Thin-Film Technology Overview and Custom-Design Guidelines

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THIN FILM TECHNOLOGY SERVICES

The Thin-Film Division at NANOWAVE Technologies Inc. manufactures microwave thin film circuits and RF passive components to serve the Space, Aerospace, Defense, Communications, Industrial and Medical industries.

The thin film facility houses more than 5000 sq-ft class 100 to class 10,000 clean room area. Thin film coating equipment includes 3-target sputtering systems, E-beam evaporation systems, and a CVD system, delivering a variety of reliable metallizations for conductor, barrier, resistor, and dielectric films. In addition to standard photo-patterning and etching, Ion-beam milling and the e-beam evaporation/lift-off lithography capabilities offer patterning to 10 micron ±3.0 micron precision.

Products include custom thin film circuits consisting of sputtered and electroplated gold and thick copper conductors, metalized or filled via holes, sheet resistors, nickel barrier layers, and complex shaped substrates in a wide choice of ceramics and dielectric materials. The MHMICs (Miniature-Hybrid-Microwave Integrated Circuits) integrate the passive circuitry typically found on GaAs MMICs, such as thin film resistors, air-bridges, overlay capacitors, spiral inductors, on less expensive alumina and AlN substrates reducing cost and development time.

NANOWAVE Technologies TFD also manufactures a series of Passive components including broadband Attenuators, Microwave chip Resistors and MIS (Metal-Insulator-Silicon) chip capacitors for RF applications.

QUALIFICATIONS

All the products are fully qualified and tested to meet or exceed the requirements of MIL-STD-883, MIL-STD-202, and MIL-C-49464 for capacitors.

NANOWAVE Technologies Inc. is fully ISO9001:2008 and AS9100C certified.

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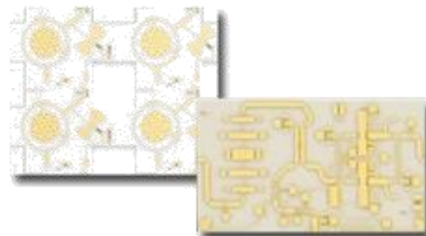
THIN FILM SUBSTRATES

ALUMINUM OXIDE SUBSTRATES

Aluminum Oxide offers excellent RF features for frequencies up to 100 GHz. It is a very low loss material, and has excellent bonding capability. The via holes are plated or filled

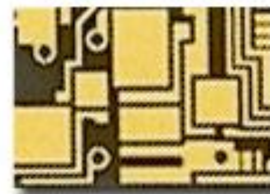
- Material: 99.6 % Al_2O_3 as fired or polished
- Size: up to 4“ x 4“
- Substrate Thickness: typical 0.005”, 0.010”, 0.015”, 0.025” 0.040”
- Critical Dimensions: 20 µm (lines) and 12 µm (spaces)
- Metal layer thickness: 4 µm +/- 1 µm
- Conductor Metal Au
- Diffusion barrier: Ni



ALUMINUM NITRIDE SUBSTRATES

Typical applications for AlN substrate material are Laser Sub-mounts and other high power applications.
The material offers low RF loss, and very good heat conductivity for mounting on heat spreaders.

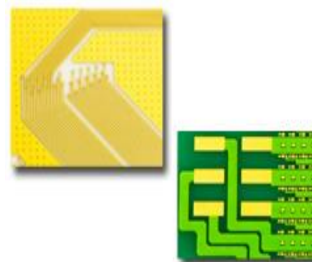
- Material: AlN
- Size: up to 4“ x 4“
- Substrate Thickness: typical 0.010”, 0.015”, 0.025” 0.040”, 0.070”
- Critical Dimensions: 20 µm (lines) and 12 µm (spaces)
- Metal layer thickness: 4 µm +/- 1 µm
- Conductor Metal Au
- Diffusion barrier: Ni



THICK COPPER TECHNOLOGY

Thick Copper Technology is used whenever high supply currents occur and/or high heat dissipation is required. The copper layers offer very low losses.

- Substrate material: Al_2O_3, AlN, BariumTitanate
- Size: up to 7,65“ x 5,15“
- Substrate Thickness: 0.015”, 0.025”, 0.040” typical
- Critical Dimension: 75 µm (lines & spaces)
- Cu layer thickness: 75 µm
- Cap metals: Ni / Au (excellent bond ability)
- Solder Mask: optional (c.f. green layer on photograph)



