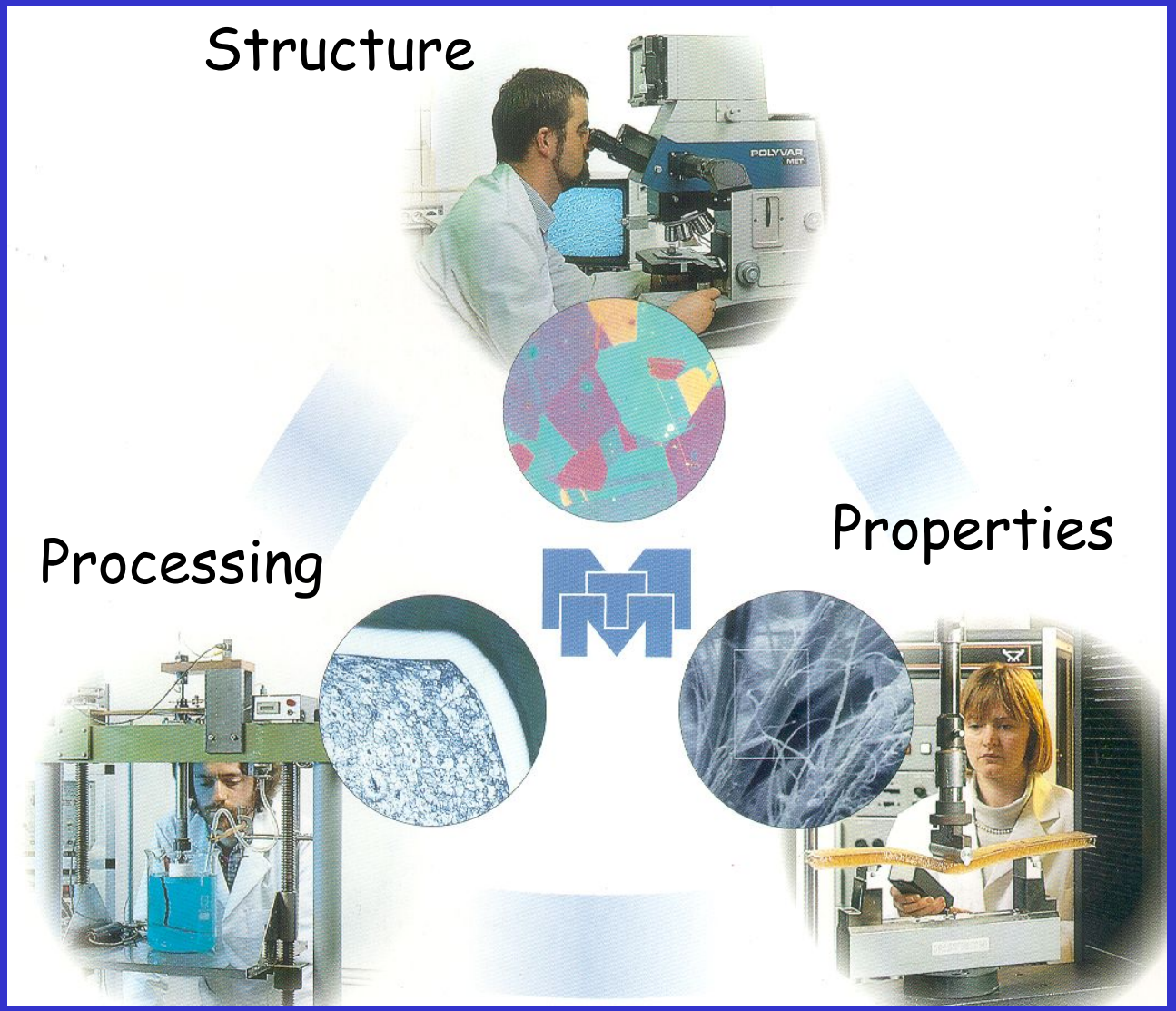
Research on ceramics

Department of Metallurgy and Materials Engineering

www.mtm.kuleuven.be

The MTM triangle



Ceramics research group

ZAP (Professors):

