RESISTENZA ALL'USURA DI UN CERAMICO A STRUTTURA MULTILAMINARE

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Faenza

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Summary

- Why laminated composites
- Preparation of laminated composites
- Evaluation of residual stresses
- Wear behaviour

Why laminated composites

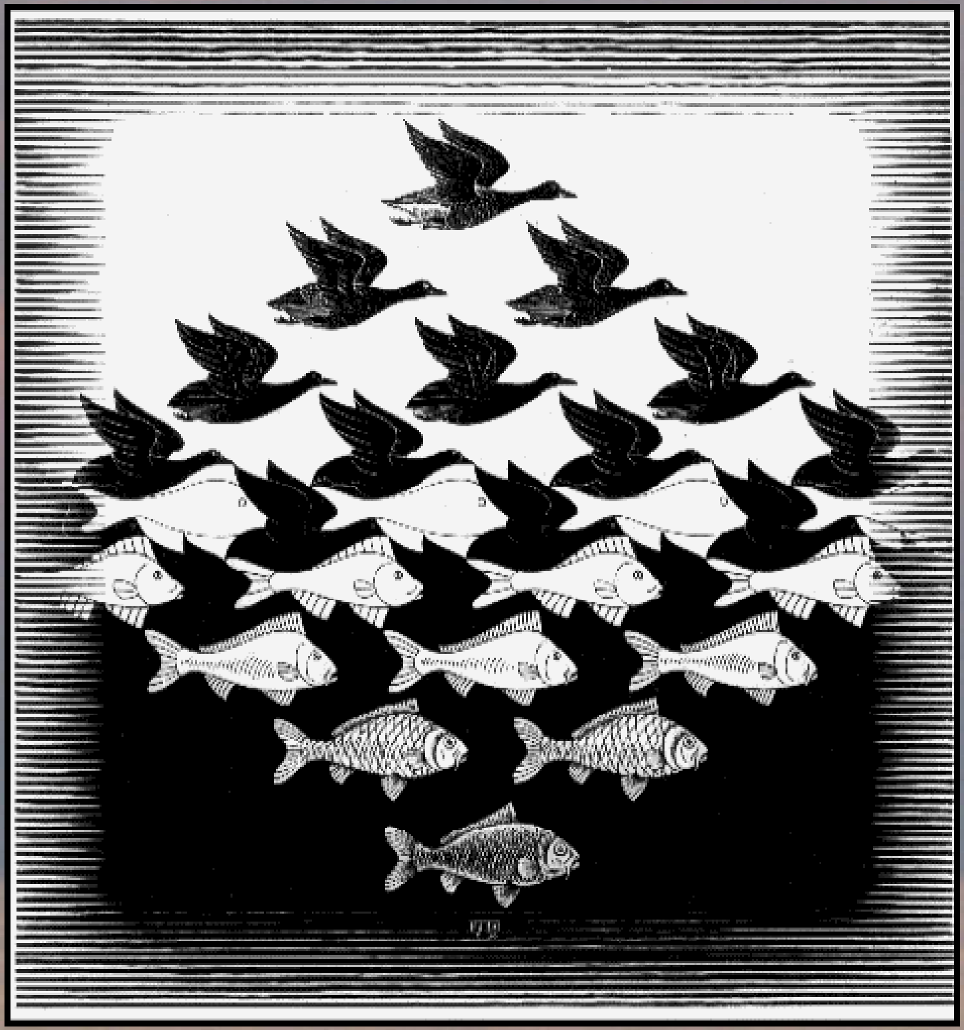
- The performances of wear-resistant materials are mainly related to the properties of thin surface layers

- Removal of material in engineering ceramics under sliding conditions is generally caused by the propagation of surface cracks resulting from tensile stresses in the wake of rubbing contact

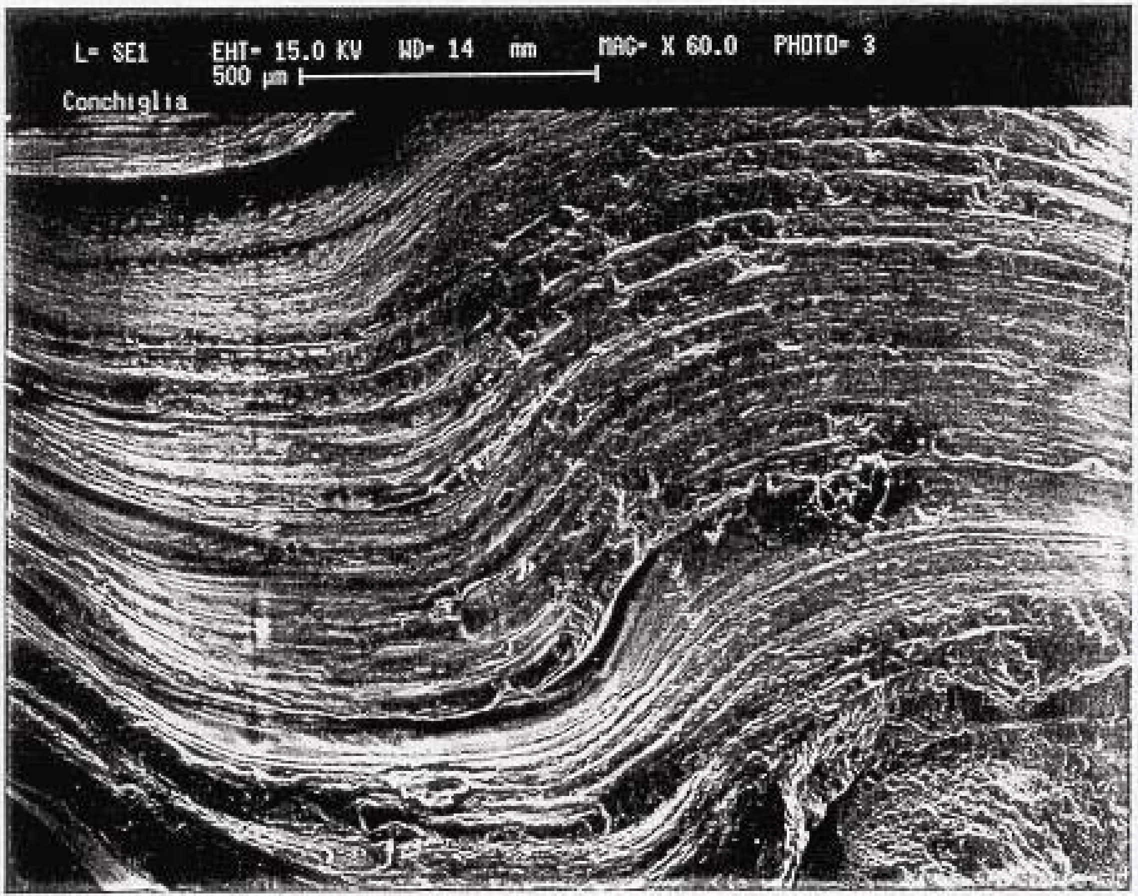
- An increase in apparent surface toughness should lead to an improvement in wear resistance

- Laminated structures can be designed to induce compressive residual stresses at the surface by combining the different thermo-physical characteristics (i.e. thermal expansion and shrinkage on sintering) of the different materials used

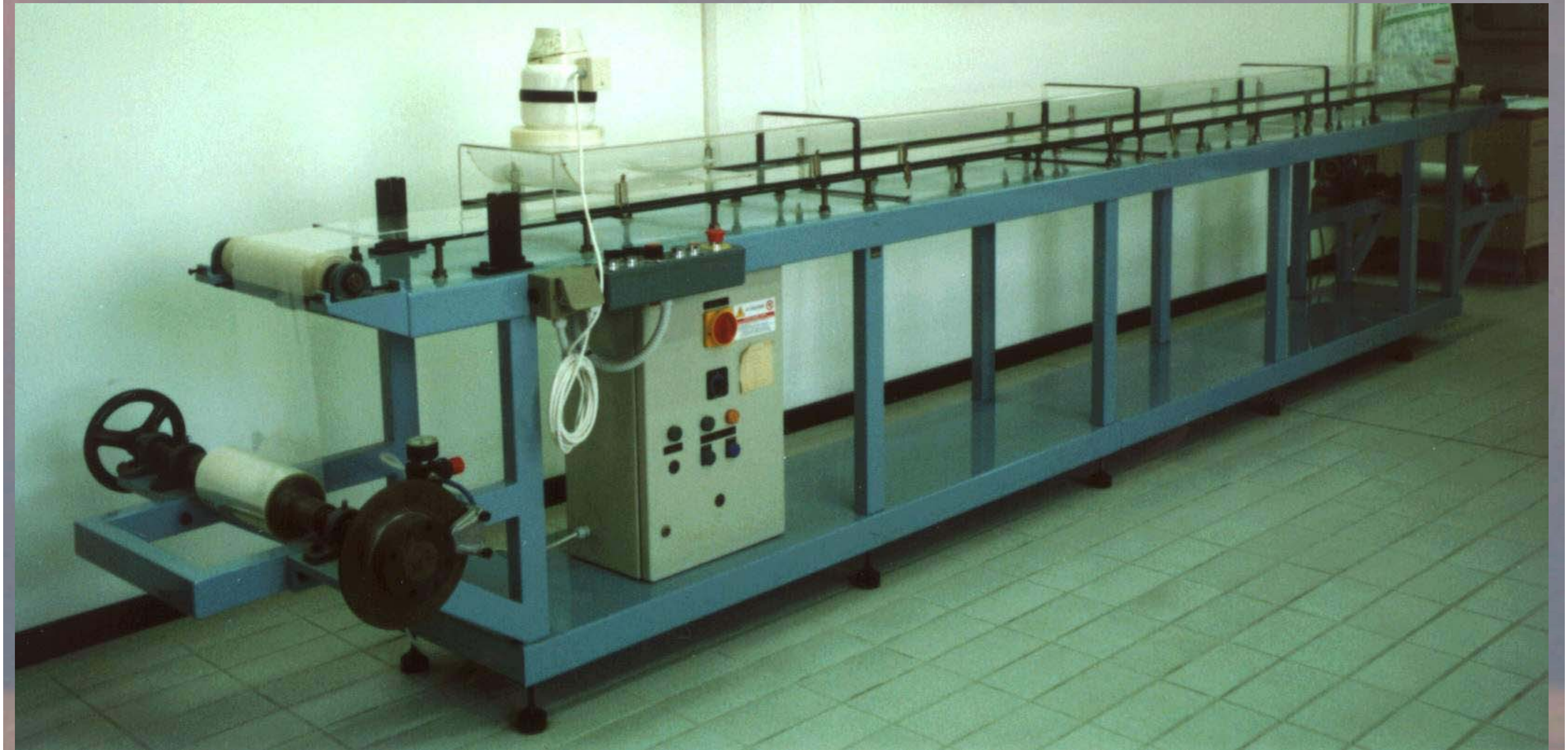
Artistic view of a Functional Graded Material



