


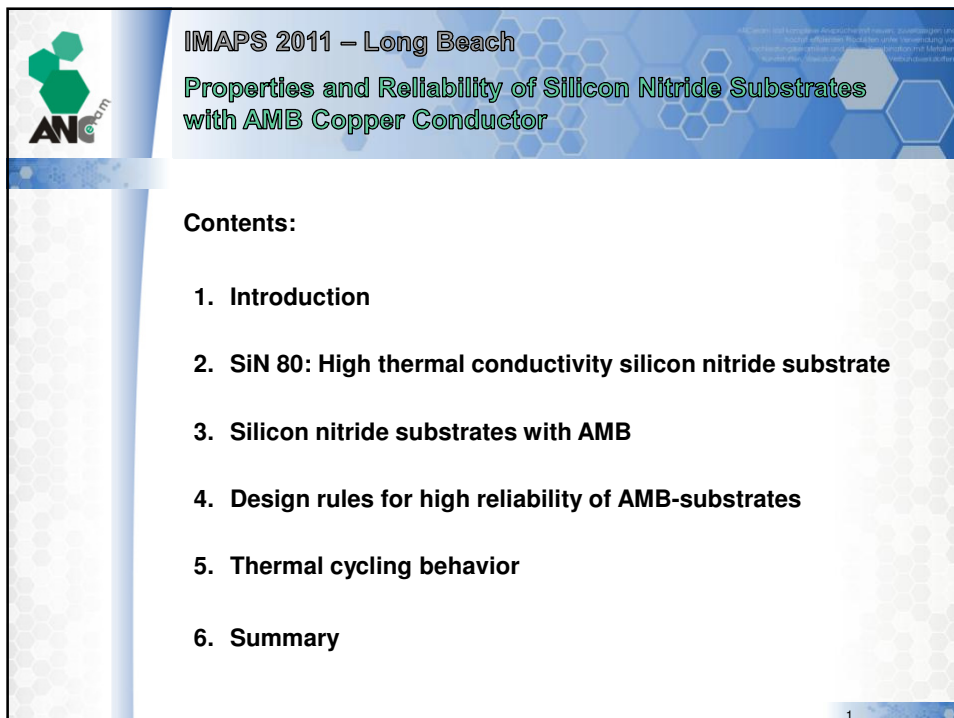
## IMAPS 2011- Long Beach


### *Properties and Reliability of Silicon Nitride Substrates with AMB Copper Conductor*

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### Properties and Reliability of Silicon Nitride Substrates with AMB Copper Conductor

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3. Silicon nitride substrates with AMB
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**1. Introduction:**

- ❖ high fracture toughness
- ❖ high mechanical strength even at high temperatures
- ❖ excellent thermal shock resistance
- ❖ low thermal expansion

**Problem:** regular material shows low thermal conductivity

➔ **Combination of the good properties with high thermal conductivity needed for best performance**

