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**HIGH PERFORMANCE
SUBSTRATES
FOR
THIN FILM APPLICATIONS**

**HIGH PERFORMANCE SUBSTRATES FOR THIN FILM APPLICATIONS:
A contemporary survey of materials**

A wide array of substrate materials suitable for thin-film applications will be reviewed. This will include the standard thin-film hybrid 99% + alumina tape-cast ceramics as well as many less common hot pressed ceramics, glasses, glass-ceramics, single crystals, metals, polymers, etc, useful in specialized high performance applications.

The main characteristics pertinent to the thin film technologist will be discussed, viz the surface finishes attainable, the mechanical, machining and wear properties, the physical, chemical electrical and thin film adhesion qualities. These substrate materials have applications in hybrids, very high density interconnect packaging, microwave, high power devices, magnetic thin film heads and many other specialized sensors or devices.

**THIN FILM SUBSTRATES
A TECHNICAL OVERVIEW**

THIN FILM SUBSTRATE CRITERIA:

- * SUBSTRATE MATERIAL
- * SURFACE FINISHING TECHNIQUES
- * TESTING SUBSTRATE PARAMETERS
- * SUBSTRATE RELATED SUBJECTS:
ADHESION
METALLIZING

CERAMICS

MANUFACTURING PROCESSES:

- * TAPE CASTED
PARTICLES IN POLYMERIC BINDER
SLURRY + DOCTOR BLADE
- * DRY PRESSED
ROOM TEMP, LOW PRESSURE
LITTLE POLYMERIC BINDER
- * HIPPED
NO BINDER
HEAT + PRESSURE (gas in vessel)
to 1400°C 30,000 psi
- * HOT-PRESSING
NO BINDER
MECHANICAL PRESSURE
to 1800°C 80,000 psi

CRITERIA TO CHOOSE A SUBSTRATE MATERIAL

- * MECHANICAL
STRENGTH
POROSITY
SURFACE FINISH
EASE OF MACHINING
- * THERMAL
CONDUCTIVITY
CAPACITY
EXPANSION COEFFICIENT
- * CHEMICAL
STABILITY
SURFACE STATE (ADHESION)
THIN FILM COMPATIBILITY
- * ELECTRICAL
BULK RESISTIVITY
DIELECTRIC CONSTANT
DIELECTRIC BREAKDOWN
DISSIPATION FACTOR

CERAMICS

* ALUMINAS	99.5%+ Al_2O_3 LUCALOX (Polycrystalline) Al_2O_3 -TiC
* BERYLLIAS	99.5%+ BeO
* CARBIDES	B_4C , SiC, TiC
* NITRIDES	AlN, Si_3N_4 , Sialon
* TITANIAS	BaTiO_3 , CaTiO_3 , TiO_2
* ZIRCONIAS	ZrO_2
* FERRITES	Zr, Ni-Zr, Mn-Zn
* BORIDES	TiB_2

MATERIAL PROPERTIES (HOT PRESSED)

MATERIALS	FLEXURAL STRENGTH (Kg cm^{-2})
* BaTiO_3	1250
* CaTiO_3	1500
* BeO	1750
* Al_2O_3	3200
* AlN	4000
* SiC	4500
* Al_2O_3 -TiC	6000
* Al_2O_3 (Sapphire)	7000
* ZrO_2	8500

HARDNESS (Knoops Indentation Test)

MATERIAL	Kg mm ⁻² (@ 100g load)
* C (Graphite)	200
* PZT	400
* Fotoceram	500
* Quartz	570
* Mn-Zn (Ferrite)	650
* Zn (Ferrite)	700
* Ni-Zn (Ferrite)	750
* CaTiO ₃	800
* SiO ₂	800
* BaTiO ₃	850
* ThO ₂	1000
* AlN	1200
* BeO	1200
* Al ₂ O ₃	1600
* Si ₃ N ₄	1850
* Al ₂ O ₃ -TiC	1850
* Al ₂ O ₃ (Hot Pressed)	2000
* ZrO ₂	2000
* B ₄ C	3000