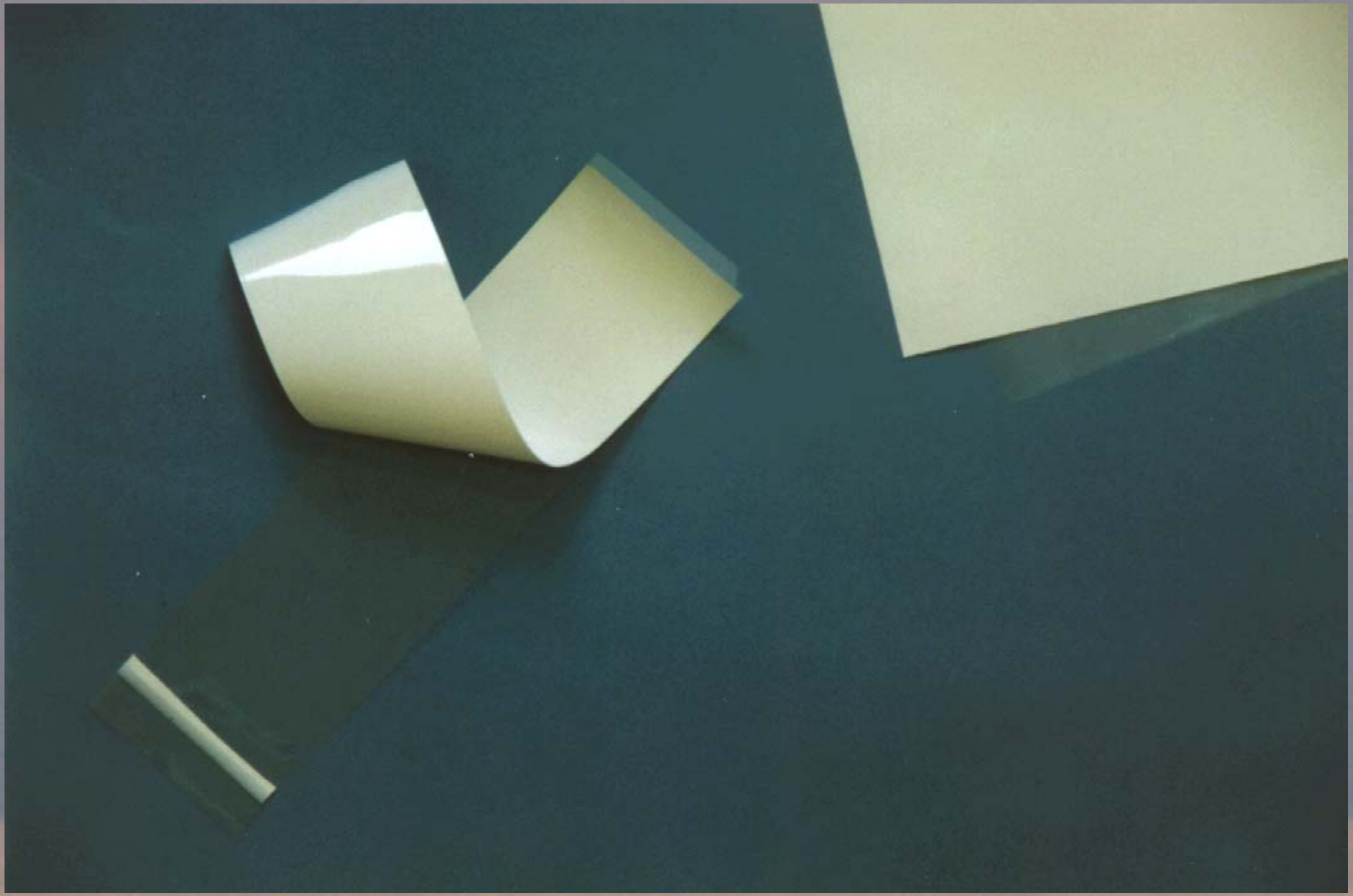
Cross Section Micrograph of a Shell



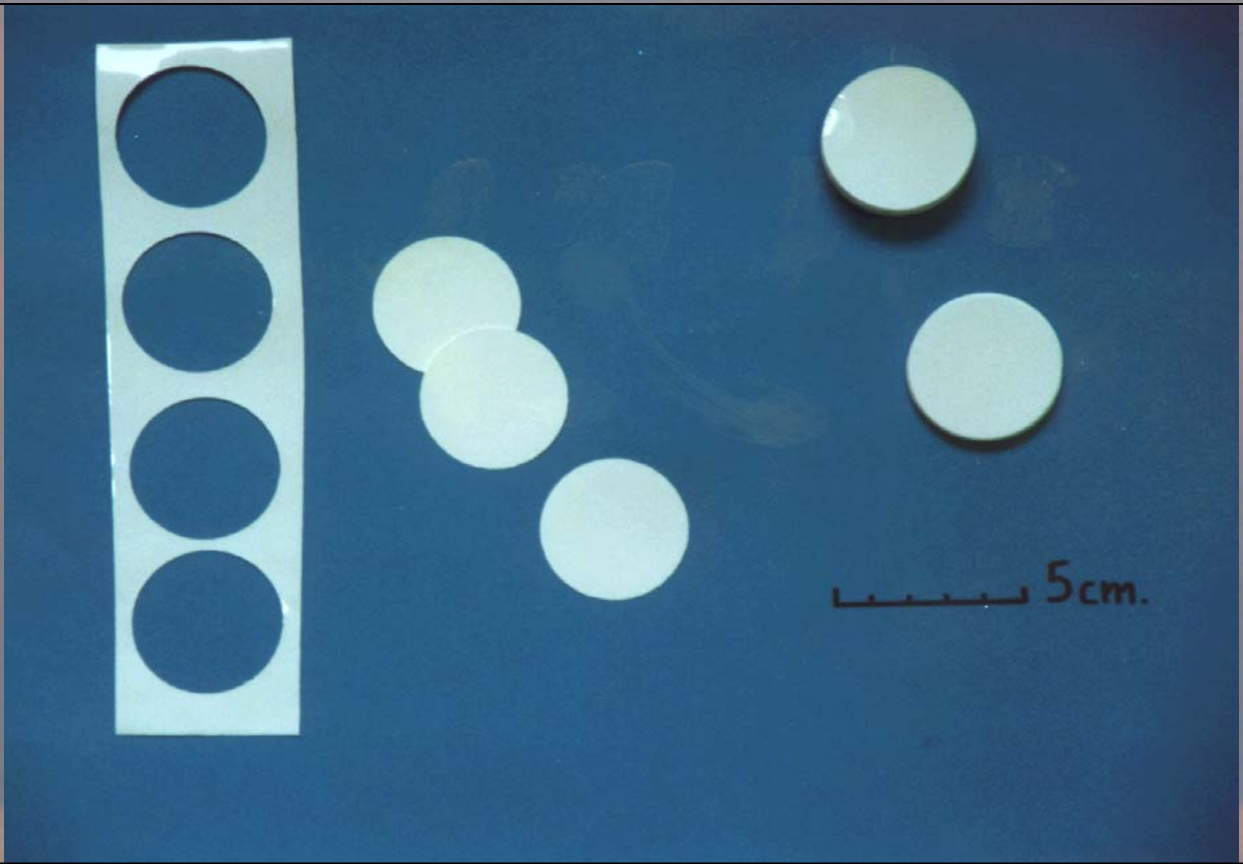
Tape - Casting Apparatus



Ceramic sheets produced by tape-casting



Technique for preparing laminated composites



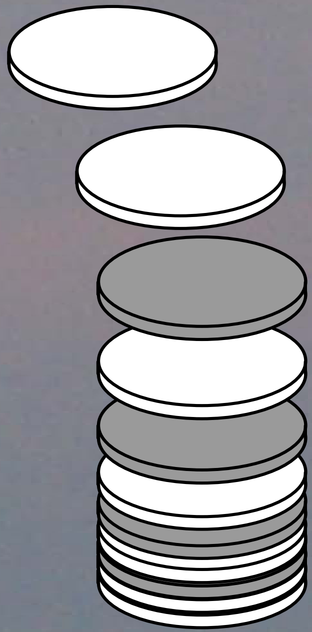
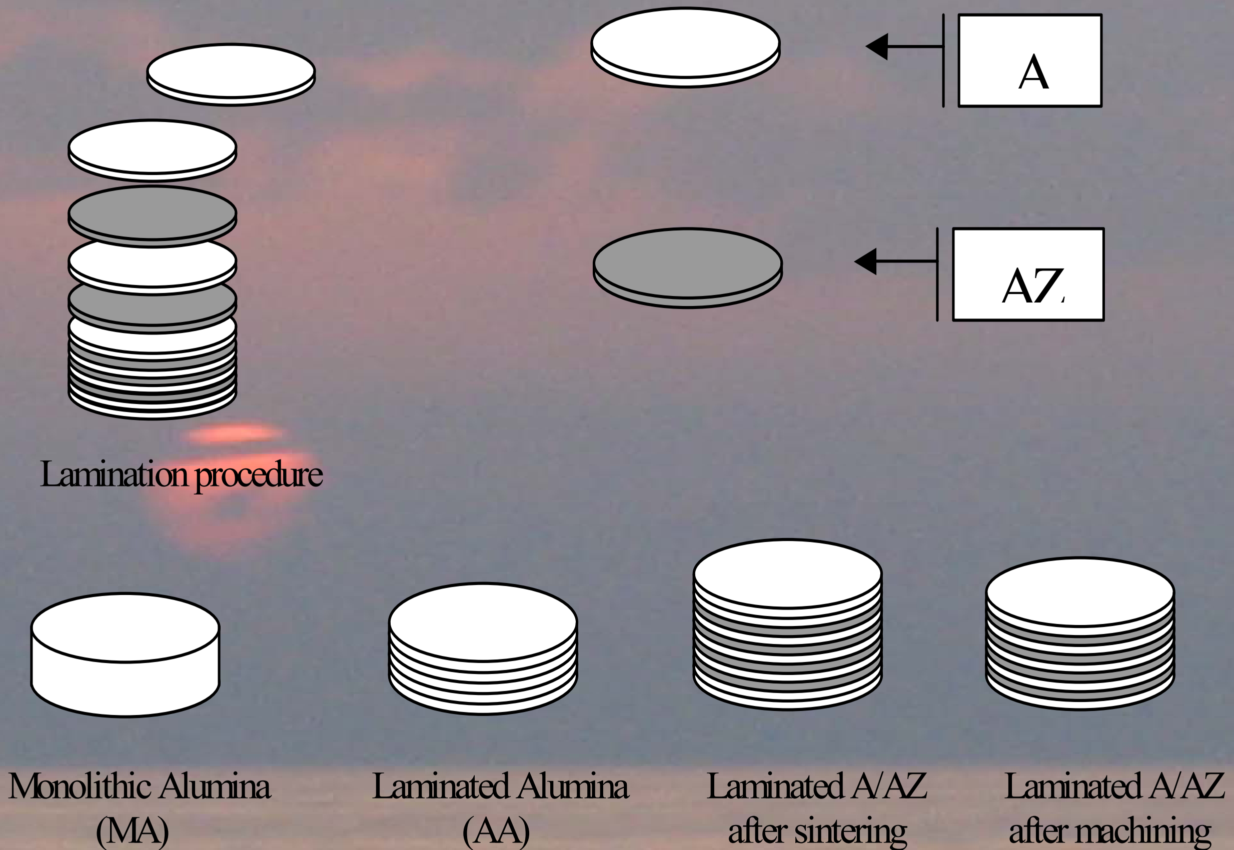
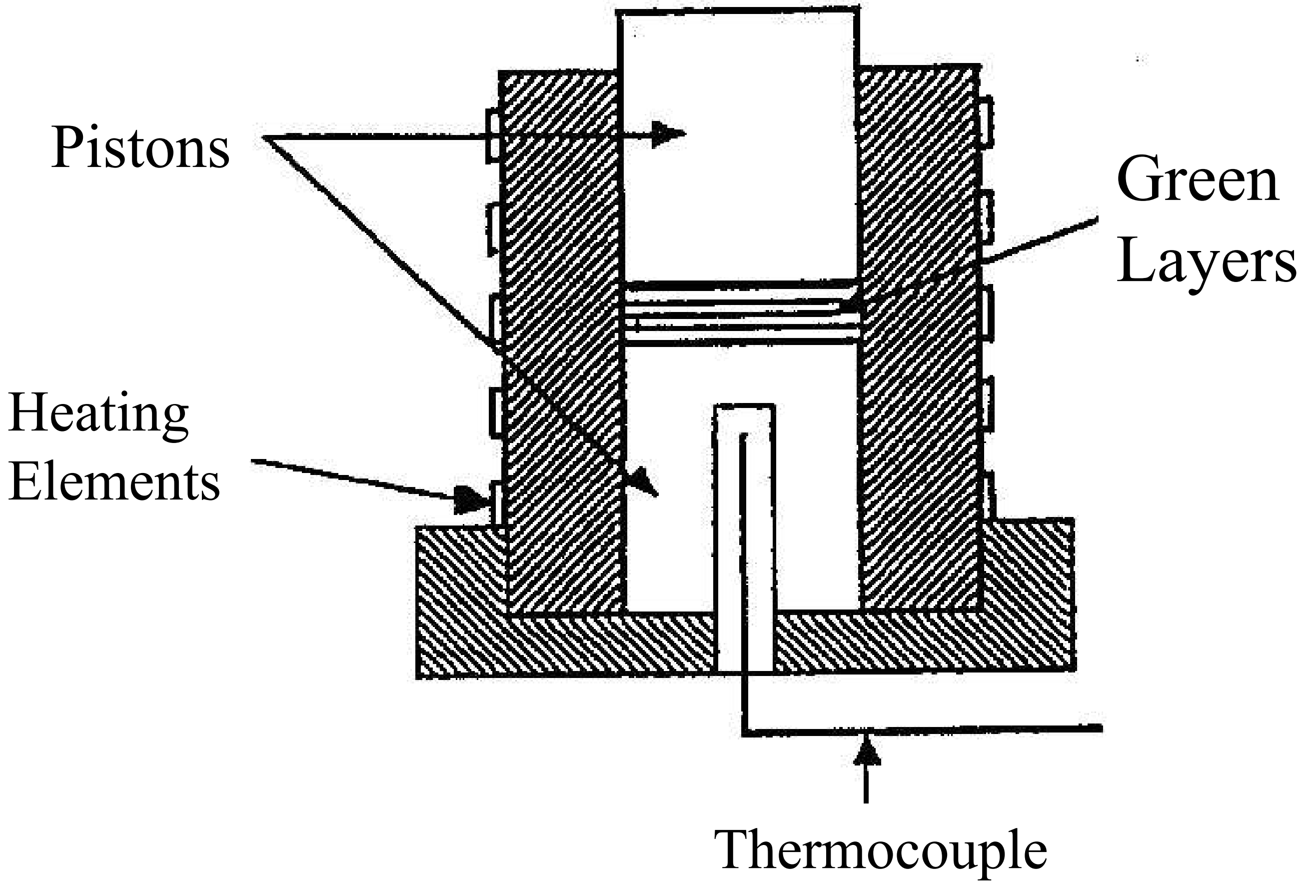


