Euromat 2005

Praha, 4-8 September 2005

Potential of SiC multilayer ceramics for high temperature applications in oxidising environment

M. Pavese, P. Fino, A. Ortona*, C. Badini

* *FN S.p.a. Nuove Tecnologie e Servizi Avanzati, S.S 35bis dei Giovi, 15062 Alessandria.*

Why multilayers?

Ceramic materials are suitable for applications at high temperature but their use is strongly limited by their brittle mechanical behaviour.

Toughened ceramic matrix composites

Long fibre reinforced composites

- High costs
- Need protection coating to safe the interface properties

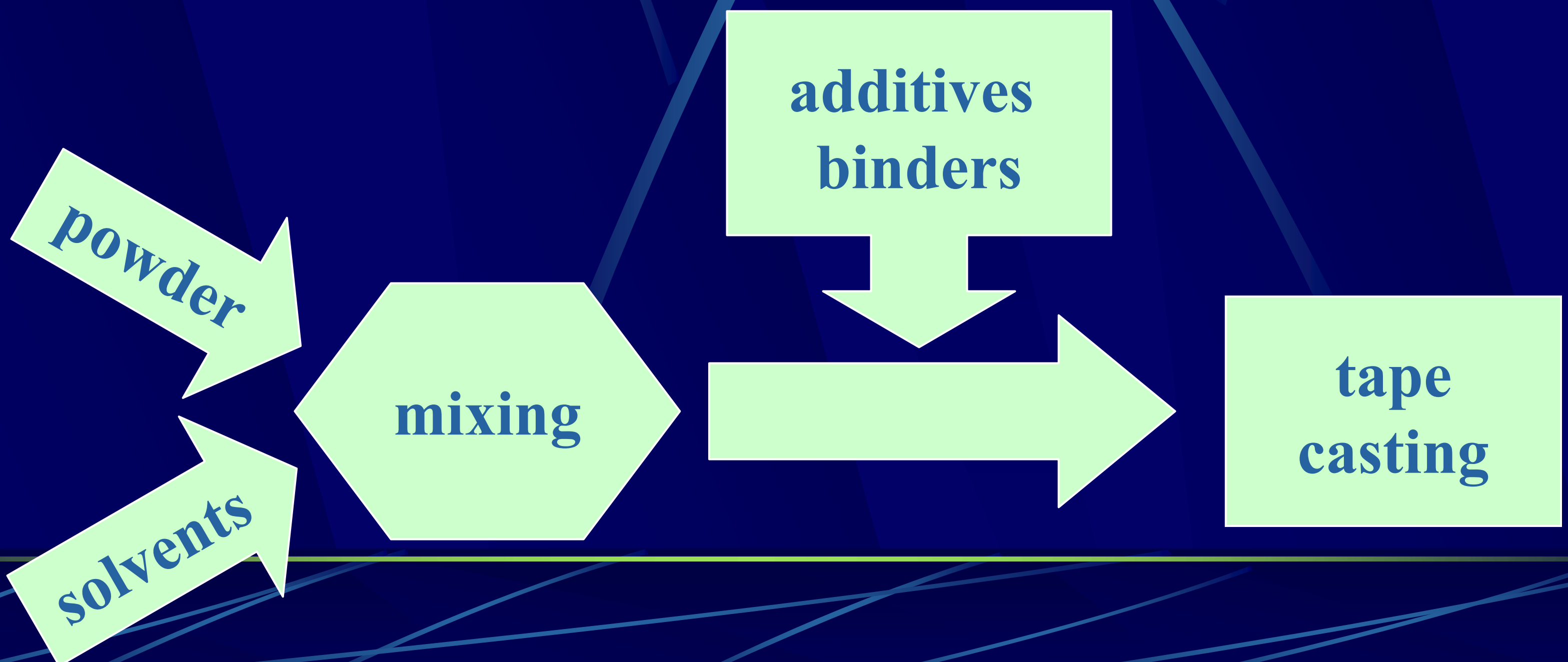
Multilayered ceramics

- Lower costs
- Toughened mechanism must be improved

Multilayer preparation

Produced in collaboration with the Italian industry **FN S.p.A.**
by the **Tape Casting** technique

A slurry is produced, containing:
→ fine SiC powder (15 m^2/g)
→ solvents
→ binder
→ additives



Multilayer preparation

Phases:

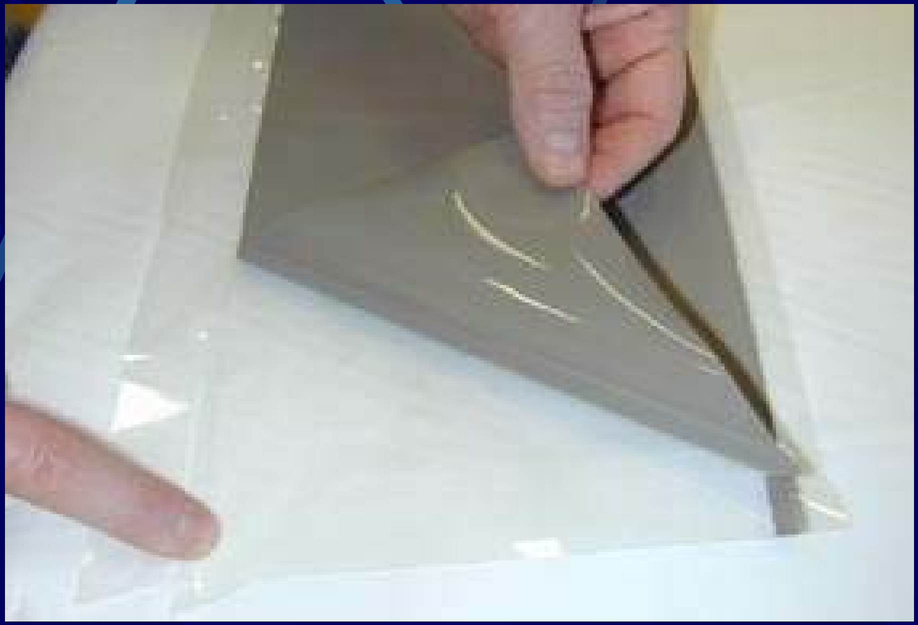
- Casting of the slurry on a Mylar film
- Levelling with a doctor blade
- Slow evaporation of the solvent (48 h)