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THIN FILM DESIGN GUIDELINES

Fig. 1: Sample Substrate Design

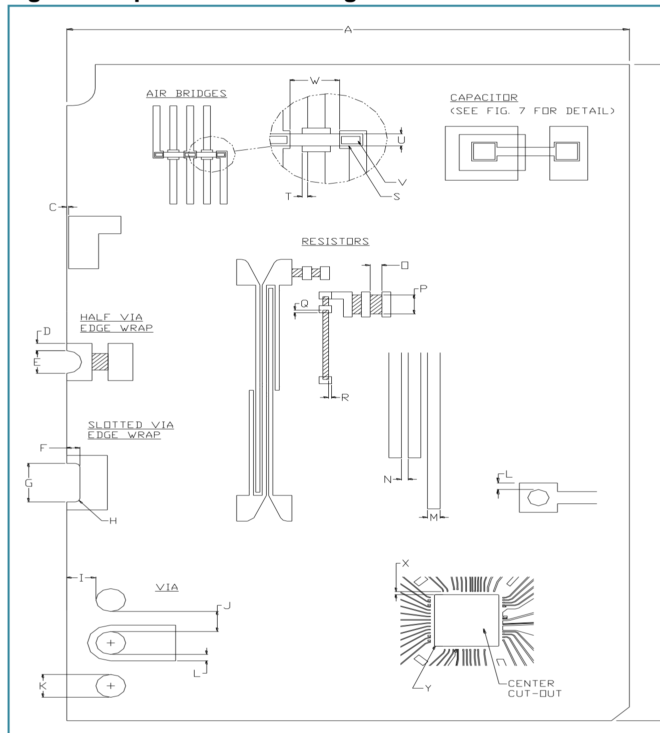

Table 1: Substrate Material

Material	Alumina (96.5%, 99.6%); Aluminum Nitride (K=170 W/m°K); Quartz; (Ba)TiOxide, (ZrSn)TiOxide (Er=37-39)
Wafer Size (inches)	1x1, 2.25x2.25, 4x4
Thickness (mils)	5, 10, 15, 20, 25
Surface finish (micro-inches)	Polished <1 μ-inches for alumina; <2 μ-inches for AIN As-fired < 3 μ-inches

Table 2: Metallization Specification

Conductor layer	Gold Typical 3 – 5 micron. Resistivity <10mΩ/sq. Current carry capacity : 20mA/micron of trace width on alumina Copper Typical 5 – 75 micron
Adhesion layer	TiW 300 – 500A°
Resistive layer	Tantalum Nitride (TaN) 10, 25, 50, 100 Ω/sq. TCR –150+/-50ppm/°C. Power Handling: 250W/in^2 on Alumina or 1000W/in^2 on AIN
Barrier layer	Nickel (if thin film is solder mounted with AuSn or AuGe). 1500-2000A°
Air bridge	Gold 3 - 5 micron. Resistivity < 10mΩ/sq. Current carry capacity: 20mA/micron of line width.
Polyimide Dielectric	Thickness Typical 7 +/- 1 micron

Table 3: Features and Dimension Specifications (Refer to Fig. 1)

Ref	Feature	Spec
A/B	Circuit Size (tolerance : +/- 0.002")	3.75" x 3.75" (max)
C	Metal Pull Back from substrate edge (Front or Back)	0.002" (min)
	Edge Wraparounds:	
D	Pad size from edge of via hole or cut out or castellation	0.003" (min)
E	Size of half via edge wrap	70% material thickness or 0.010" min.
F	Edge slot (castellation) depth	0.002" min.
G	Edge slot width	0.020" min., 0.050" max.
H	Edge slot radius	0.004" min.
	Via Holes: (Placement tolerance :+/- 0.002")	
I	Spacing from via edge to substrate edge	0.010" min. or 1x material thickness.
J	Via to via spacing (edge to edge)	0.010" min. or 1x material thickness.
K	Plated Via diameter (tolerance: +/- 0.002")	0.005" min. or 50% of material thickness.
L	Pad size around via	0.003" min.
	Conductor:	
M/N	Width / Spacing (tolerance: +/- 0.0001")	0.001" min./ 0.0004" min.
	Front to Back pattern registration	+/- 0.001"
	Resistor:	
O	Minimum Length	0.002"
P	Minimum Width	0.002"
	Length to Width ratio	1/10 min. ; 10/1 max.
Q	Resistor overlap to terminal pad	0.002" min.
R	Resistor underlap from pad	0.0005" min.
	Terminal pad size	0.004"x0.004" min.
	Resistor value per element	5Ω min.; 1kΩ max.
	Resistor sheet resistivity (ohms/sq)	10,25 50, 75, 100
	Resistor Tolerance	+/-15% Standard. +/-1% laser trimmed.
	Air Bridge:	
U	Width	0.002" min.; 0.005" max.
W	Length between post	0.002" min.; 0.015" max
V	Contact Post size	0.0015" min. each side
S	Air bridge size at post	+0.0001" each side of contact post.
	Crossover insulation	Si_3N_4 dielectric 3000A – 3500A or polyimide
T	Crossover overlap	+0.0001" over conductor
	Bridge height/clearance	0.0004" nominal
	Overlay Capacitor :	
	Dielectric	Si_3N_4 3000 – 3500A°
	Standard value (Tolerance +/-20%)	1.0 pF to 20pF
	Max capacitor per circuit	80pF
	Capacitance density	230pF/mm^2 (0.15pF/mil^2)
	Breakdown voltage	25V (70V max)
	TCC	70ppm/°C
	Interconnect to other element	Air bridge
	Top plate size A	Per capacitance area
	Dielectric size	A+0.002" min. per side
	Bottom plate size	A+0.002" min. per side
	Dicing / Cut out:	
	Dicing Tolerance	+/- 0.002" max.
	Cut out Tolerance	+/- 0.002" max.
X	Cut out to circuit clearance	0.002" min.
Y	Cut out radius	0.004" min.
	Cut out positioning	+/- 0.002"