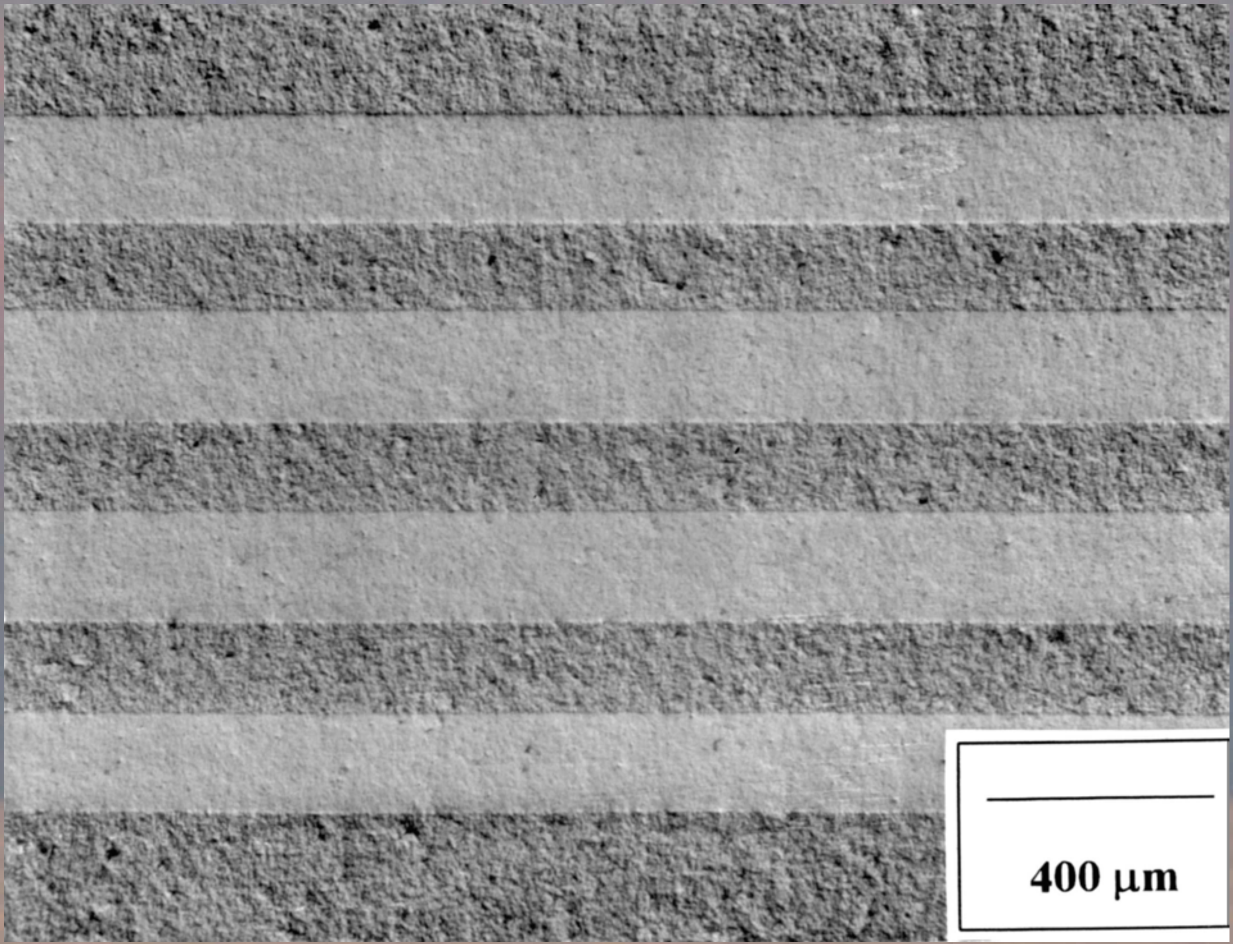
Diagram of samples preparation



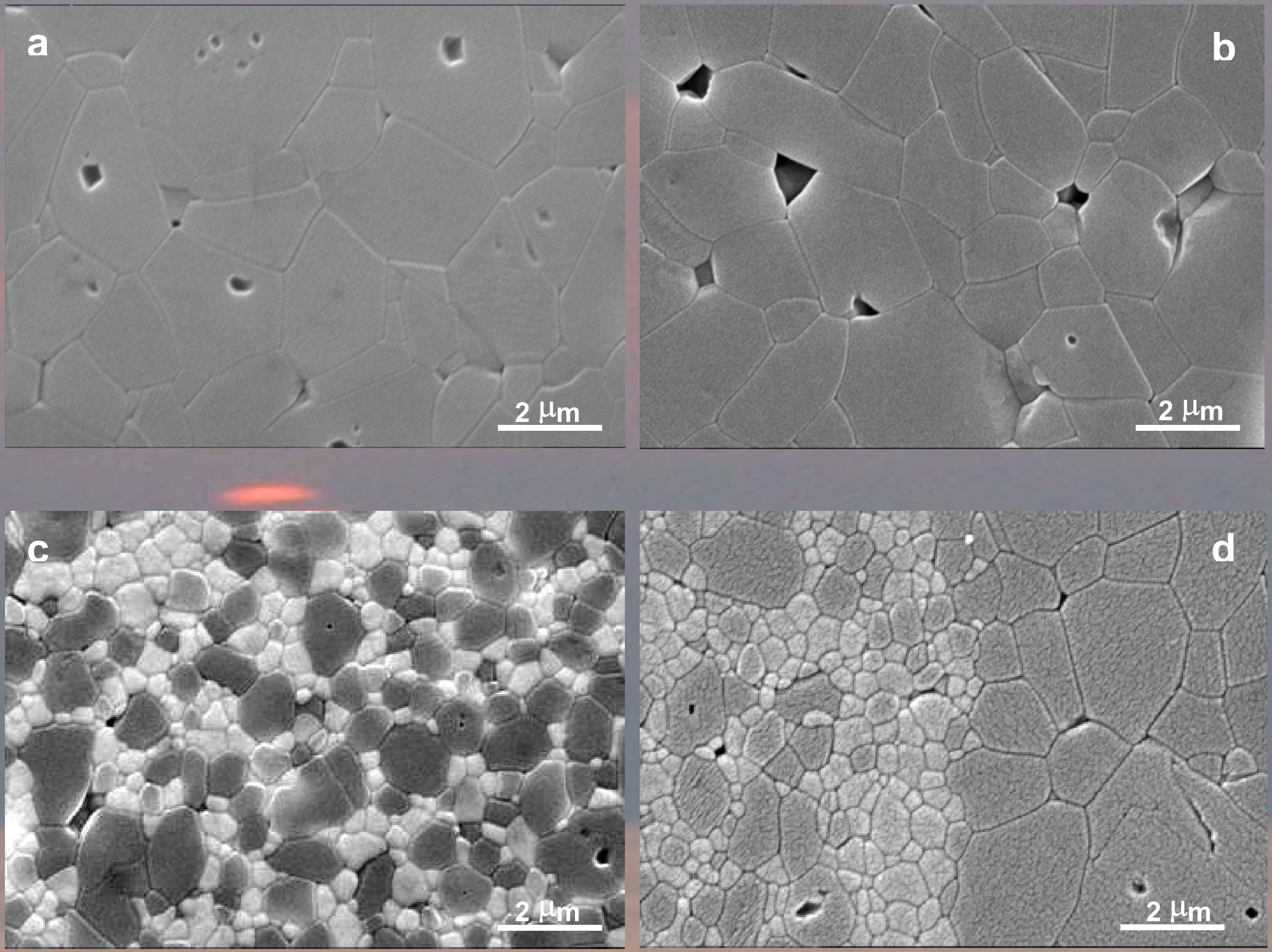
Warm Pressing



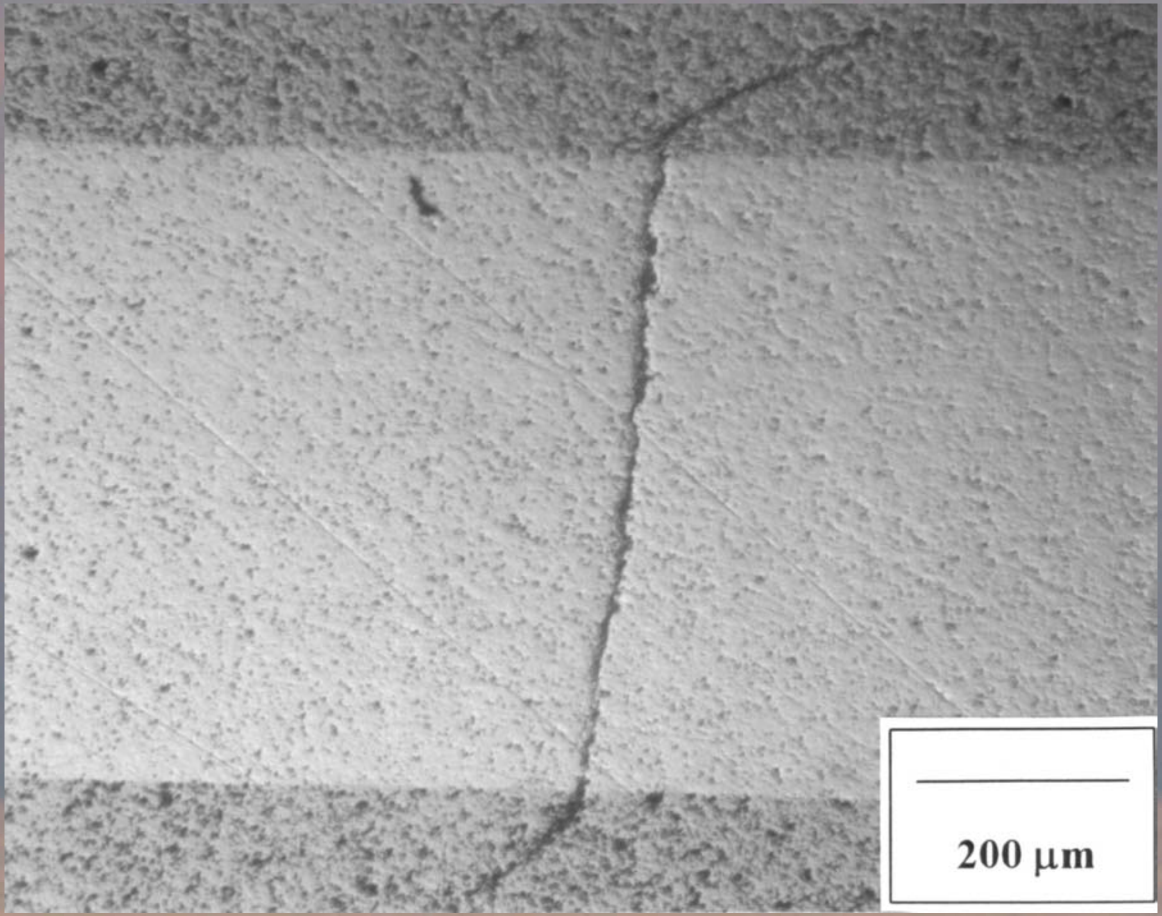
Section of Al_2O_3/Al_2O_3-ZrO_2 laminated composites



