1, Material Selection:

- Electrical Properties: Low resistance materials (e.g., silicon, glass, ceramics) ensure efficient conduction.
- Thermal Conductivity: High conductivity materials (e.g., copper, metal alloys) are critical for heat dissipation in high-power applications.
- Mechanical Strength: Hard, flexible materials (e.g., stainless steel, ceramics) ensure durability against cracking or warping.

2, Deposition Techniques:

- PVD (Physical Vapor Deposition): Common for high-quality, controlled thickness coatings.
- CVD (Chemical Vapor Deposition): Produces uniform, dense films with good adhesion.
- Other Methods: ALD or electrodeposition may be used based on specific requirements.

3, Film Thickness and Uniformity:

- Film thickness typically ranges from nanometers to micrometers, with uniformity critical for consistent performance.

4, Substrate Surface Preparation:

- Clean and smooth substrates improve adhesion and film quality.

5, Adhesion and Bonding:

- Strong adhesion ensures reliability, with techniques like surface priming or plasma treatment enhancing bonding.

6, Thermal Expansion Mismatch:

- Materials with similar thermal expansion rates prevent stress, cracking, or warping.

7, Environmental and Chemical Resistance:

- Resistance to harsh conditions (e.g., temperature, humidity, chemicals) is crucial for long-term durability. Protective coatings can enhance resistance.

8, Optical Properties (for Optical Applications):

- For optical applications, controlling refractive index, transparency, and reflectivity is essential.

9, Cost and Scalability:

- Material and deposition method choices affect cost and scalability. Mass production may benefit from large-area deposition or roll-to-roll processing.

1, Optional Substrates-1

Substrates :	Alumina ($Al2O3$)	Aluminum Nitride (AlN)	Beryllium Oxide (BeO)	Zirconium Dioxide ($ZrO2$)	Quartz Glass ($SiO2$)	Sapphire	Microwave Substrate
Max Application Operating Temperature (°C):	662 - 1832	1832	2300	2432	1200	2000	300
Max Power Density (W/in²):	75	1010	250	300	10	100	30
Max Ramp Up Speed (°F/sec):	122	572	400	350	20	20	10
Thermal Conductivity (W/mK):	20 ~ 35	180 ~ 220	200 ~ 300	2.0 ~ 5.0	1.3 ~ 1.5	30 ~ 40	4 ~ 6
Density (g/cm³):	3.75	3.26	2.8	5.9	2.2	3.98	3
Dielectric Loss:	0.0001 ~ 0.001	0.0001 ~ 0.0005	0.0001 ~ 0.0002	0.0005 ~ 0.001	0.0002 ~ 0.0005	0.0001 ~ 0.0003	0.0003 ~ 0.005
Dielectric Constant:	9.4 ~ 10.2	8.5 ~ 9.0	6.0 ~ 7.0	25 ~ 30	3.78 ~ 4.0	9.4 ~ 10.0	5.5 ~ 10.0
CTE, ppm/°C:	6.0 ~ 8.0	4.0 ~ 5.0	7.0 ~ 9.0	10.0 ~ 11.0	0.5 ~ 0.7	5.0 ~ 7.0	5.0 ~ 10.0
Substrate Thickness (mm):	0.25 ~ 2.0	0.25 ~ 2.0	0.25 ~ 2.0	0.25 ~ 2.0	0.2 ~ 2.0	0.3 ~ 2.0	0.5 ~ 3.0
Typical Max. Dimension (inch):	6 x 12	5 x 11	6 x 6	4 x 4	12 x 12	8 x 8	8 x 8
Theoretical Total Wattage (W):	5400	55000	15000	20000	20	100	50

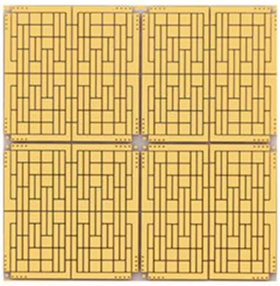
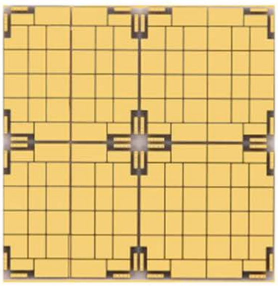
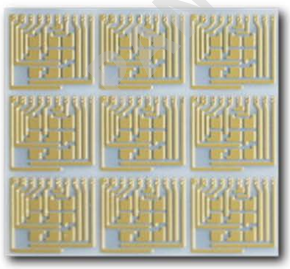
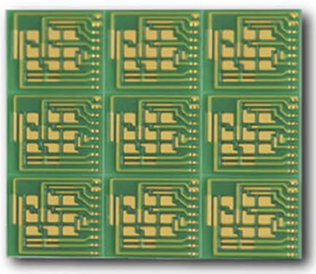
Optional Substrates-2