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PhD students:

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Swarnakar Akhilesh Kumar
Li Zhang
Khuram Shahzad

PhD students:

Annabel Braem
Olivier Malek
Ezhil Jothinathan

Activities ceramics research group

Processing of ceramics

- Powder synthesis (sol-gel, carbo- and borothermal reduction)
- Powder metallurgical shaping
- Colloïdal shaping by electrophoretic deposition (EPD)

Microstructural analysis and functional properties

- Sintering (pressureless, hot pressing, microwave, SPS)
- Microstructural analysis (SEM, EPMA, XRD, TEM)
- Mechanical properties (hardness, toughness, strength, etc.)
- Elastic and damping properties at room and elevated temperature

Modelling

- Chemical compatibility
- Electrophoretic deposition (EPD)
- Functionally graded materials (FGM)
- Damping
- Field assisted sintering technology (FAST, SPS, PECS)

Ceramic Materials under investigation

Composites

Glass-ceramics

Bariumaluminosilicate (BAS)
Magnesiumaluminosilicate (MAS)

Ceramic matrix composites

Matrix: Si_3N_4, ZrO_2, Al_2O_3, ZrB_2, TiB_2
Additive: Al_2O_3, TiB_2, TiN, TiC, TiCN, WC, NbC, ZrC, HfC, HfTiC, ZrN, B_4C, SiC, etc.

Cermets

WC-Co, TiCN-based
NbC-based

Reinforced ceramics

Fibre reinforced

Borosilicate, MAS & BMAS with SiC fibres

Platelet reinforced

Sialon, Al_2O_3, mullite with Al_2O_3 platelets

Monoliths

Oxides

Mullite, Al_2O_3
Y-TZP & Ce-TZP
Mixed stabiliser ZrO_2

Non-oxides

SiAlON, Si_3N_4
SiC, TiB_2, TiN, TiCN, WC, ZrB_2, B_4C,etc

Graded Materials

Functionally graded (FGM)