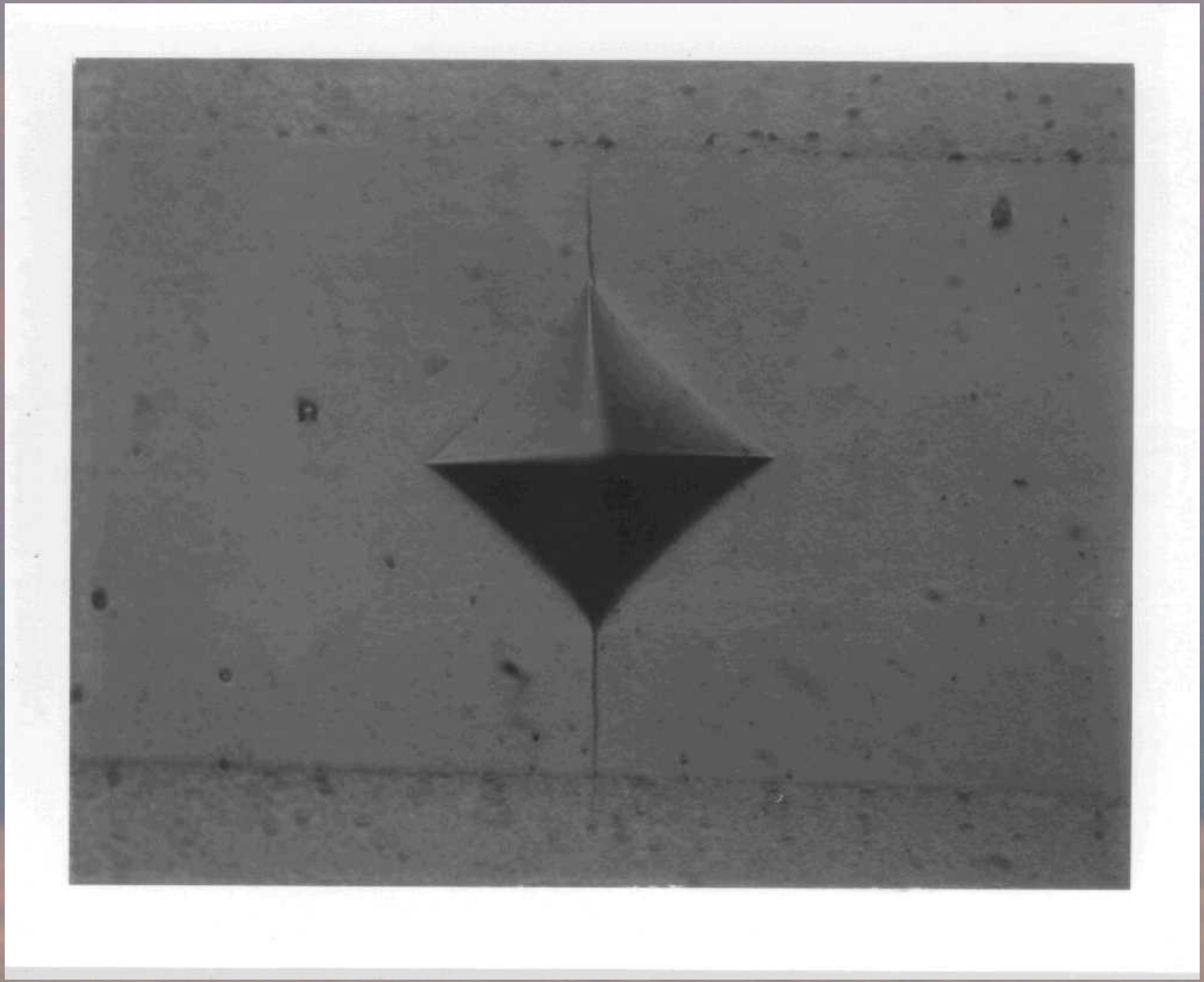
Microstructure of polished and thermally etched surface of the three materials: a) MA; b) AA; c) AZ; d) interface A/AZ



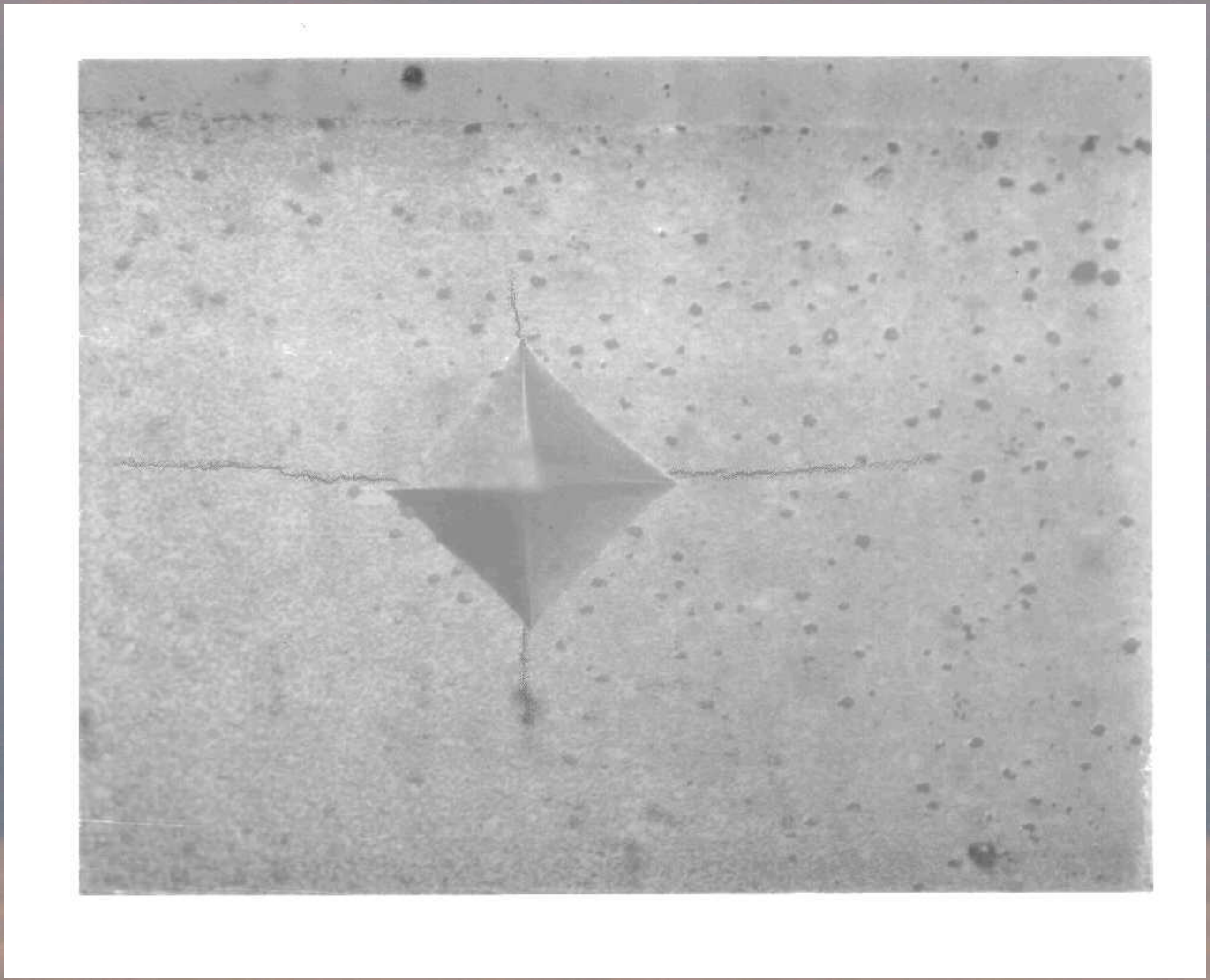
Tunneling Crack in Laminated Composite



Vickers Impression on Layer in Tension



Vickers Impression on Layer in Compression



Indentation model: relationship among K_{IC}, indentation load and crack length

$$K_{Ic} = \chi \cdot \frac{P}{c_0^{3/2}}$$

K_{Ic} = toughness of the stress free material
χ = dimensionless constant (experimentally determined)
P = indentation load
c_0 = crack length

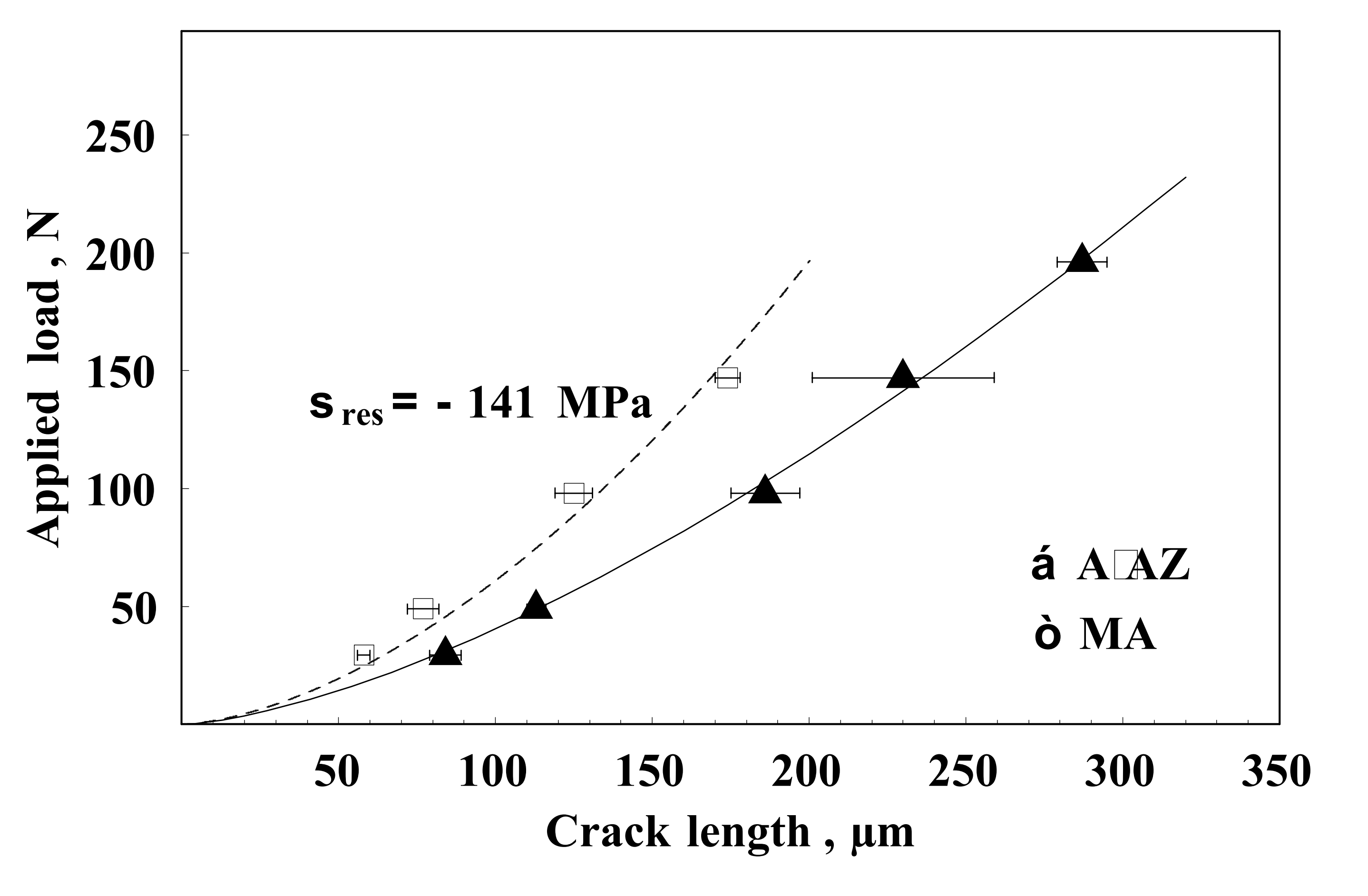
Relationship among K_{IC}, indentation load and crack length in presence of residual stress

$$K_{Ic} = \chi \cdot \frac{P}{c_1^{3/2}} + Y \cdot \sigma_{res} \sqrt{c_1}$$

where:

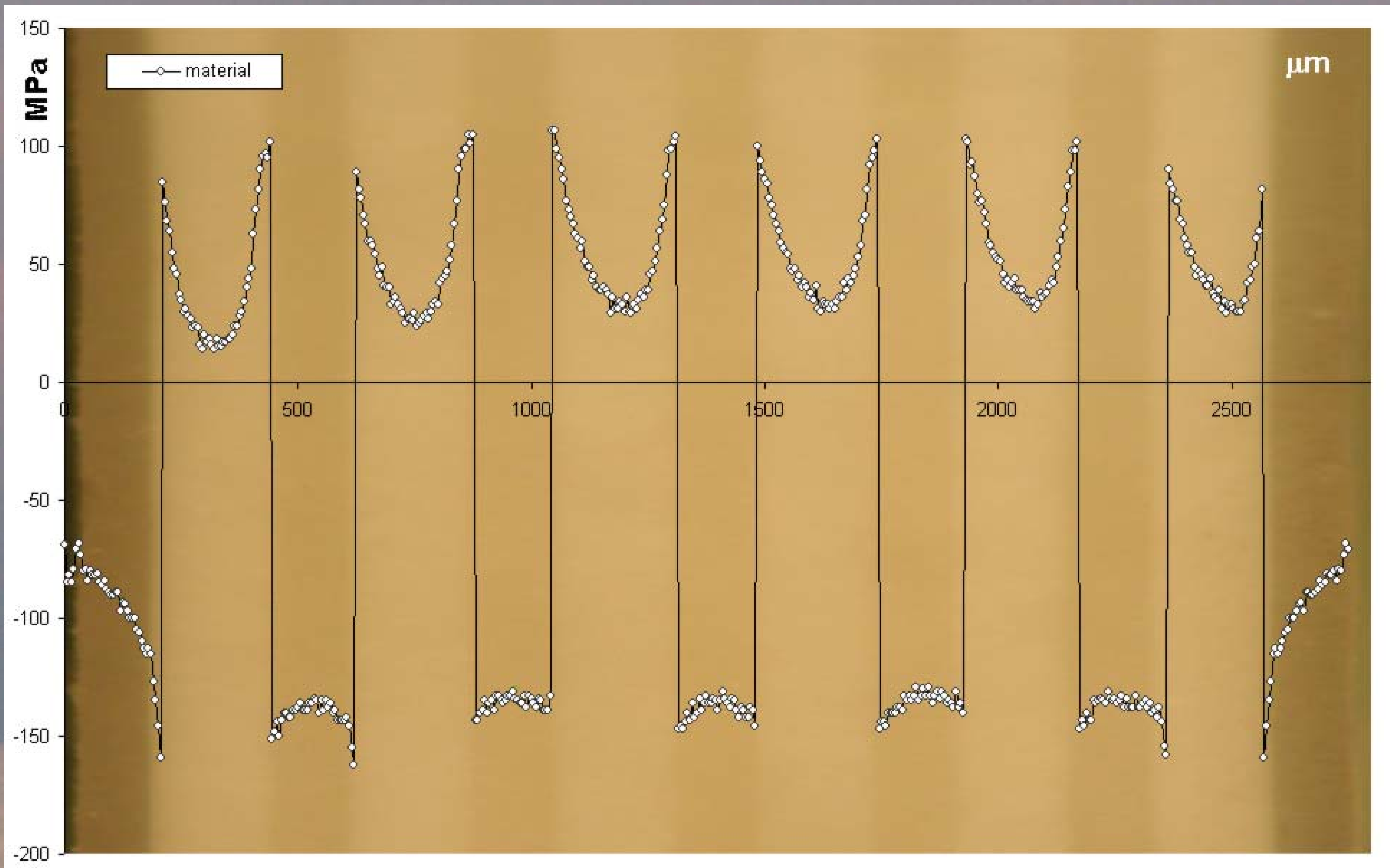
c_1 = crack length in the stressed material
Y = 1.29 geometrical factor
σ_{res} = residual stress

Evaluation of residual stress in laminated composite

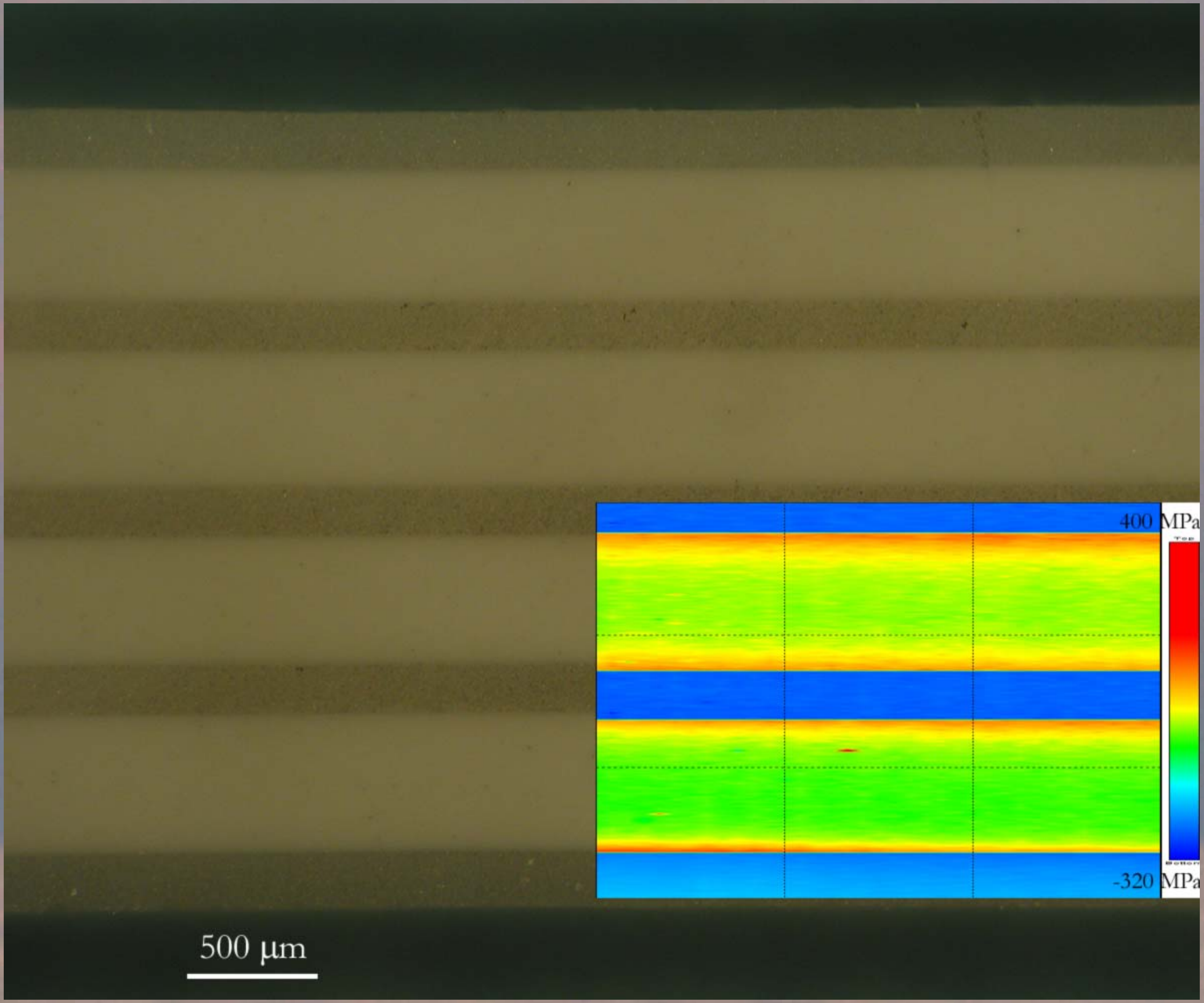


Stress Map in A/AZ Laminated Composite

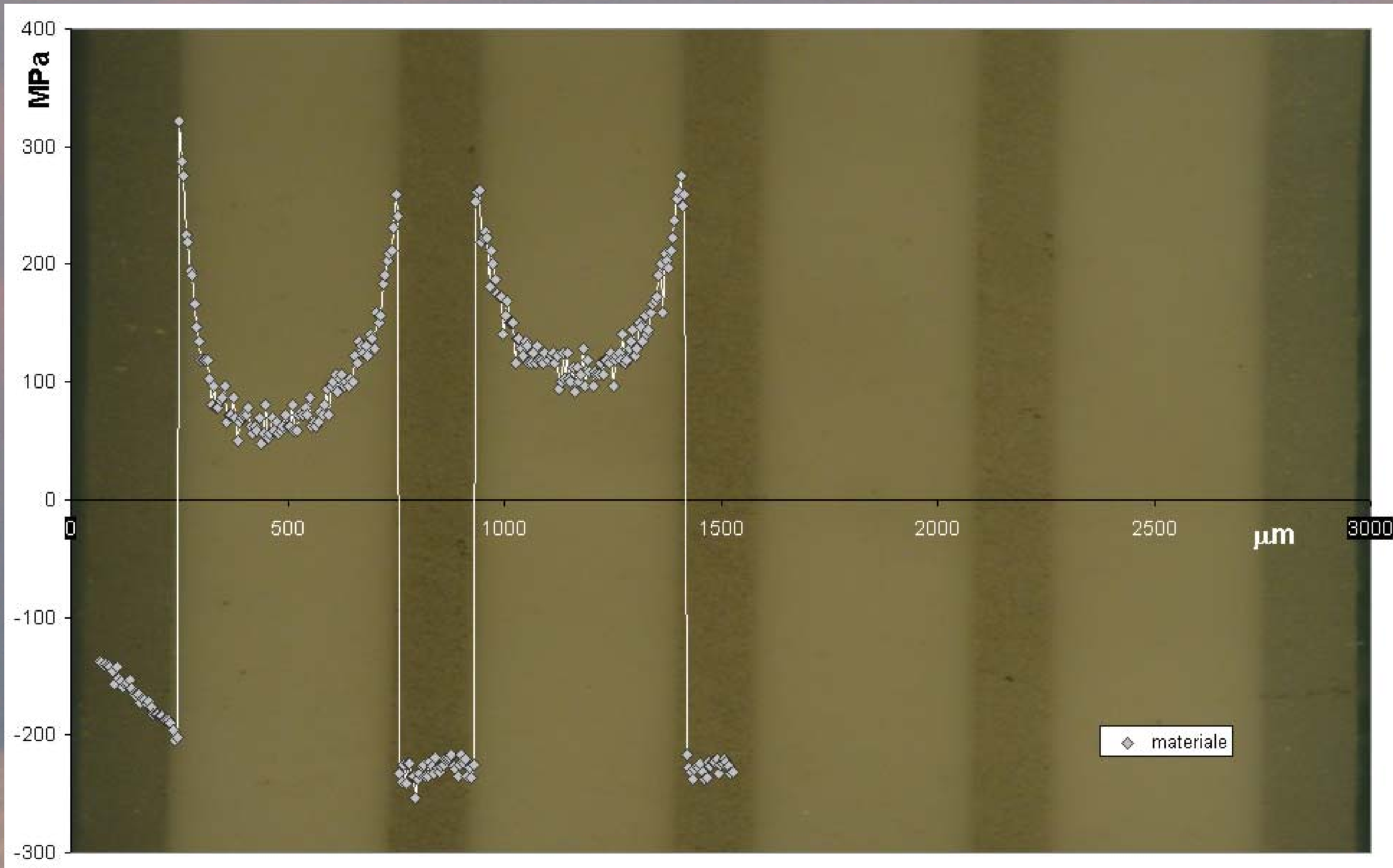
Stress Profile in A/AZ Laminated Composite



Stress Map in A/2AZ Laminated Composite



Stress Profile in A/2AZ Laminated Composite



Measured hardness, calculated Young's modulus and surface toughness for the different materials