Tape Casting apparatus

Multilayer preparation

After solvent evaporation the layers can be easily handled

"green" layer detachment

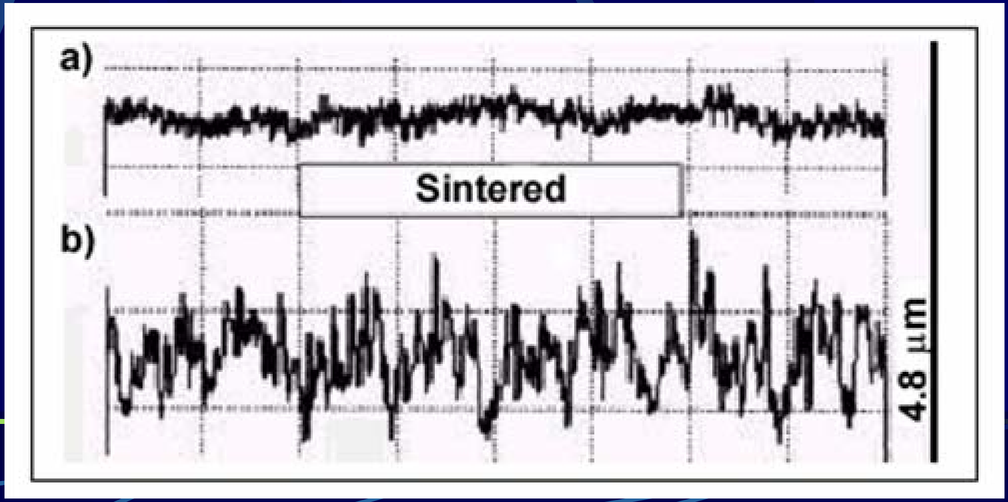


Multilayer preparation

wrapping around a mandrel
→ **tubular specimens**

The roughness profile on the two faces of the tape was measured after sintering

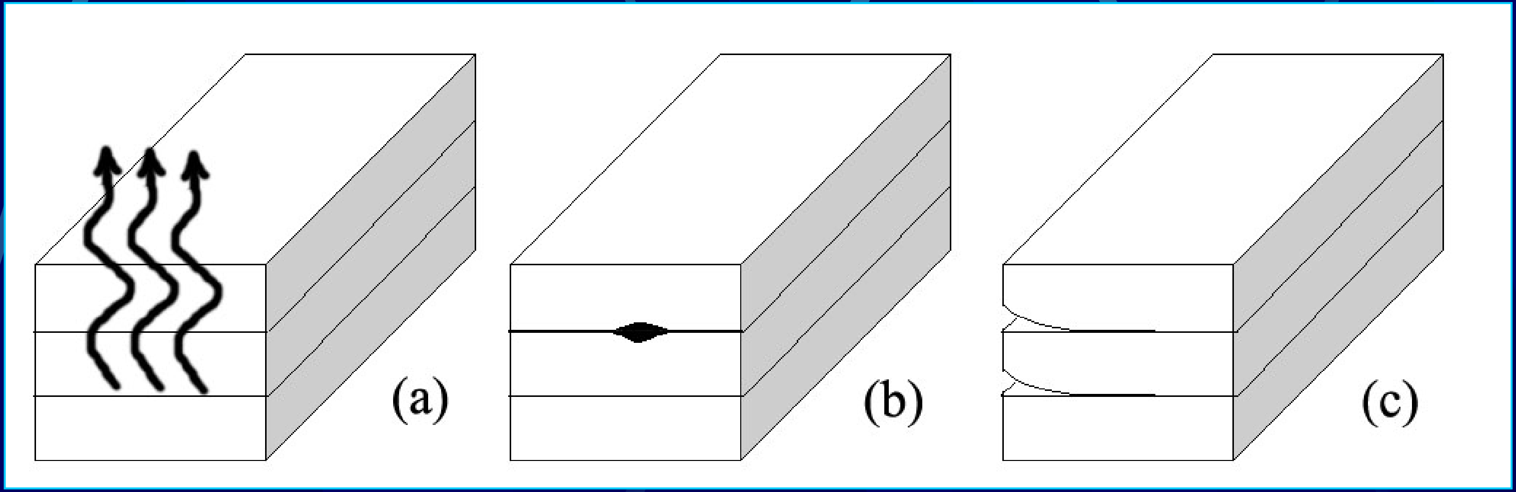
roughness profile



Multilayer preparation

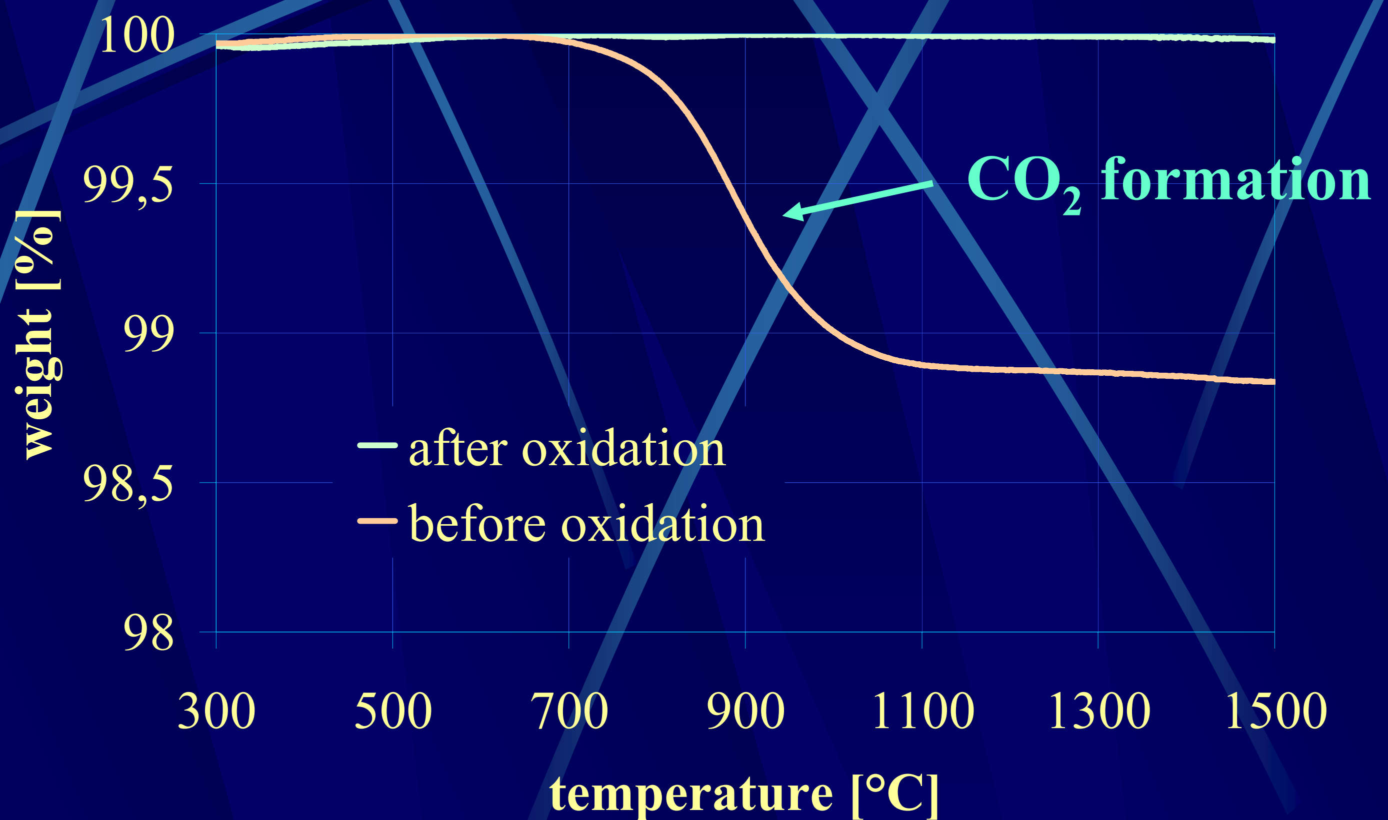
Thermal treatment:

→ **Slow heating** up to 500 °C (**binder decomposition**)
→ **Sintering** at 2180 °C in inert atmosphere



During heat treatment (a) there is the risk of:
→ bubbles (b)
→ delaminations (c)

Oxidation behaviour: TGA analysis



Possible reactions: $SiC + O_2 \rightarrow SiO_2 + CO_2$ → weight increase

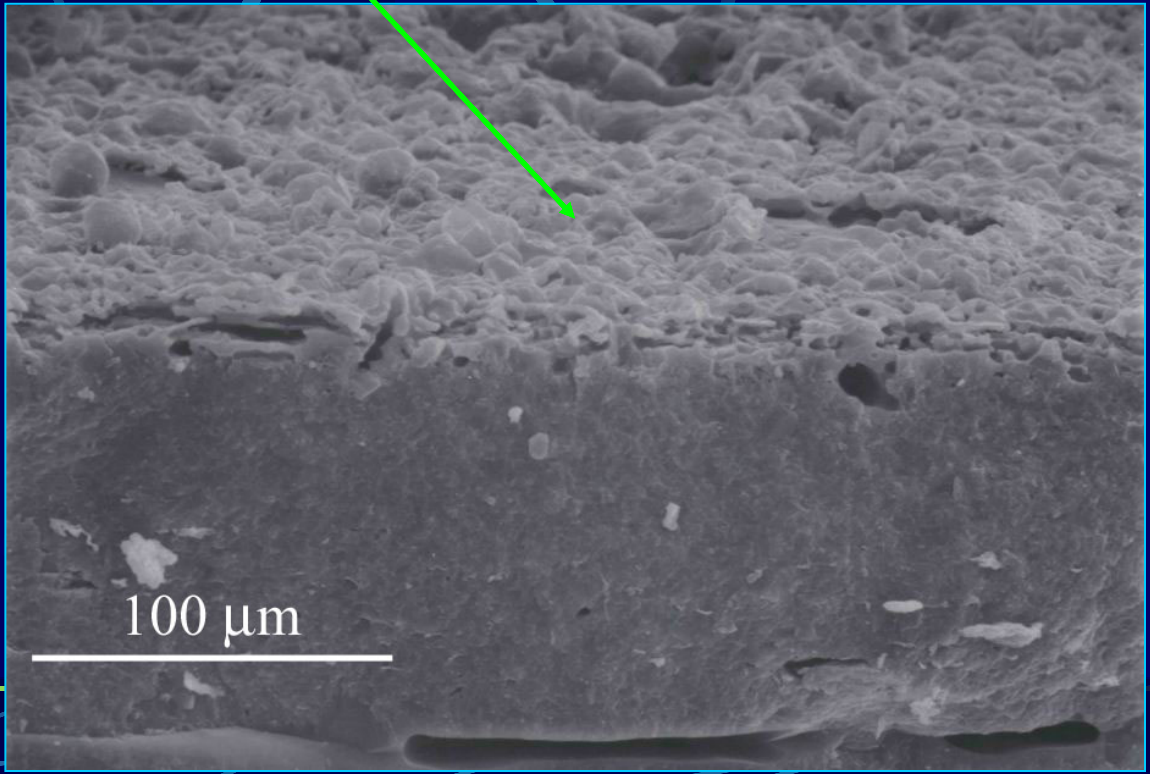
$C + O_2 \rightarrow CO_2$ → weight decrease

Oxidation behaviour

phases:

before heat treatment: SiC (different polytypes)