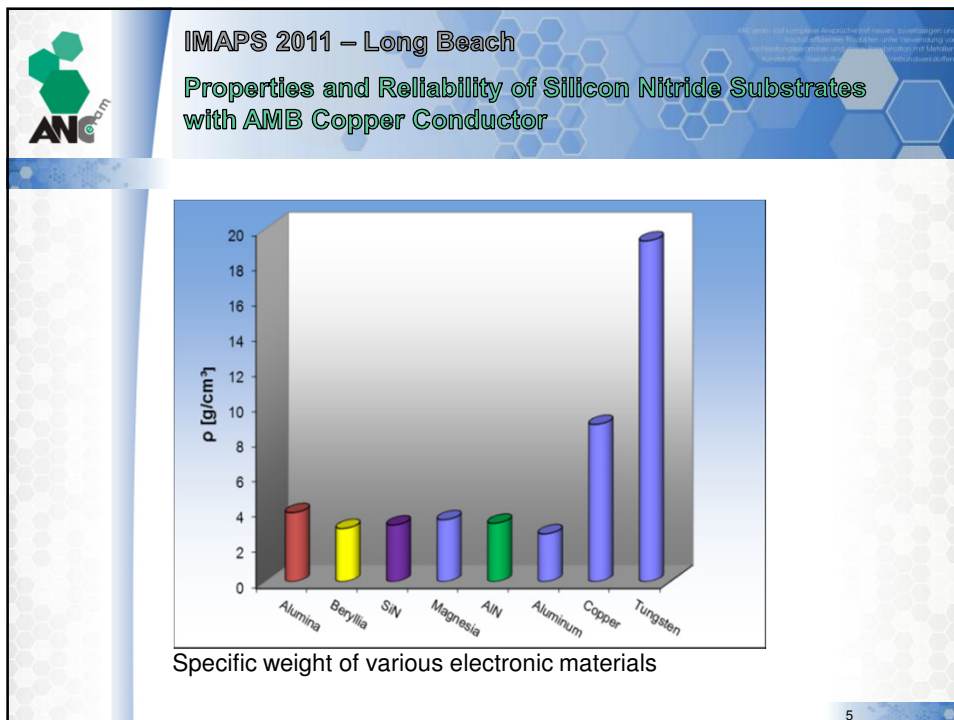
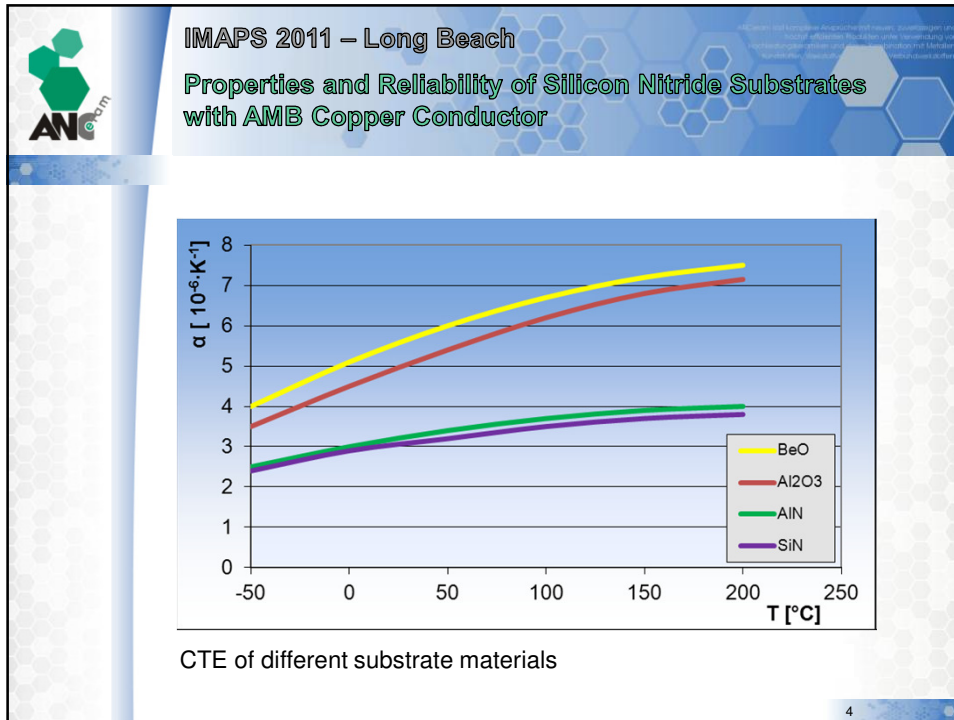
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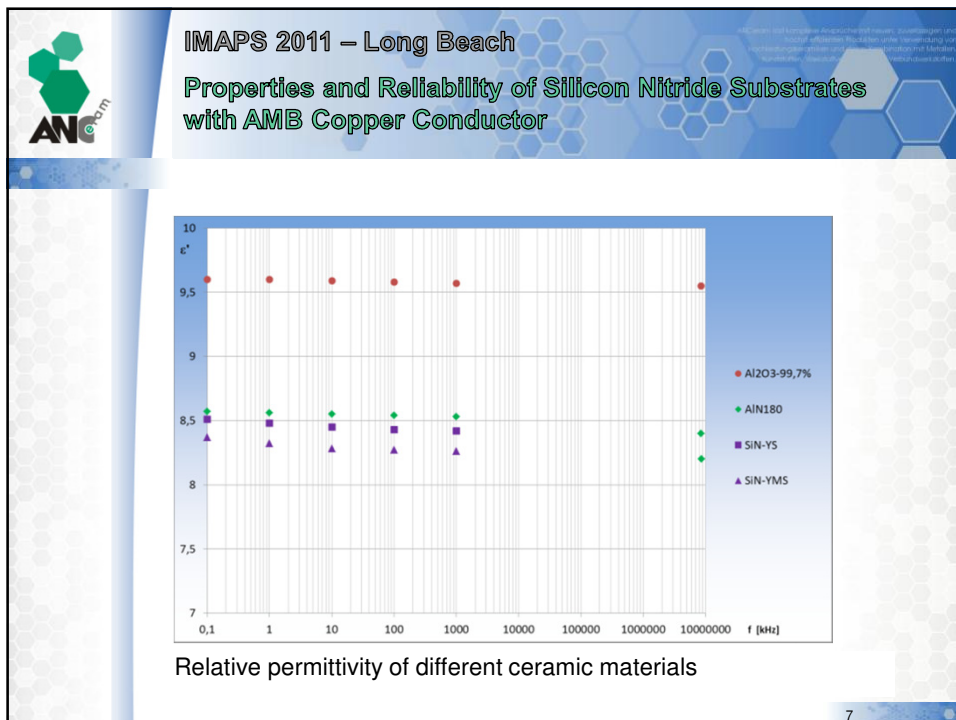
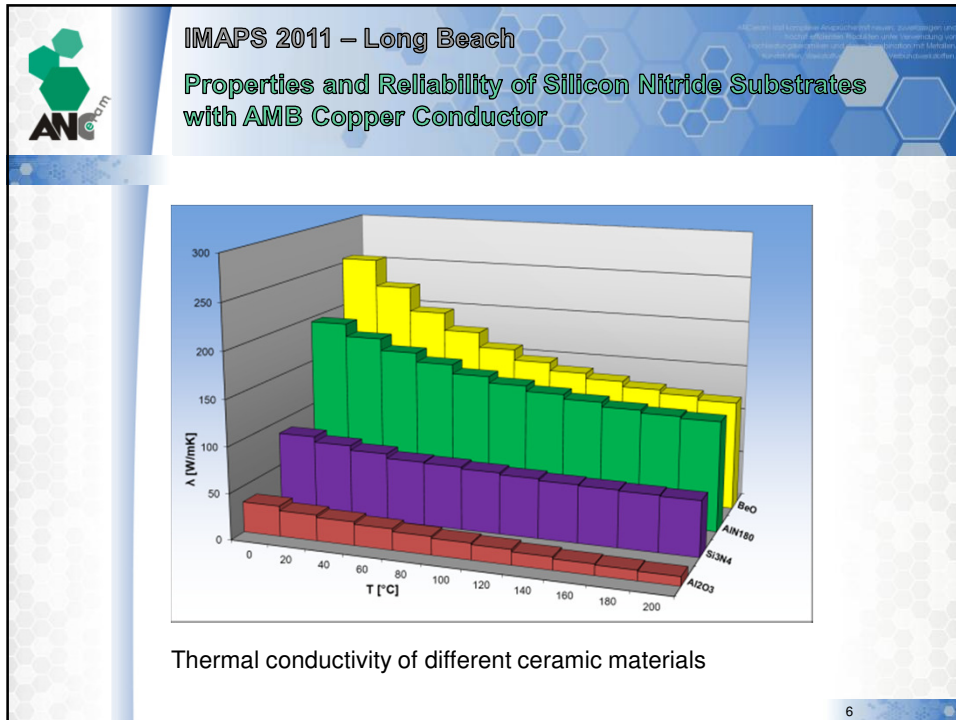