MATERIAL	HV (GPa)	E (GPa)	K_{Ic} (MPa·√m)*
A/AZ	17.6 ± 0.8	375	5.37 ± 0.50 [+]
AA	16.4 ± 0.6	375	3.04 ± 0.23 [+]
MA	16.6 ± 0.5	410	3.35 ± 0.43 [+] (3.61 ± 0.13 [§])

Distribution of stresses in sliding contacts

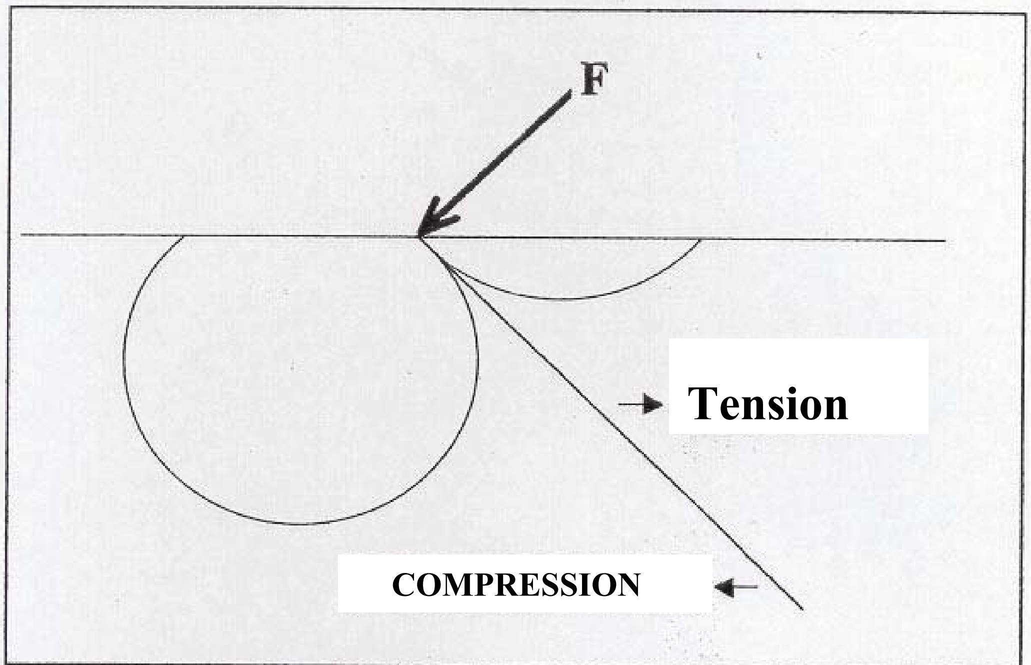
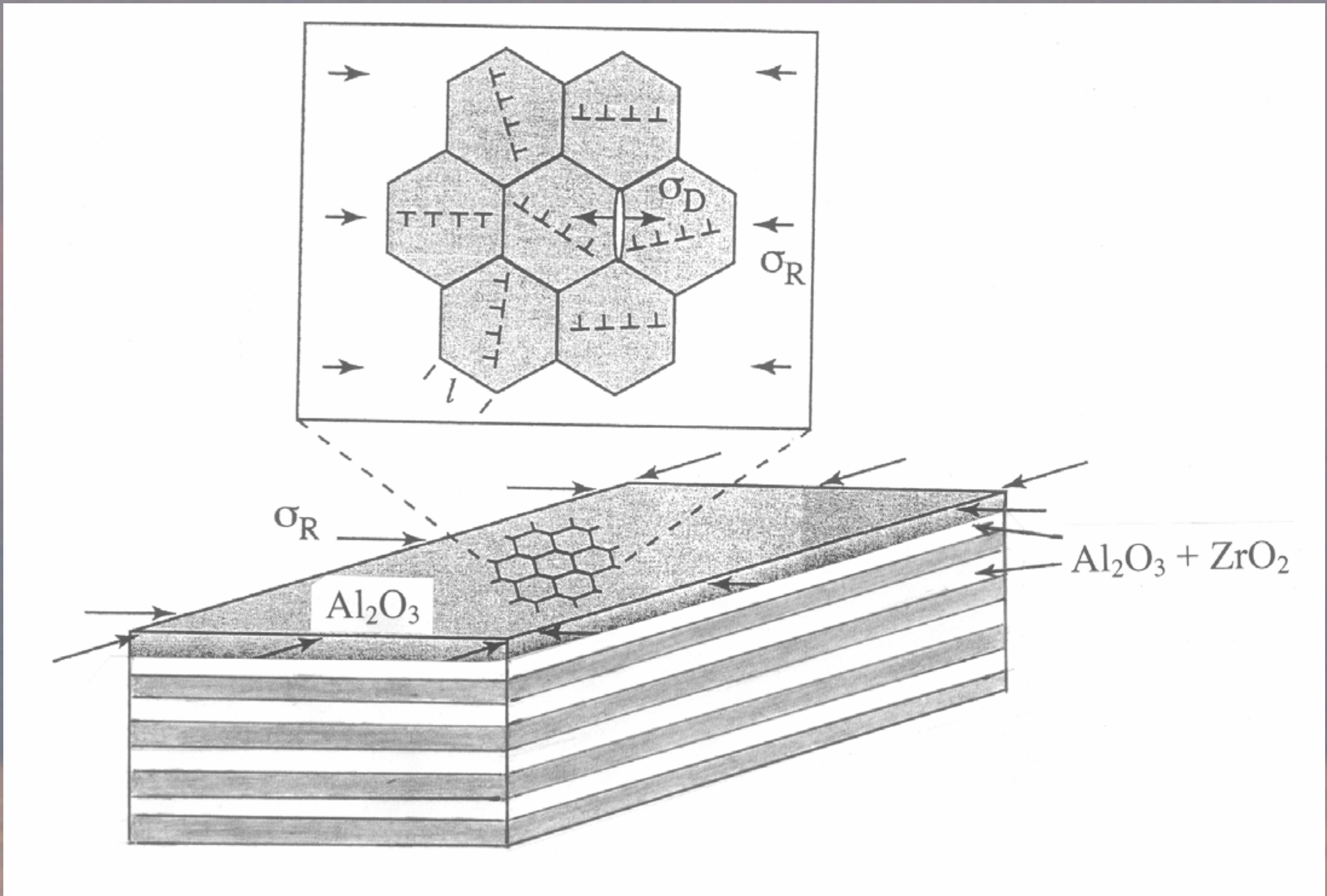
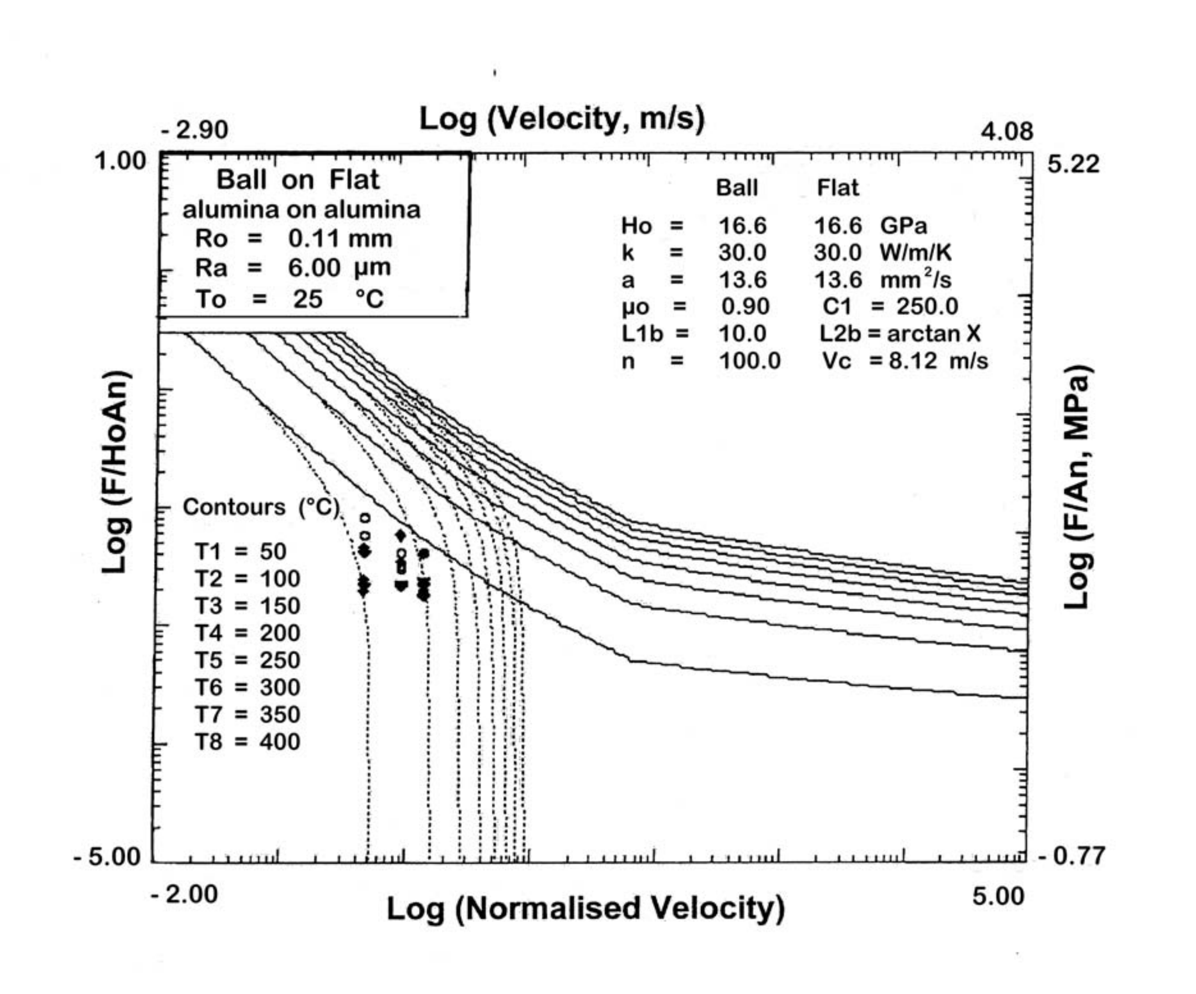


Fig.1.2.3.14. Stato delle tensioni e delle deformazioni per un materiale elastico-perfettamente plastico sollecitato da un carico concentrato F. Gli archi di cerchio rappresentano i luoghi di tensione tangenziale massima costante.

Schematic of the effects of compressive residual stresses in the surface

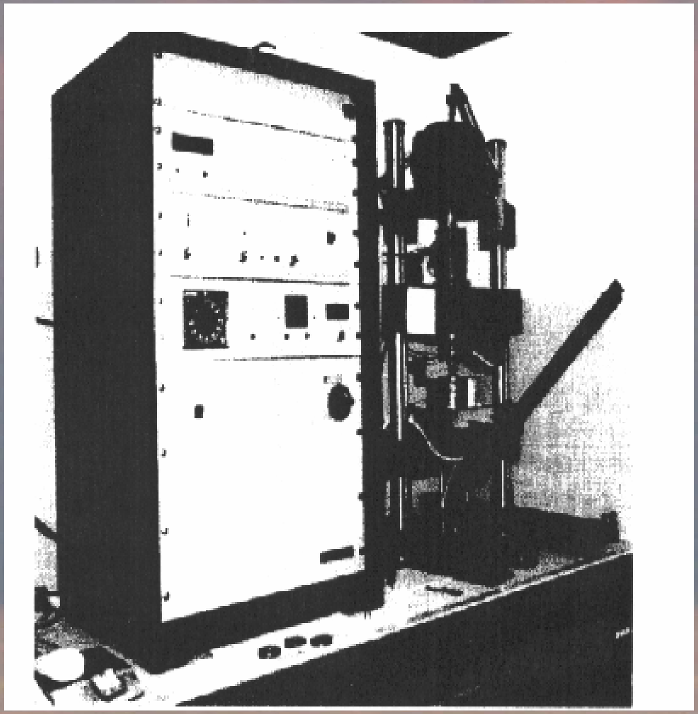


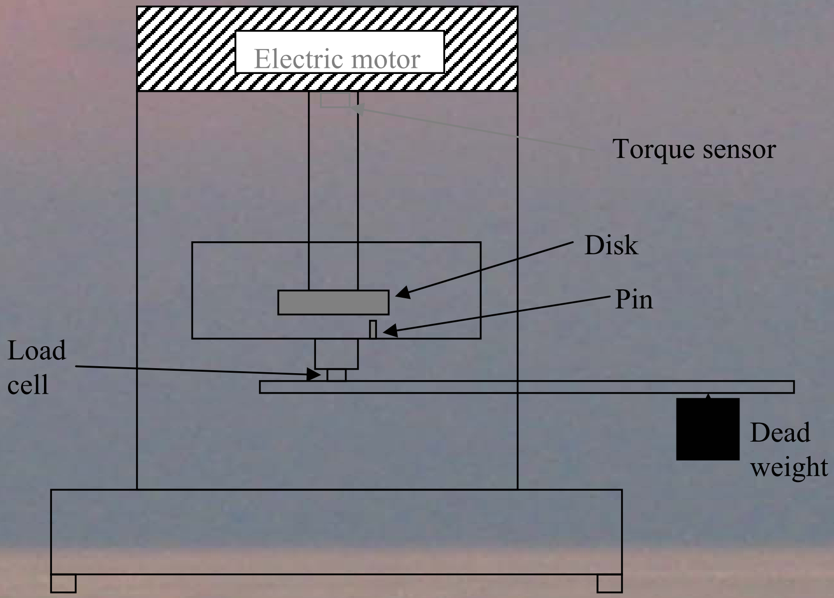
Ashby map with the points relative to the test conditions