DIELECTRIC PROPERTIES

MATERIAL	CONSTANT (1 MHz)	LOSS TANGENT (10^{-4})
Polyimide	3.5-3.8	20
Quartz	3.7	1
BN	4.1	13
Glass	4.5-6.0	20
Fotoceram	6.0	40
BeO	6.5	1
Si ₃ N ₄	7-10	3
Al ₂ O ₃ (99.5%+)	9.0	1.5
AlN	9.1	71
Al ₂ O ₃ (Sapphire)	9.3	1
Si	12	100
GaAs	13	16
YIG	14	2
CaTiO ₃	25 (5 GHz)	5
BaTiO ₃	37 (5 GHz)	5
TiO ₂	100 (5 GHz)	4

THERMAL CONDUCTIVITY

MATERIAL	W/m C
* Quartz	1.4
* Glass	1.2-2.0
* ZrO ₂	2.0
* Fotoceram	2.5
* BaTiO ₃	3.6
* Zn (Ferrite)	4.0
* Ni-Zn (Ferrite)	4.0
* Mn-Zn (Ferrite)	4.0
* CaTiO ₃	5.2
* ThO ₂	12.0
* Al ₂ O ₃ -TiC	16.0
* Al ₂ O ₃	17.0
* Si ₃ N ₄	32.0
* B ₄ C	32.0
* BN	44.0
* SiC-Si	50.0
* TiB ₂	70.0
* AlN	125.0
* Al	140.0
* BeO	240.0
* SiC	270.0
* C (Graphite)	800.0
* C (Diamond)	1000.0

THERMAL COEFFICIENT OF EXPANSION

MATERIAL	ppm/C
* Zerodur	-0.02
* Quartz	0.55
* Glass	1.2
* Si ₃ N ₄	3.0
* C (Graphite)	3.2
* Si	3.4
* AlN	4.8
* SiC	5.1
* Al ₂ O ₃ (Sapphire)	5.6
* Al ₂ O ₃ (Ceramic)	6.5-8.0
* Al ₂ O ₃ -TiC	7.8
* TiB ₂	8.2
* Zn (Ferrite)	8.5
* BeO	8.0-9.0
* Ni-Zn (Ferrite)	9.1
* ThO ₂	9.3
* BaTiO ₃	9.6
* Fotoceram	10.0
* ZrO ₂	10.0
* CaTiO ₃	11.5
* Mn-Zn (Ferrite)	12.1
* Cu	18.0
* Al	23.0

BULK RESISTIVITY

MATERIAL	OHMS-cm
* Al	2.7×10^{-6}
* Cu	1.7×10^{-6}
* TiB ₂	1.0×10^{-5}
* C (Graphite)	1.0×10^{-4}
* Mn-Zn (Ferrite)	1
* SiC	5
* B ₄ C	5
* Al ₂ O ₃ -TiC	10
* Zn (Ferrite)	$>10^3$
* Ni-Fe (Ferrite)	$>10^6$
* Quartz	$>10^9$
* ThO ₂	$>10^{10}$
* ZrO ₂	$>10^{10}$
* AlN	$>10^{11}$
* Al ₂ O ₃	$>10^{14}$
* BeO	$>10^{14}$
* BaTiO ₃	$>10^{14}$
* CaTiO ₃	$>10^{14}$
* Polyimide	$>10^{14}$

SUBSTRATE MEASUREMENTS

- * CHEMICAL
ESCA, AUGER, ETC.
- * DIELECTRIC CONSTANT
BRIDGE, PHASE-METER, LOCK-IN-AMP
- * CONDUCTIVITY
BRIDGE, 4 POINT PROBE, ELECTROMETER
- * FLATNESS
OPTICAL FLAT, AIR GAUGE, INTERFEROMETER
- * CAMBER
PARALLEL PLATES, INTERFEROMETER
- * POROSITY, SCRATCHES, PITS & BURRS
MICROSCOPE, SEM
- * CRACK DETECTION
DIES, VAPOR CONDENSATION
- * SURFACE FINISH
STYLUS PROFILOMETER, OPTICAL PROFILOMETER
- * WEAR TEST
SLIDING PIN ON DISC