Substrates :	Ceramic Glass	Silicon Wafer	Silicon Nitride	Diamond			
Max Application Operating Temperature (°C):	800	400	1200	2000			
Max Power Density (W/in^2):	10 ~ 100	20 ~ 100	100 ~ 1000	>1000			
Max Ramp Up Speed (°F/sec):	5 ~ 10	10 ~ 20	20 ~ 30	50 ~ 100			
Thermal Conductivity (W/mK):	1 ~ 10	140	70	2200			
Density (g/cm^3):	2.5 ~ 3.0	2.33	3.2	3.5			
Dielectric Loss:	Low (typically <0.01)	Low	Very low	Extremely low			
Dielectric Constant:	4 ~ 7	11.7 (at 1MHz)	7 ~ 9	~5			
CTE, ppm/°C:	5 ~ 10	2.33	2.5 ~ 3.0	~1.0			
Substrate Thickness (mm):	0.2 ~ 1.0	0.1 ~ 0.5	0.1 ~ 0.3	0.1 ~ 0.5			
Typical Max. Dimension (inch):	12 x 12	12 x 12	6 x 6	4 x 4			
Theoretical Total Wattage (W):	200 ~ 500	500 ~ 2000	1000 ~ 5000	>5000			

- **Aluminum Oxide (Al_2O_3):** Good electrical insulation and high-temperature resistance, but lower thermal conductivity. It is suitable for general electronic and ceramic substrates.
- **Aluminum Nitride (AlN):** Excellent thermal conductivity and electrical insulation, ideal for high-power electronic applications, but more expensive.
- **Beryllium Oxide (BeO):** Exceptional thermal conductivity and electrical insulation, suitable for high-performance electronic devices, but its toxicity and cost limit widespread use.
- **Zirconium Dioxide (ZrO_2):** Excellent mechanical strength and wear resistance, suitable for high-temperature and high-pressure environments, but heavy and brittle.
- **Quartz Glass:** Good transparency and chemical stability, suitable for optical and high-temperature applications, but relatively brittle.
- **Sapphire:** High hardness and excellent thermal stability, commonly used in semiconductor substrates and optical windows, but expensive.
- **Microwave Dielectric Substrates:** Excellent high-frequency performance, suitable for microwave communication and RF applications, but with lower mechanical strength.
- **Microcrystalline Glass:** Good thermal stability and mechanical properties, suitable for precision electronic components, but may lose some properties at high temperatures.
- **Silicon Wafers:** A mature semiconductor material, ideal for integrated circuit manufacturing, but with lower thermal conductivity and susceptible to temperature changes.
- **Silicon Nitride (Si_3N_4):** High strength, thermal stability, and low thermal expansion, suitable for high-power and high-frequency applications, but more expensive.
- **Diamond:** Extremely high thermal conductivity, hardness, and wear resistance, widely used in cutting tools and thermal management, but difficult to process and very expensive.

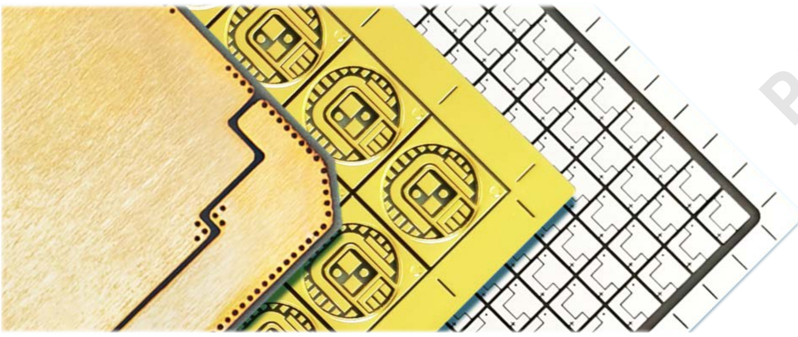
2, Optional Conductive Metal Material (Single Layers)