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**2. SiN 80: Silicon nitride substrate with high thermal conductivity**

- ❖ Improved microstructure to achieve required properties
- ❖ Tape casting and gas pressure sintering as cost effective manufacturing technologies
- ❖ Two different combinations of sintering aids have been identified:  $Y_2O_3/Sc_2O_3$  and  $Y_2O_3/MgO/SiO_2$  (high performance or good price-performance ratio)
- ❖  $Al_2O_3$  should be avoided → lattice imperfections
- ❖ Thermal conductivity 3 times higher than regular material
- ❖ Following slides show typical properties of SiN80 ( $\approx 80$  W/mK) compared to different electronic materials

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Properties	Method	SiN 80
$\rho_{th}$ Density (theoretical) (g/cm <sup>3</sup> )	calculated	3.25
$\rho_m$ Density (as measured) (g/cm <sup>3</sup> )	buoyancy	3.22
$\sigma_B$ Flexural strength (MPa)	Ball on ring	> 800
E Young's modulus (GPa)	Ultrasonic	336
$\lambda$ Thermal conductivity (W/mK)	Laser flash	80 ± 10
$\alpha$ Coeff. of thermal expansion (10 <sup>-6</sup> K <sup>-1</sup> ) RT - 1000 °C	Dilatometric	3.0 – 3.5
$c_p$ Specific heat (J/kgK)	Calorimetric	632 ± 20
Volume resistivity ( $\Omega$ cm)	at 5 kV	> 10 <sup>12</sup>
Dielectric strength (kV/mm)	in fluorintert	> 15
$\epsilon_r$ Dielectric constant (at 1 MHz)	LCR meter	8.4 – 8.5
$\tan \delta$ Loss tangent (at 1 MHz)	LCR meter	1.0 · 10 <sup>-3</sup>
Max. working temperature under air	---	800 °C
Thermal shock resistance	---	excellent