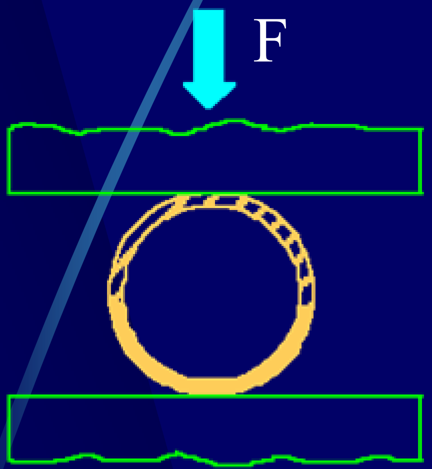
after treatment at 1600 °C: SiC + SiO_2



Mechanical behaviour

Compression test setup (ISO 2739/2000)

$$\sigma = \frac{F(D-e)}{Le^2}$$



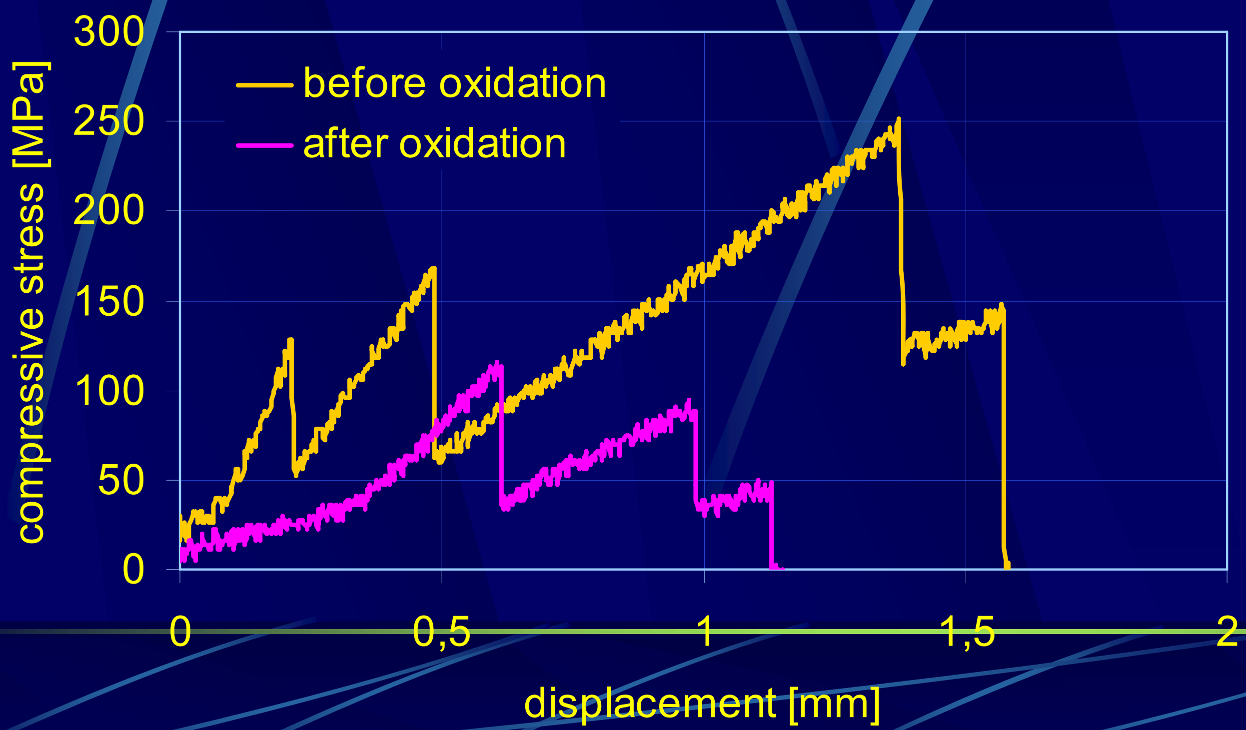
F = load at failure

L = buckle length

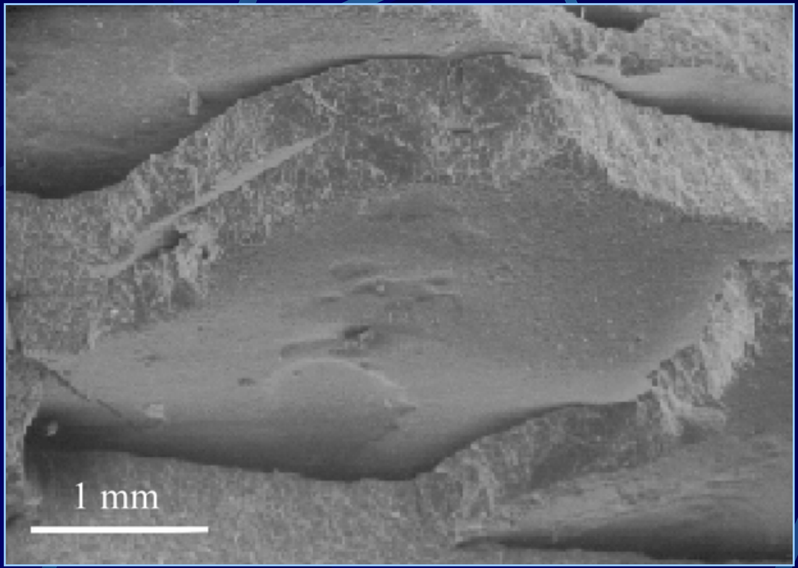
D = buckle external diameter

E = thickness of the buckle wall

typical stress-displacement curve

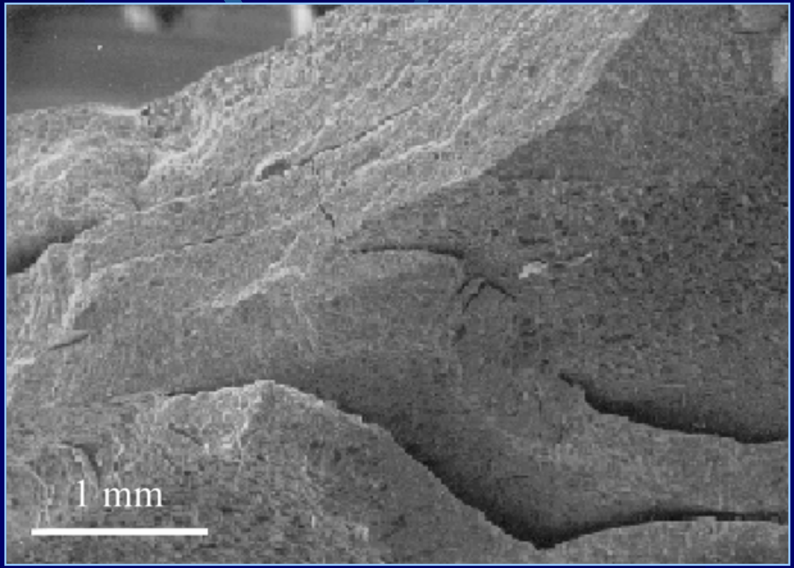