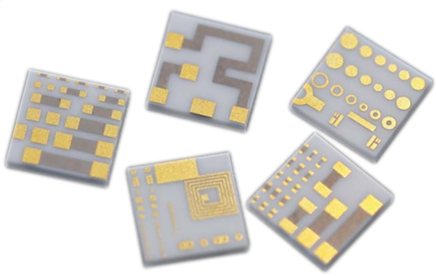
Layer Types	Metal Material	Electrical Conductivity (S/m)	Melting Point (°C)	Density (g/cm³)	Hardness (HV)	Corrosion Resistance	Thermal Expansion Coefficient (ppm/°C)	Operating Temperature Range (°C)	Applications
Conductor Layer	Copper (Cu)	5.8×10^7	1085	8.96	35	Poor	16.5	-200 to 250	Circuits, contact materials
	Gold (Au)	4.1×10^7	1064	19.32	25	Excellent	14.2	-100 to 250	High-reliability electronic devices
	Silver (Ag)	6.3×10^7	961	10.49	25	Poor	19	-200 to 300	High-frequency signal transmission
	Aluminum (Al)	3.8×10^7	660	2.7	15	Poor	23.1	-200 to 150	Low-power electronic devices
Adhesive Layer	Chromium (Cr)	1.4×10^7	1907	7.19	600	Excellent	5.9	-150 to 450	Coatings, adhesion enhancement
	Titanium (Ti)	2.4×10^7	1668	4.54	350	Excellent	8.6	-200 to 500	Adhesive layer, conductive layer
Isolation Layer	Molybdenum (Mo)	2.0×10^7	2623	10.28	150	Good	4.8	-200 to 300	Isolation, shielding materials
	Tungsten (W)	1.8×10^7	3422	19.25	400	Good	4.5	-200 to 350	High-temperature isolation layer
	Nickel (Ni)	1.4×10^7	1455	8.9	200	Good	13.4	-200 to 300	Isolation layer, soldering materials
Resistance Layer	Chromium (Cr)	1.4×10^7	1907	7.19	600	Poor	5.9	-150 to 450	Resistors, conductive layers
	Nickel-Chromium Alloy (NiCr)	1.0×10^6	1400	8.4	200	Poor	13.4	-100 to 400	Resistance layers, heating elements
	Aluminum-Nickel Alloy (AlNi)	3.5×10^6	660	7.12	150	Poor	22	-50 to 300	Resistors, sensors
Soldering Layer	Tin (Sn)	1.2×10^7	232	7.31	15	Good	23.3	-100 to 250	Soldering materials, contact layers
	Tin-Lead Alloy (SnPb)	6.0×10^6	183	8.53	40	Good	24	-100 to 250	Soldering layers, connection materials
	Silver Alloy (AgSn)	3.7×10^6	960	10.48	100	Poor	19	-50 to 250	High-efficiency soldering, contact layers
	Copper Alloy (CuSn)	5.8×10^7	1085	8.96	30	Poor	16.5	-200 to 250	Soldering, electronic component connections