Main properties of SiN 80

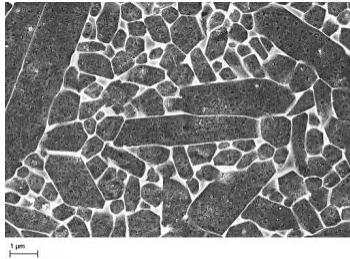
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**Relationship between properties & microstructure**

- β-crystallites up to 15 μm ↑:  $\lambda$  ↑ ;  $\sigma_B$  ↓
- Sustained grains ↑ :  $\sigma_B$  ↑
- Secondary phase up to 55nm ↑ :  $\lambda$  ↓
- Combination of high thermal conductivity with high fracture toughness can be achieved



Good reliability in applications where heat dissipation meets harsh conditions

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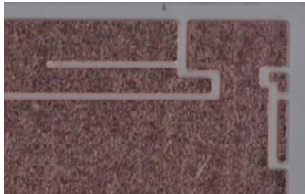
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**3. SiN 80 substrates with AMB Copper:**

**SiN 80 substrates with AMB copper conductor lines are the right choice when following requirements are applicable:**

- ❖ High power density of semiconductor components
- ❖ High dissipated heat of semiconductor components
- ❖ High amperage
- ❖ Good thermal cycling resistance



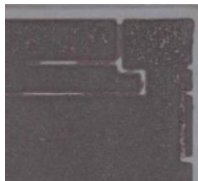
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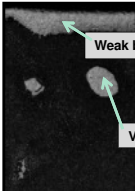
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**The Aluminium Nitride AMB process was tuned to fit the high thermal conductive SiN 80 silicon nitride :**

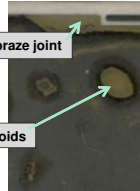
- ❖ Weak braze joints in peripheral areas
- ❖ Voids between copper and braze
- ❖ Braze links between adjacent conductor lines and pads



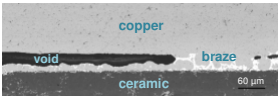
Braze spreading



Brazing defects - SAM image



Brazing defects - surface image with etched off copper



Cross section through a void

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**Silver/copper based braze with  $TiH_2$  as active component**

**Identified influencing parameters:**


- ❖ Surface condition of silicon nitride
- ❖ Amount of active component
- ❖ Process control during debinding segment
- ❖ Quality of vacuum or inert gas atmosphere

**Results:**

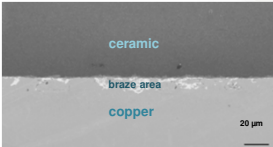
- ❖ Void free braze joint
- ❖ No braze spreading, no bleeding
- ❖ Perfect joint even in peripheral areas



Braze spreading before improvement



Braze spreading after improvement



Cross section of a faultless brazed joint

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**4. Design rules for high rel SiN 80 AMB-substrates:**

- ❖ Avoid sharp edges at corners of copper pattern  
→ minimizes stress at highly exposed areas
- ❖ Different copper pattern on top and back sides:  
balance copper volume on both sides to prevent warpage of AMB-substrate  
→ copper on one side has to be thinner!
- ❖ Copper thickness has to be adapted to ceramic thickness  
SiN 80 allows a higher copper/ceramic ratio than other ceramics
- ❖ Copper thickness between 100 µm and 500 µm with gradations of 50 µm are feasible

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**5. Thermal cycling behavior:**

Passive cycling conditions: -55 C to 150 C / min

The figure shows four micrographs arranged in a 2x2 grid. The top row shows the initial state (0 cycles) for AIN and Si<sub>3</sub>N<sub>4</sub> substrates. The bottom row shows the state after 125 cycles. Green arrows labeled 'AIN' and 'Si<sub>3</sub>N<sub>4</sub>' point from the initial state to the state after 125 cycles. The AIN samples show some surface degradation, while the Si<sub>3</sub>N<sub>4</sub> samples appear more stable.

Initial state 0 cycles                      After 125 cycles

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**Thermal Cycling:**

- Initial state:  
No difference between AIN-AMB and SiN 80-AMB
- After 125 cycles:  
AIN shows beginning delamination  
SiN 80 shows no degradation
- After 200 cycles:  
AIN shows massive delamination  
SiN 80 still not degraded
- After 300 cycles:  
SiN 80 shows no degradation

The figure shows two micrographs. The top one is labeled 'AIN' and shows a sample after 200 cycles with significant surface delamination. The bottom one is labeled 'Si<sub>3</sub>N<sub>4</sub>' and shows a sample after 300 cycles with a clean surface.

AIN  
After 200 cycles

Si<sub>3</sub>N<sub>4</sub>  
After 300 cycles

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