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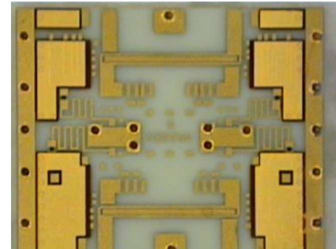
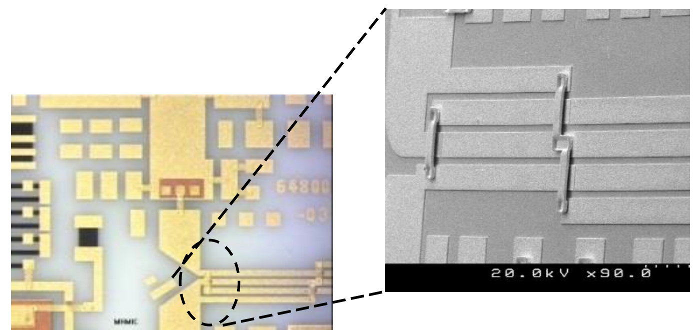
MHMIC (MINIATURE HYBRID MIRCROWAVE IC)

This proprietary hybrid IC technology offers higher reliability compared to conventional hybrid circuits because of a reduction of required bond wires and component attachments. At the same time, the RF performance is enhanced and fabrication costs reduced. The filled via technology together with chip-level active devices enables superior thermal management at the module level.
Amongst others, the following features can be integrated into HMICs:

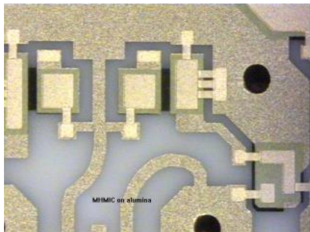
- Overlay Capacitors (MIM)
- Spiral Inductors
- Resistors
- Thick copper heat spreaders
- Lange Couplers with air-bridges
- Supported / non-supported (real) air-bridges
- Filled /non-filled via holes
- Smallest feature size: 20 µm (lines and spaces)