3, Optional Metallization Processes

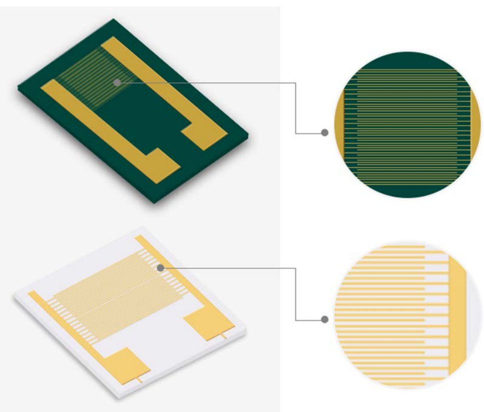
Metalization Types :	Thick Film Substrates (Screen-Printed)		Thin Film Substrates (Photo-Imaged)		
Process Types :	TFM Capabilities	HTCC / LTCC Capabilities	DBC Capabilities	DPC Capabilities	AMB Capabilities
Layer Counts :	1, 2, 3, 4 Layers	1, 2, 4, 6 Layers	1, 2 Layers	1, 2 Layers	1, 2 Layers
Max Board Dimension :	200*230mm	200*200mm	138*178mm	138*190mm	114*114mm
Min Board Thickness :	0.25mm	0.25mm	0.30mm~0.40mm	0.25mm	0.25mm
Max Board Thickness :	2.2mm	2.0mm	2.0mm	2.0mm	1.8mm
Conductor Thickness :	10um - 20um	5um - 1500um	1oz - 9oz	1um - 1000um	1oz- 22oz
Min Line Width/Space :	8/8mil (0.20/0.20mm)	6/6mil (0.15/0.15mm)	10/10mil (0.25/0.25mm)	6/6mil (0.15/0.15mm)	12/12mil (0.30/0.30mm)
Substrates Types :	Al203, ALN, BeO, ZrO2	Al203, ALN, BeO, ZrO2	Al2O3, AlN, ZrO2, PbO, SiO2, ZTA, Si3N4, SiC, Sapphire, Polycrystalline Silicon, Piezoelectric Ceramics	Al2O3, AlN, ZrO2, PbO, SiO2, ZTA, Si3N4, SiC, Sapphire, Polycrystalline Silicon, Piezoelectric Ceramics	Al203, ALN, BeO, ZrO2, Si3N4
Min Hole Diameter :	4mil (0.15mm)	4mil (0.15mm)	4mil (0.1mm)	4mil (0.1mm)	4mil (0.1mm)
Outline Tolerance :	Laser: +/-0.05mm Die Punch: +/-0.10mm	Laser: +/-0.05mm Die Punch: +/-0.10mm	Laser: +/-0.05mm Die Punch: +/-0.10mm	Laser: +/-0.05mm Die Punch: +/-0.10mm	Laser: +/-0.05mm Die Punch: +/-0.10mm
Substrate Thickness :	0.25, 0.38, 0.50, 0.635, 0.80,1.0, 1.25, 1.5, 2.0mm, Customizable	0.25, 0.38, 0.50, 0.635, 0.80,1.0, 1.25, 1.5, 2.0mm, Customizable	0.25, 0.38, 0.50, 0.635, 0.80,1.0, 1.25, 1.5, 2.0mm, Customizable	0.25, 0.38, 0.50, 0.635, 0.80,1.0, 1.25, 1.5, 2.0mm, Customizable	0.25, 0.38, 0.50, 0.635, 0.80,1.0, 1.25, 1.5, 2.0mm, Customizable
Thickness Tolerance :	0.25-0.38: +/-0.03mm 0.50-2.00: +/-0.05mm	0.25-0.38: +/-0.03mm 0.50-2.00: +/-0.05mm	0.25-0.38: +/-0.03mm 0.50-2.00: +/-0.05mm	0.25-0.38: +/-0.03mm 0.50-2.00: +/-0.05mm	0.25-0.38: +/-0.03mm 0.50-2.00: +/-0.05mm
Surface Treatment :	Ag, Au, AgPd, AuPd	Ag, Au, AgPd, AuPd	OSP/Ni Plating, ENIG	OSP/ENIG/ENEPIG	OSP/ENIG/ENEPIG
Min Solder PAD Dia :	10mil (0.25mm)	10mil (0.25mm)	8mil (0.20mm)	6mil (0.15mm)	8mil (0.20mm)