Fracture surface



before oxidation

after oxidation

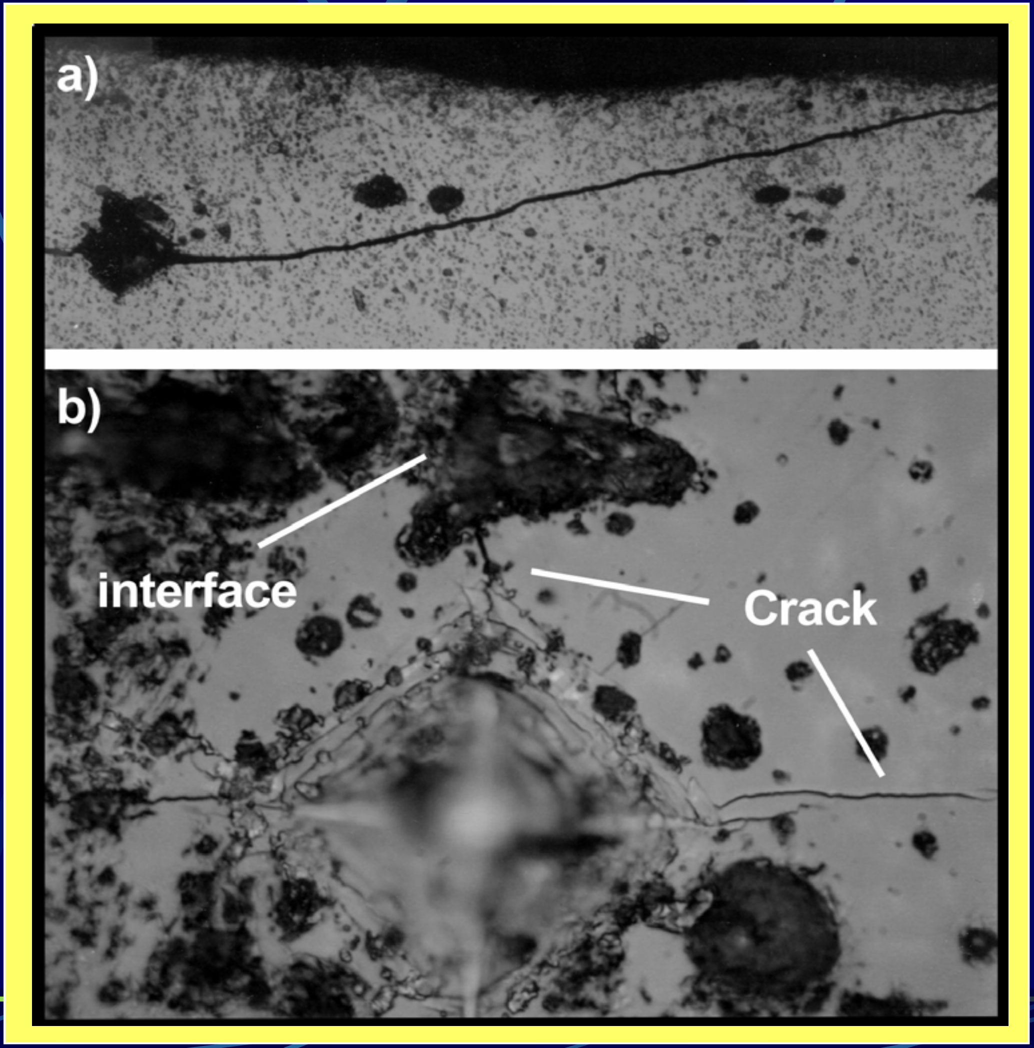


the toughening mechanisms operate also after oxidation

Vickers indentation

a) external layer
(80X, 10 kg load)

b) internal layer
(500X, 3 kg load)



Layer thickness

Green tape thickness [mm]	Average layer thickness after sintering [μm]	Number of layers	Cylinder wall thickness after sintering [mm]
0.8	140-150	6	0.9
0.6	90-125	7	0.7