ZrO_2/Al_2O_3 & ZrO_2/WC
WC-Co/WC-Co
TiCN-based/WC-Co
Ce-TZP/Y-TZP

Laminates

SiC / graphite & SiC / porous SiC

Coatings

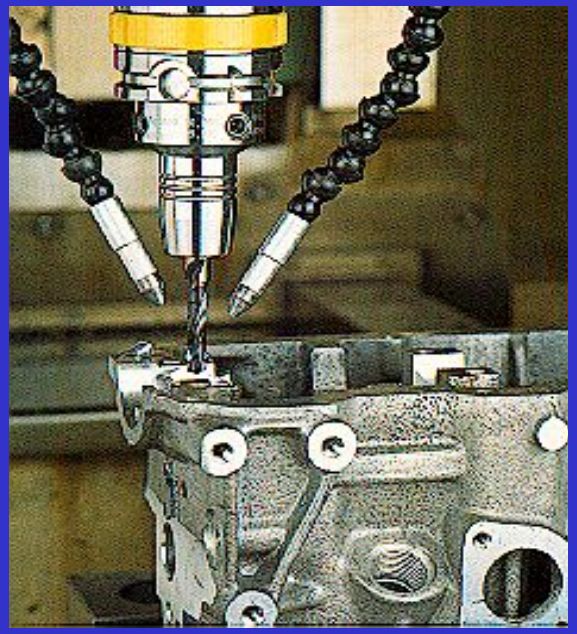
Metal / ZrO_2
WC-Co / steel

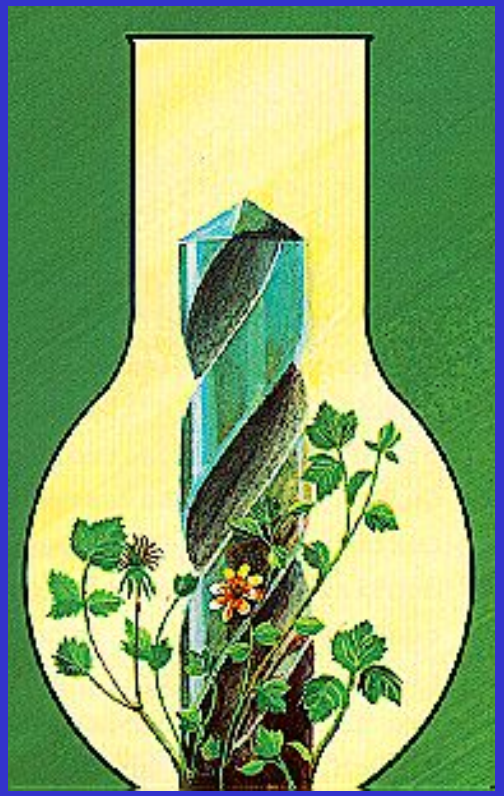
Research Topics

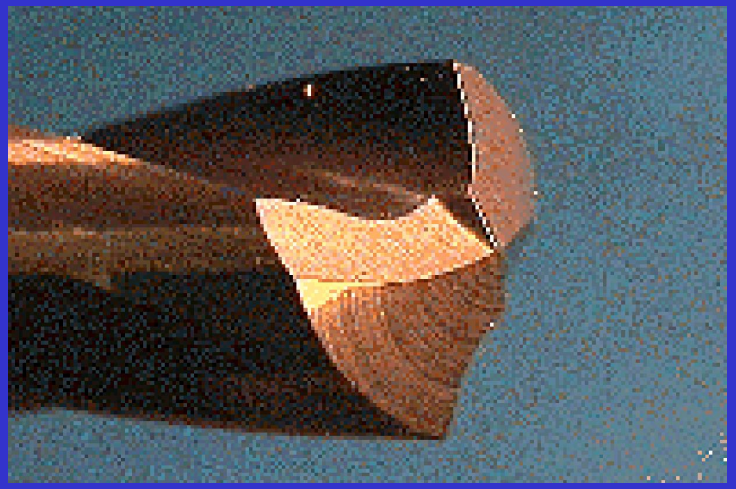
- Processing and characterisation of functionally graded materials (FGM)
- Colloidal processing by means of electrophoretic deposition (DC & AC-EPD)
- Development and characterisation of ceramic, CMC's and cermets
- Modelling and application of field assisted sintering (FAST, SPS, PECS)
- Investigation of elastic and damping properties of materials
- Cutting tool development and chemical compatibility assessment
- Nanomaterials and nanocomposites (biomaterials, photovoltaics, batteries)
- Processing of Porous materials (ceramics, glass & metals)
- Mechanical alloying