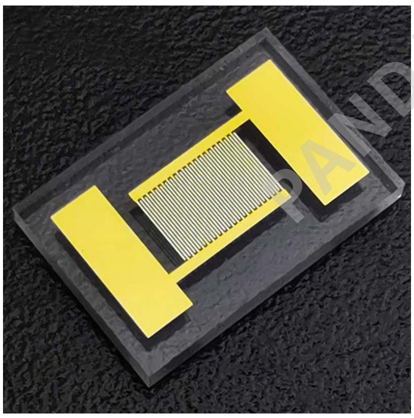


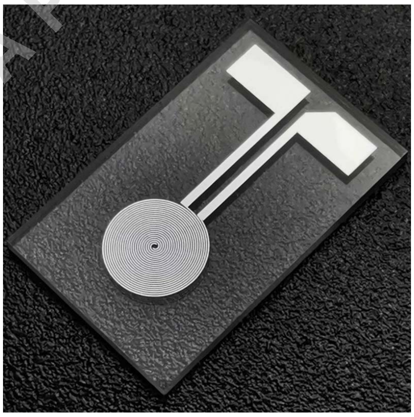


4, Thin-Film Composite Layers

Layer Types	Maximum Reflow Temperature (°C)	Gold Wire Bonding	Soldering Properties	Application Areas
Metal Thin-Film Composites (e.g., Au/Cr, Au/Ni)	250 - 350	Good	Suitable for low-temperature soldering, good contact and conductivity	Electronic packaging, chip connections, microelectronic components
Titanium/Metal Thin-Film Composites	250 - 300	Good	Can be soldered at high temperatures, strong corrosion resistance	Microelectronic devices, sensors, packaging materials
Aluminum/Titanium Thin-Film Composites	300 - 350	Fair	Good thermal stability and soldering performance, suitable for high-frequency applications	Integrated circuit packaging, microwave communication, power devices
Lead-Solder Alloy/Silver Thin-Film Composites	200 - 250	Moderate	Suitable for low-temperature reflow soldering, but sensitive to high temperatures	PCB soldering, electronic connections
Copper/Gold Thin-Film Composites	250 - 350	Fair	Good conductivity and thermal stability, suitable for high-power applications	Semiconductor device packaging, microelectronic component connections
Gold/Palladium Thin-Film Composites	250 - 300	Good	Good soldering properties, suitable for precision connections	High-end electronic components, sensor packaging, packaging applications
Silver/Gold Thin-Film Composites	200 - 250	Good	Good soldering properties, suitable for high-frequency and microwave soldering	High-frequency communication, microwave packaging, signal transmission
Tungsten/Gold Thin-Film Composites	300 - 350	Poor	Suitable for high-temperature applications, but poor soldering performance	Circuit connections in high-temperature environments, electronic packaging
Nickel/Titanium Thin-Film Composites	250 - 300	Fair	Good soldering properties and corrosion resistance, suitable for high-temperature environments	High-temperature sensors, environmental monitoring devices, electronic packaging
Aluminum/Copper Thin-Film Composites	200 - 250	Fair	Good conductivity, suitable for low-temperature soldering and high-frequency applications	Circuit boards, RF packaging, high-power electronic components
Chromium/Silver Thin-Film Composites	250 - 300	Good	Good soldering properties at lower temperatures, suitable for precision circuit soldering	High-precision electronic devices, sensors, integrated circuit packaging