0.4	55-60	10	0.6

Layer thickness and mechanical strength

mean compression strength [MPa]					
0.4 mm		0.6 mm		0.8 mm	
as prepared	100 h 1600 °C	as prepared	100 h 1600 °C	as prepared	100 h 1600 °C
235	184	356	210	143	123

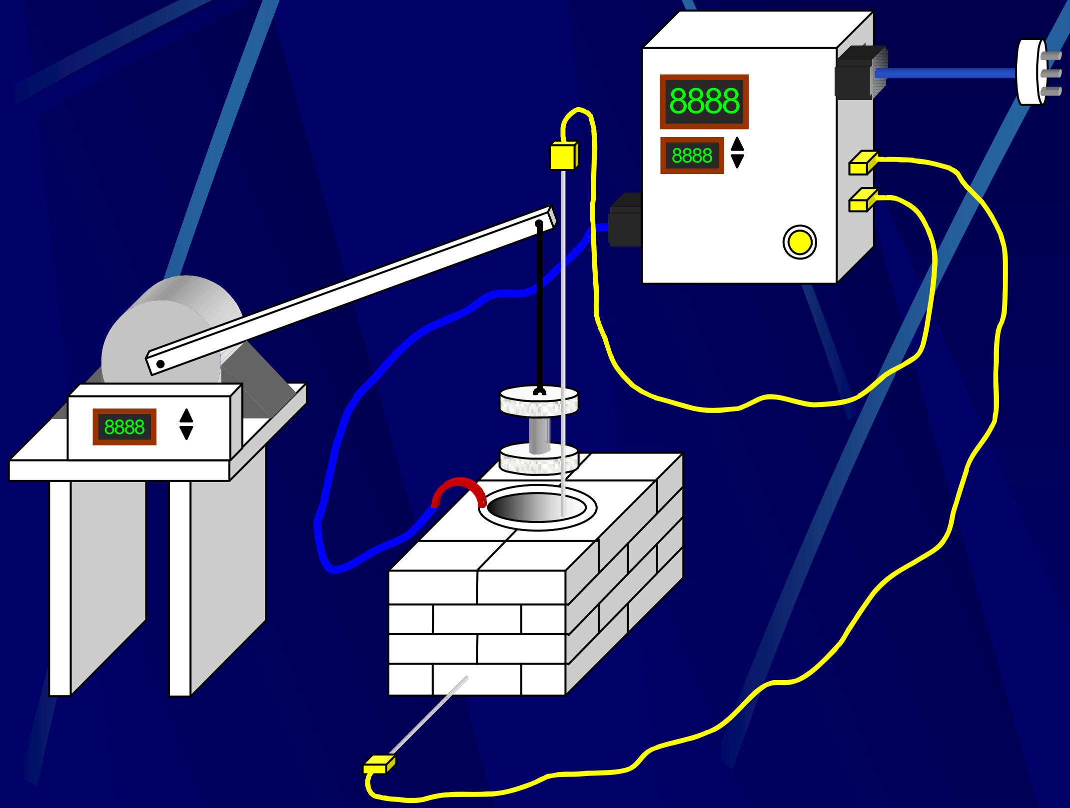
↓ Some damage during preparation

↓ Best mechanical properties

↓ Slight loss after oxidation

Best choice → 0.6 mm thick tapes (even if it loses strength after oxidation)