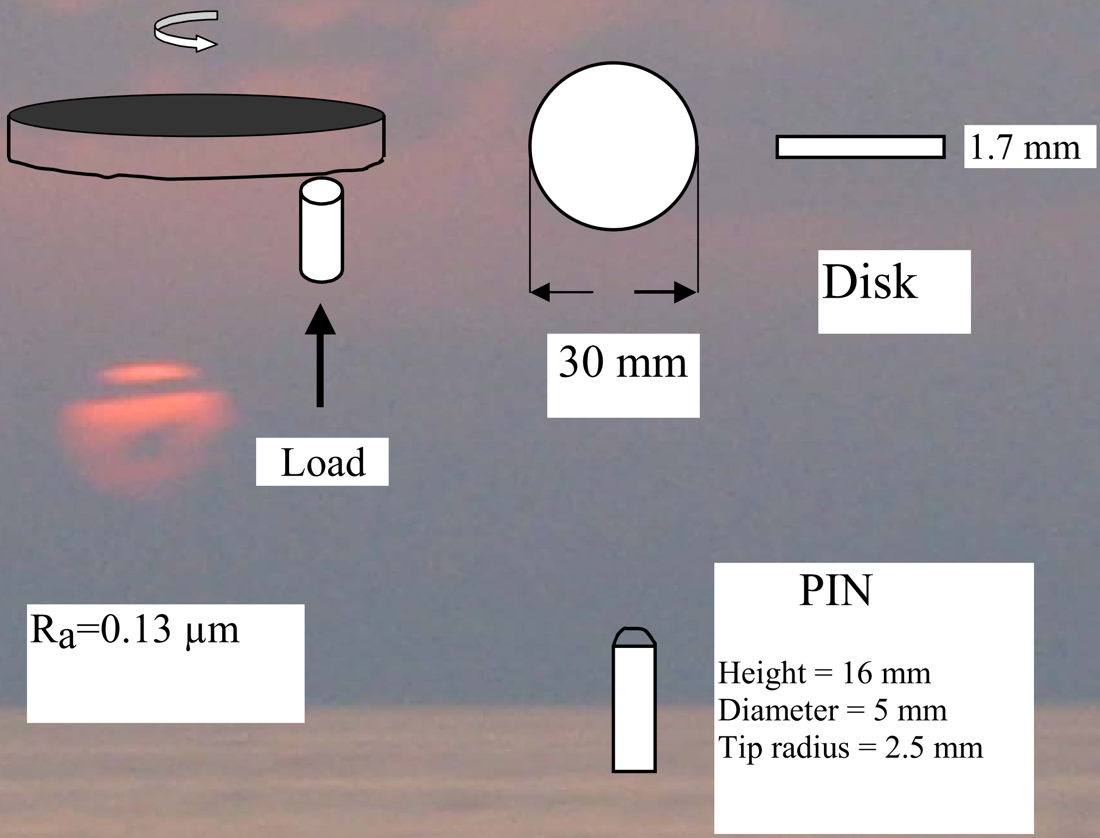
Method

- inverted pin-on-disk tests on a Wazau tribometer





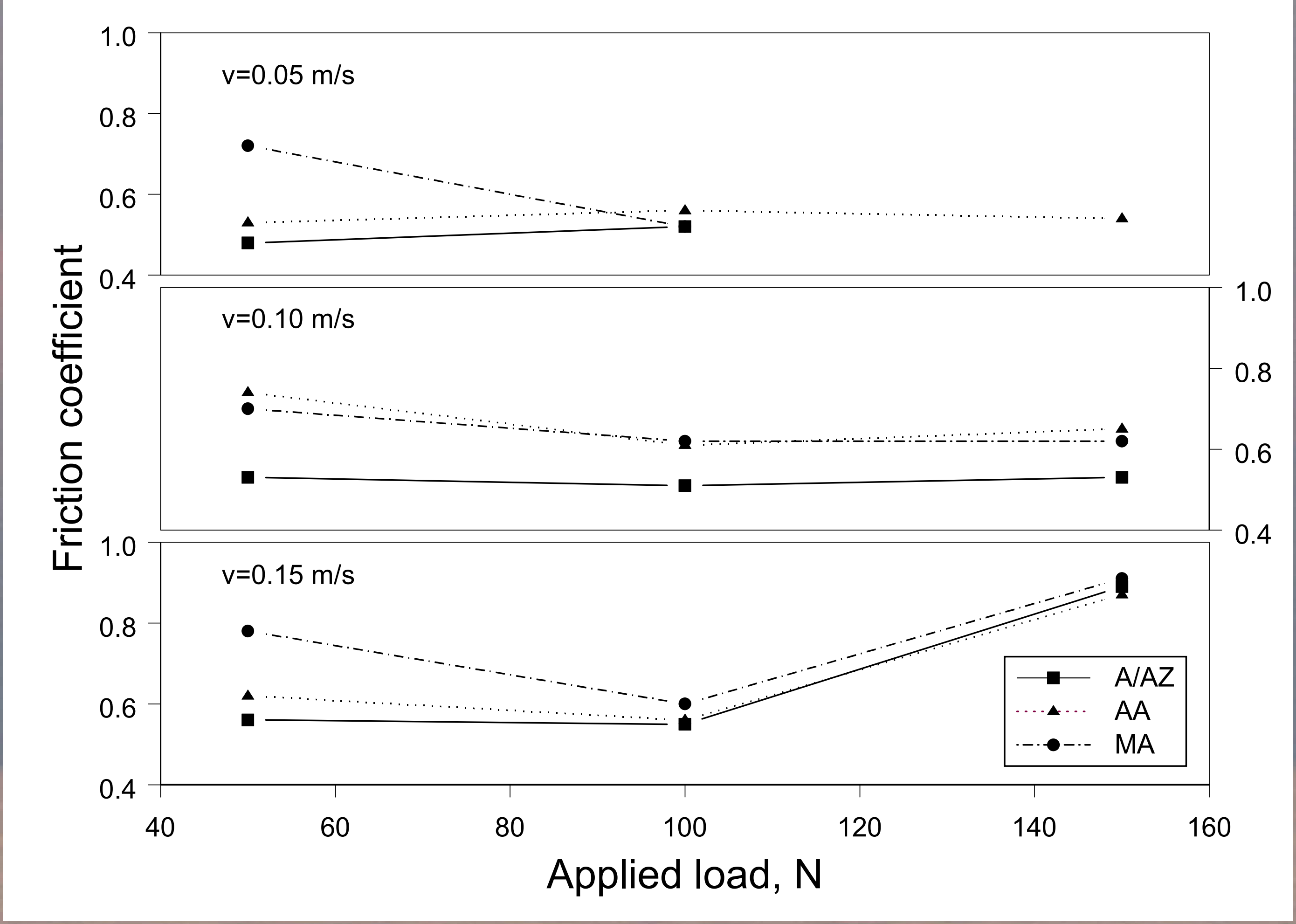
Pin-on-Disk Configuration



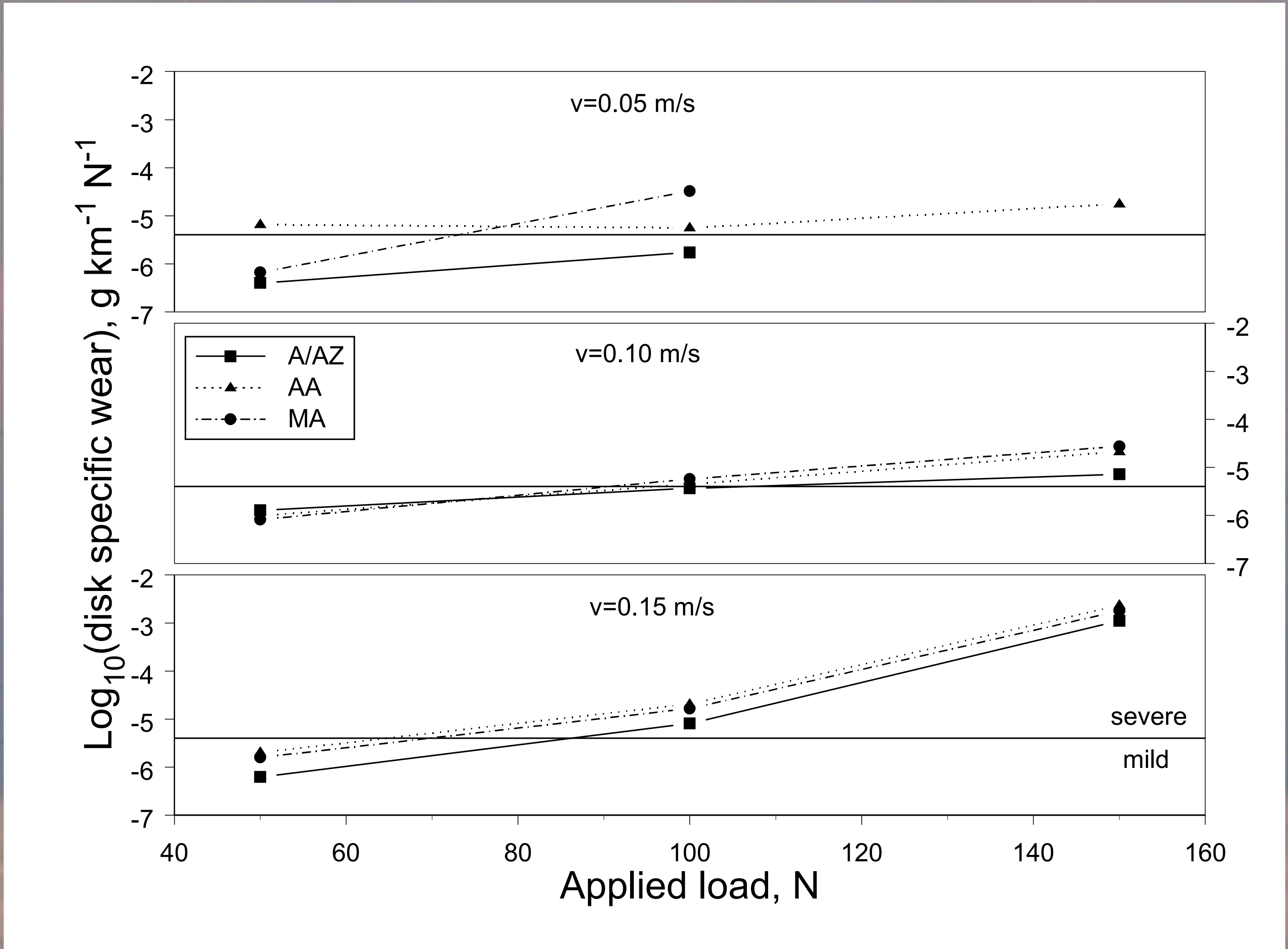
Experimental Procedures

- Load: 50 N, 100 N, 150 N
- Sliding speed: 0.05 m/s, 0.10 m/s, 0.15 m/s
- Sliding distance: 15 km
- Temperature: 22 °C
- Humidity: 70%