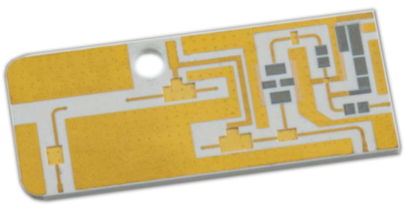


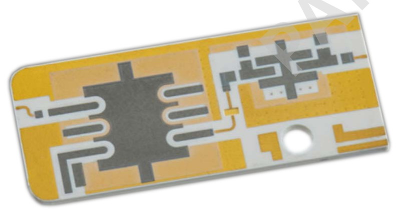


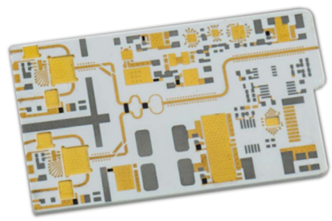


5, Engineering Design and Manufacturing Capabilities

Category	Parameter	Minimum Value/Range	Description
Circuits	Minimum Line Width (W)	10µm - 50µm	The minimum line width depends on material properties and equipment capabilities, typically ranging from 10µm to 50µm.
	Minimum Line Spacing (S)	10µm - 50µm	Line spacing is generally required to be between 10µm and 50µm, similar to line width.
	Line Dimension Accuracy	±5µm - ±20µm	Accuracy of dimensions, influenced by material, equipment precision, and process control.
	Alignment Accuracy	±5µm - ±10µm	Alignment precision is crucial for multilayer thin-film circuits; any error may cause circuit failure.
	Conductor Thickness	1µm - 10µm	The typical conductor thickness range can be adjusted based on requirements; thicker conductors are used for higher current needs.
	Minimum Line Width/Conductor Thickness Ratio	2:1 - 5:1	The ratio of line width to conductor thickness ensures reliable electrical performance.
	Minimum Line Bending Radius (R)	0.5mm - 1mm	For flexible circuits, the bending radius must ensure the stability of the lines without breaking.
Shapes	Minimum Hole Size (Ø)	0.1mm - 0.2mm	The minimum hole size is usually related to the line thickness and processing precision.
	Minimum Hole Center Distance (P)	0.2mm - 0.5mm	The minimum distance between holes, ensuring structural stability.
	Minimum Distance from Hole to Edge (Edge)	0.2mm - 0.5mm	The minimum distance from a hole to the edge of the circuit board, ensuring strength and reliability.
	Minimum Slot Width (W)	0.2mm - 0.5mm	Slot width should be within a reasonable range to ensure electrical performance and mechanical strength.
	Minimum Slot Inner Corner Radius (R)	0.2mm - 0.3mm	The radius of inner corners affects slot hole processing and longevity.
	Hole Depth-to-Diameter Ratio (L/D)	10:1 - 20:1	The ratio of hole depth to diameter, as deeper holes increase processing difficulty.
	Hole Taper (Conical Hole)	3° - 5°	The taper angle of the hole affects solderability and electrical performance, typically kept between 3° and 5°.
	Hole Wall Quality	Smooth, burr-free, crack-free	Hole walls should be smooth and free from defects to ensure good electrical contact and solderability.







6, Resistance and Capacitor Design and Manufacturing Capabilities

Category	Parameter	Minimum Range	Description
Resistor Materials	Resistor Material Selection	TaN, NiCr	Common resistor materials include TaN (tantalum nitride) and NiCr (nickel-chromium alloy).
	Resistance Range	10Ω ~ 1MΩ	The resistance value can be adjusted based on material thickness and surface treatment, usually ranging from 10 Ω to 1MΩ.
	Resistance Tolerance	±0.5% ~ ±5%	Tolerance is affected by material characteristics, process, and size control, typically ranging from ±0.5% to ±5%.
	Temperature Coefficient of Resistance (TCR)	50 ~ 300 ppm/°C	TCR affects the circuit performance under different temperature conditions, typically ranging from 50 to 300 ppm/°C.
	Minimum Resistance Line Width	5µm ~ 20µm	The minimum resistance line width is generally 5µm, ensuring good electrical contact and stability.
	Minimum Resistance Line Spacing	5µm ~ 20µm	The minimum line spacing typically ranges from 5µm, depending on design and process requirements.
	Resistor Power Handling Capability	0.1W ~ 1W	The power handling capacity is designed according to the circuit's power requirements and material thermal conductivity.
	Resistor Film Thickness	0.1µm ~ 1µm	The film thickness of thin-film resistors typically ranges from 0.1µm to 1µm, affecting resistance value and temperature coefficient.
Capacitor Materials	Capacitor Material Selection	SiO_2, Al_2O_3, TiO_2, AlN, BN, etc.	Common dielectric materials for capacitors include SiO_2 (silicon dioxide), Al_2O_3 (aluminum oxide), and AlN (aluminum nitride).
	Dielectric Constant (εr)	3 ~ 10	The dielectric constant affects the capacitor's capacitance value, usually ranging from 3 to 10.
	Capacitance Range	1pF ~ 100nF	The capacitance value can be adjusted based on design requirements, usually ranging from 1pF to 100nF.
	Capacitance Tolerance	±5% ~ ±20%	The capacitance tolerance typically ranges from ±5% to ±20%, influenced by material and process.
	Capacitor Film Thickness	0.1µm ~ 1µm	The film thickness affects the capacitor value and stability, generally ranging from 0.1µm to 1µm.
	Minimum Capacitor Electrode Size	10µm ~ 50µm	The minimum electrode size generally ranges from 10µm, determining the capacitor's surface area.
	Capacitor Dielectric Voltage Rating	10V ~ 100V	The voltage rating is determined by the capacitor's design and selected materials, usually ranging from 10V to 100V.
	Capacitor Dissipation Factor (tan δ)	≤ 0.005	The dissipation factor represents energy loss, typically required to be below 0.005, especially for high-frequency applications.
	Dielectric Thickness Control Precision	±0.1µm ~ ±1µm	The thickness control precision of the dielectric material is critical for capacitor stability and consistency.