Thermal cycling



Heating up to 1070 °C

Cooling in air

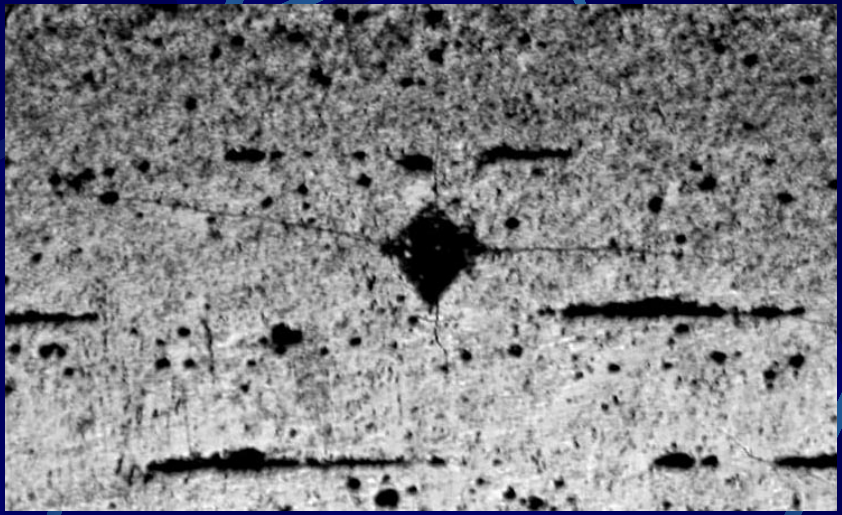
Heating up to 1070 °C

etc…

Thermal cycling: mechanical behaviour

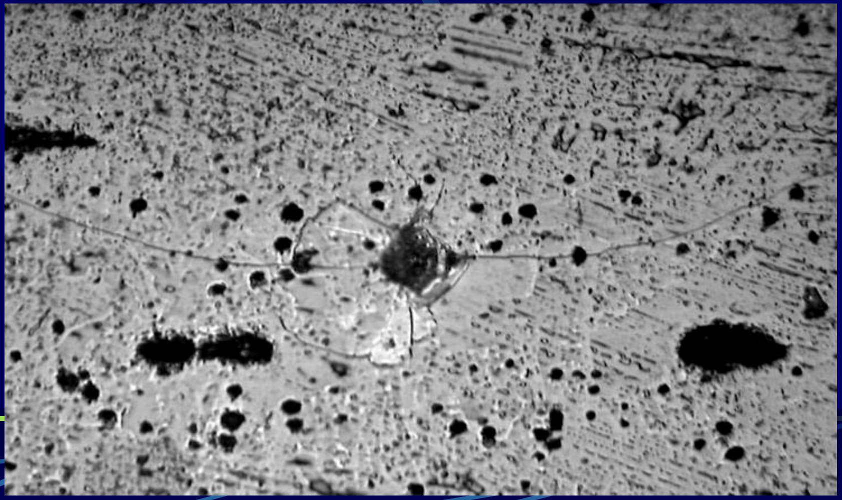
	No Cycling	10 cycles	50 cycles
Compression strength [MPa]	287	311	269

Thermal cycling: indentation tests



Before thermal cycling
(100X, 10 kg load)

After thermal cycling
(100X, 10 kg load)



Conclusions

Multilayered ceramics: suitable and low cost material for high temperature components.

Tubular SiC multilayers were produced by **tape casting** and sintering without pressure.

Multilayer **toughness** is increased owing to **delamination** phenomena, even after high temperature treatments in severe conditions (**100 h at 1600 °C**).

The **layer thickness** influences both the material strength and the oxidation resistance; **thinner layers** are **stronger** but more sensible to oxidation.

Indentation tests showed that **residual stresses** control the crack path.

Thermal cycling between 1070 °C and 300 °C **did not change** the mechanical behaviour of multilayers.

Future investigations

Production of non tubular samples.

Increase the total thickness of the multilayer.

Extend thermal shock tests to higher temperatures.

Measure residual stress on the different layers

Produce multilayers with different composition of the layers.