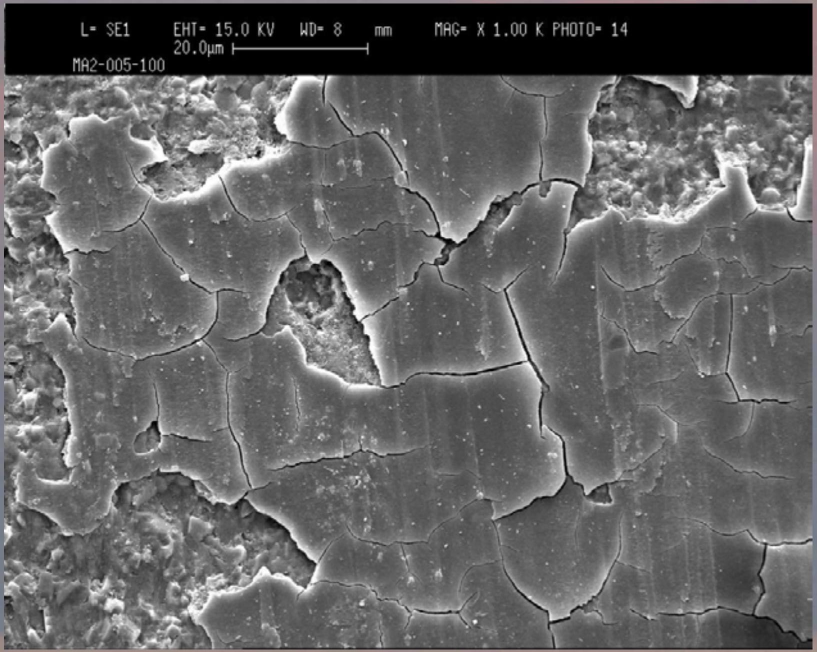
Mean values of the friction coefficients measured on the various materials for the different experimental conditions

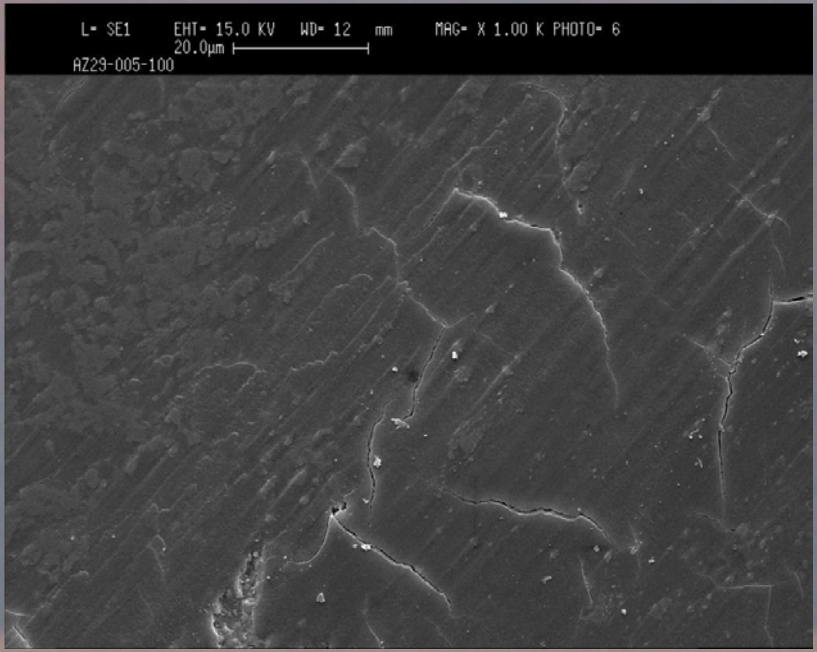


Semi-Log plot of the disc specific wear of the various materials as function of the different experimental conditions

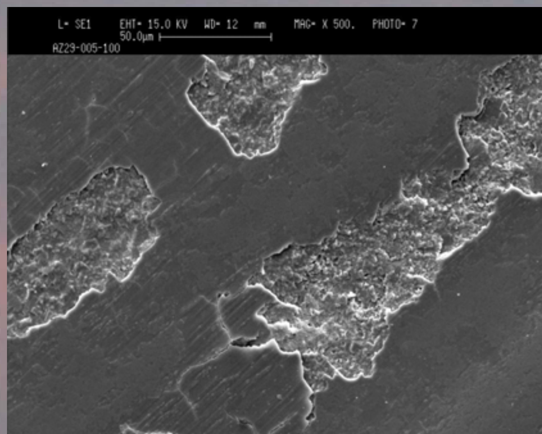


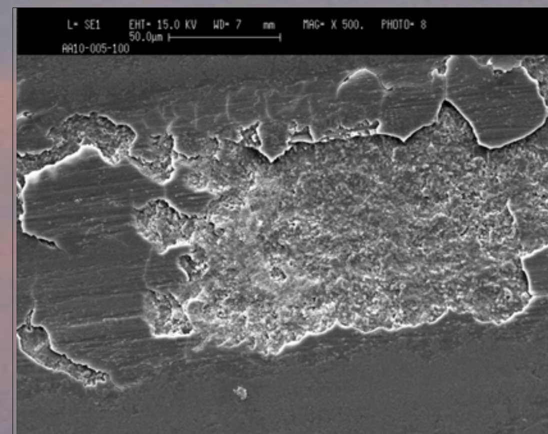
Surface cracking of stress free alumina (MA) and alumina containing compressive residual stresses (A/AZ) 100 N , 0.05 m/s

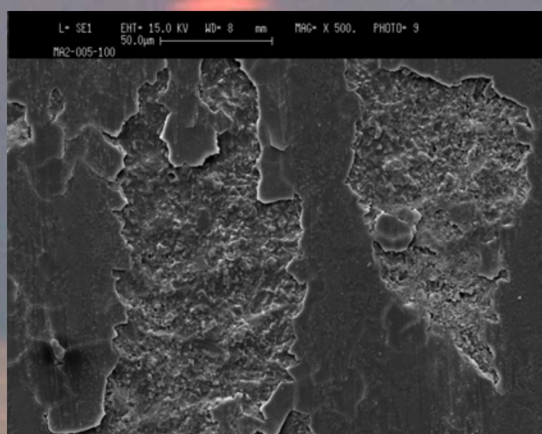




Fracture of the surface with detachment of flakes (100 N and 0.05 m/s)



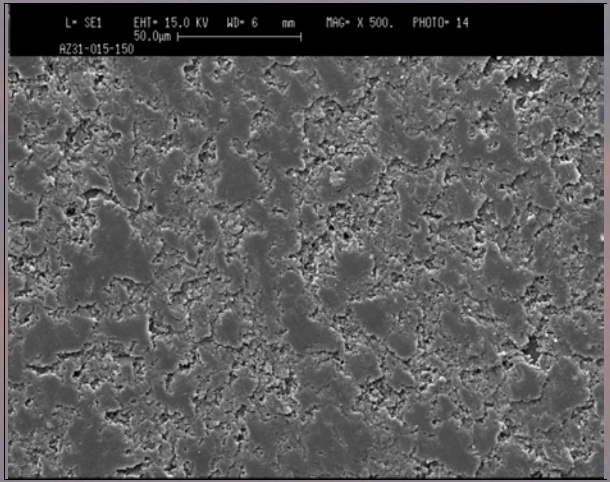


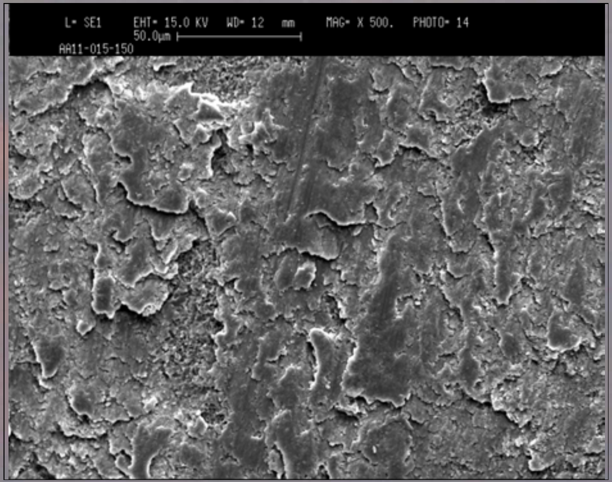


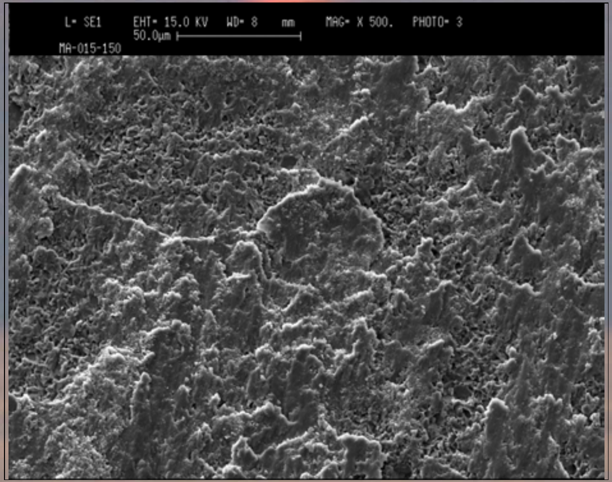
AZ AA

MA

Plastically deformed debris spread over the surface (150 N and 0.15 m/s)



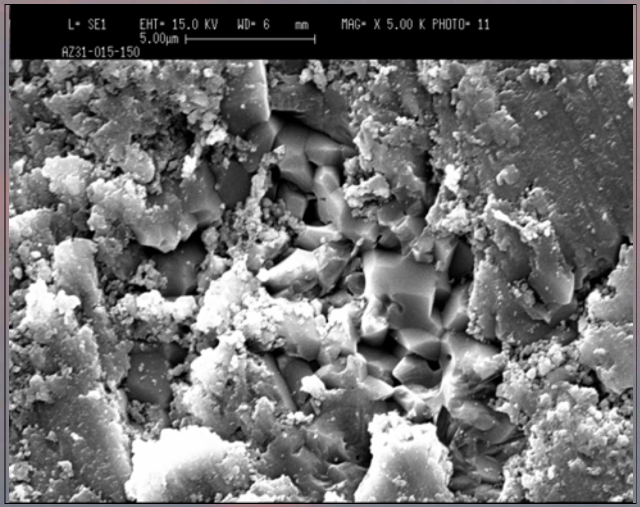


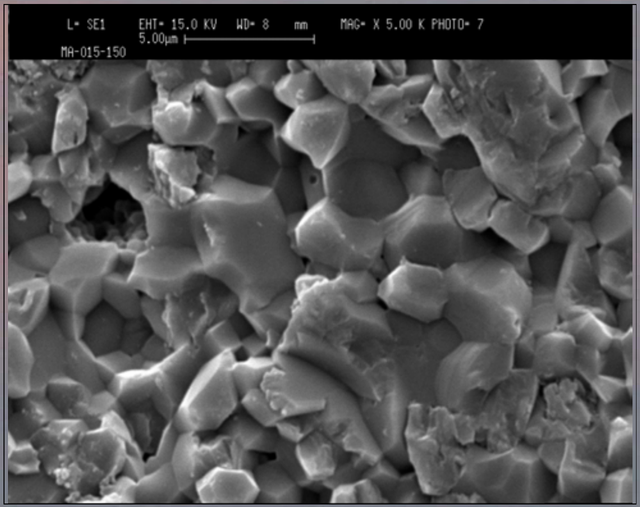


AZ AA

MA

Fracture surfaces observed in the wear tracks





- Composite A/AZ and Monolithic MA
- 150 N; 0.15 m/s (5000 X)

CONCLUSIONS 1

- Suitable design and processing can lead to the production of laminated ceramic composites with compressive residual stresses at the surface.
- The stresses can be measured also using the indentation model or raman spectroscopy.
- These stresses are responsible for an increase of hardness and apparent surface toughness.
- If the wear mechanism is microcracking, the wear resistance of ceramics can be improved and the transition from mild to severe wear retarded.

CONCLUSIONS 2

- Friction coefficient of laminated composites is lower if compared with that exibited by the stress free materials.

- Laminated ceramic composites are attractive structures suitable for structural and tribological applications.