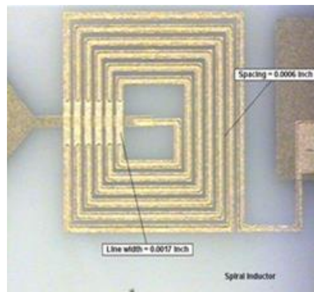


RF substrate with standard via holes to ground plane

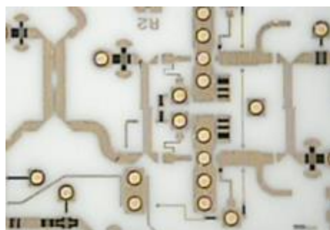


Lange Coupler with printed air-bridges





MIM capacitors, resistors, air-bridges, spiral inductor



Copper/Au filled via. Thermal management, Hermetic, Solder block

Polyimide fill via. Solder block, low cost

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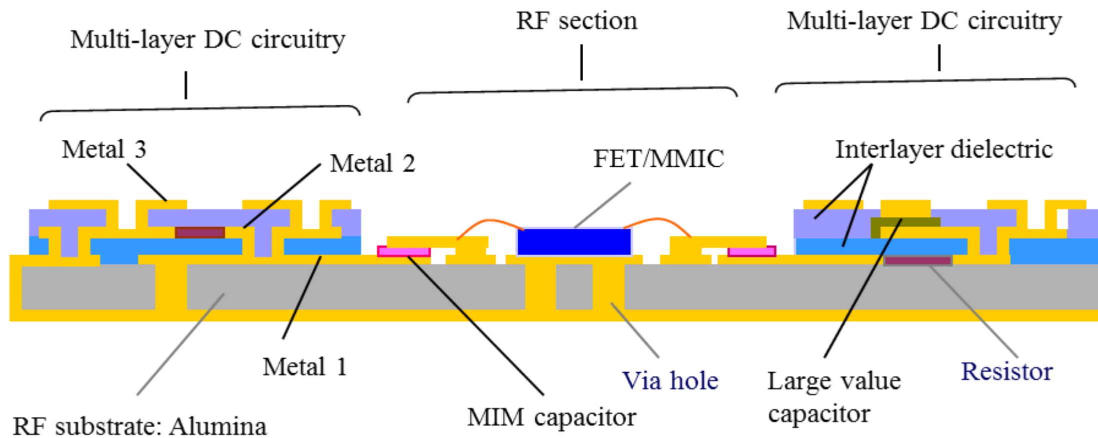
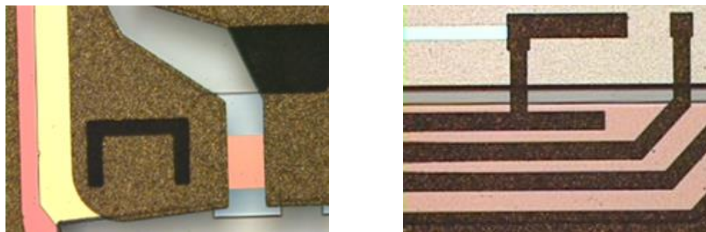


Cross sectional schematic of HMIC technology including filled vias

Spin-on layers of polyimide film allow for extremely compact modules with up to three (3) independent metal layers. Multi-layer thin-film also allows for high performance RF components, such as broadside couplers and modified Lange couplers.



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SUBSTRATE MATERIAL SPECIFICATION

Characteristics	Unit	Alumina Polished	Alumina As-fired	ALN Polished	Titanate (ZrSn Ti Oxide) Polished	Quartz (fused silica) polished
Material Purity	Weight %	99.6	99.6	> 98.0	> 98.0	> 98.0
Colour	—	White	White	Gray	Cream	Colorless
Bulk Density	g/cm^3	3.88 ± .02	3.88 ± .02	3.3 ± .02	> 5.20	2.202+-.002
Hardness (R45N)	—	87	87	70	65	59
Surface Finish (Active Side)	Micro-inches, CLA	≤ 2	≤ 4	≤ 3	4-8	60/40
Flexural Strength	kpsi	> 83	> 83	> 50	> 13	-
Young's Modules	10^{6}psi	44	44	47	31	10.6
Coefficient of Linear Thermal Expansion 25°C - 300°C	10^{-6} /°C	6 - 7	6 - 7	4.6 ± .2	6.5 ± .2	5.5 ± .2
Thermal Conductivity 20°C - 100°C	W/m°K	27^{+10}_{-5}	27^{+10}_{-5}	170^{+30}_{-10}	2.0	1.38
Dielectric Constant (Relative Permittivity) 1 KHz	—	9.9 ± 0.1	9.9 ± 0.1	8.6 ± .1	38 ± 1.5% @ 7 GHz	3.826@1 MHz 3.82@24 GHz
1 MHz	—	9.9 ± 0.1	9.9 ± 0.1	8.6 ± .1		
Dissipation Factor (Loss Tangent) 1 KHz	—	0.0003	0.0003	0.0005	0.0001 @4.5 GHz	0.000015@1 MHz
1 MHz	—	0.0001	0.0001	0.0005		0.00033@24 GHz
Volume Resistivity 25°C	ohm-cm	> 10^{14}	> 10^{14}	> 10^{14}	> 10^{13}	> 10^{15}
Length / Width Tolerance	%	< 1	< 1	< 1	< 1	< 1
Thickness Tolerance	%	< ± 3	< ± 10	< ± 3	± 5	± 5
Camber	mil / inch	≤ 1	≤ 3	≤ 1	≤ 1	≤ 3
Temperature Coefficient of Dielectric Constant	PPM / °C	—	—	—	0 ± 30	-

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ABOUT NANOWAVE

NANOWAVE Technologies Inc. was founded in 1992 and is a leading Canadian Designer and Manufacturer of Advanced Microwave and Millimeter Wave Components and Sub-Systems for the Radar, Communications, Industrial and Medical markets.

The company's products can be found on the most advanced commercial and defense aircrafts, as well as ground based Radar and Communication Systems.

NANOWAVE's commitment to annual investments in R&D combined with in-house control of critical design, manufacturing and test processes results in rapid response to our customers' demands for:

- Customization
- Obsolescence Mitigation
- Demanding Technical Specifications
- On-time Delivery
- High Reliability
- Traceability

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