Cutting tool development and chemical compatibility studies

DEVELOPMENT OF NEW CUTTING MATERIALS, TOOLS, MACHINE CONCEPTS AND TECHNOLOGIES FOR DRY HIGH SPEED CUTTING



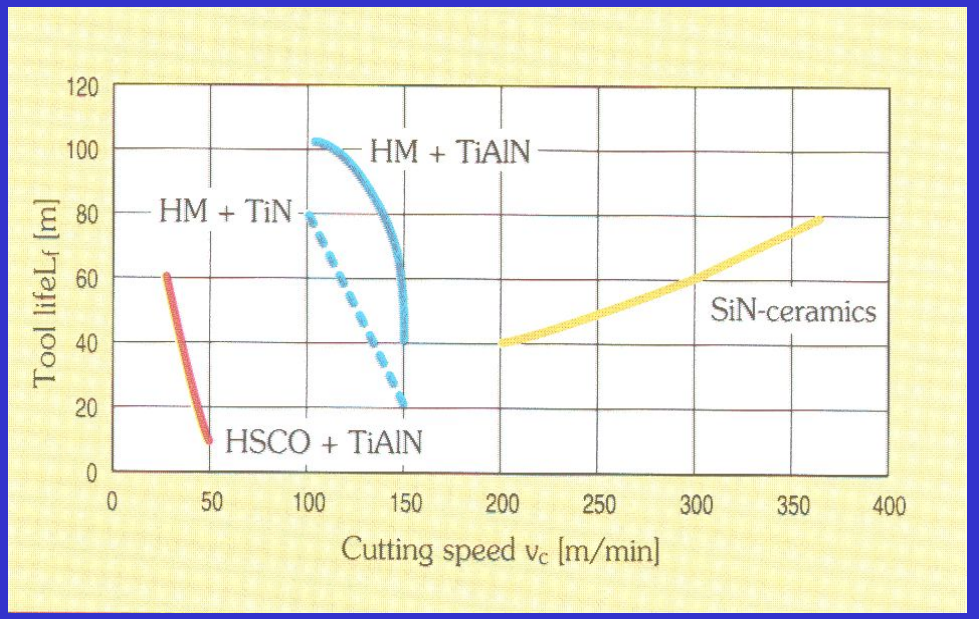




- New composites
- Chemical wear assesment
- Gradient materials

Cutting tool development

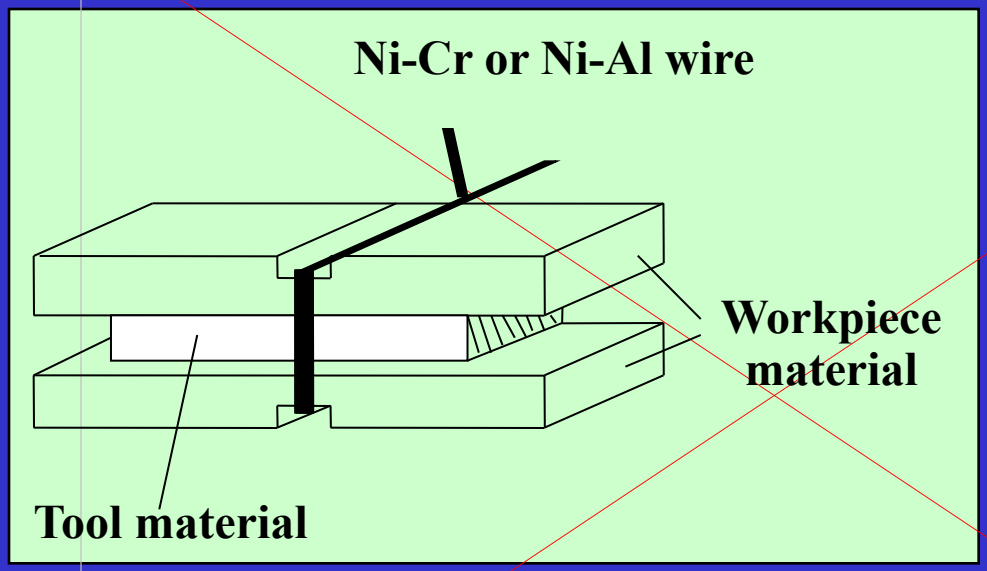
Dry machining of cast iron with siliconnitride tools

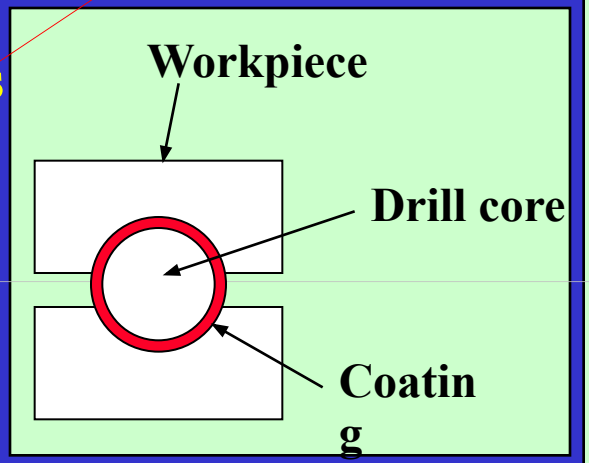


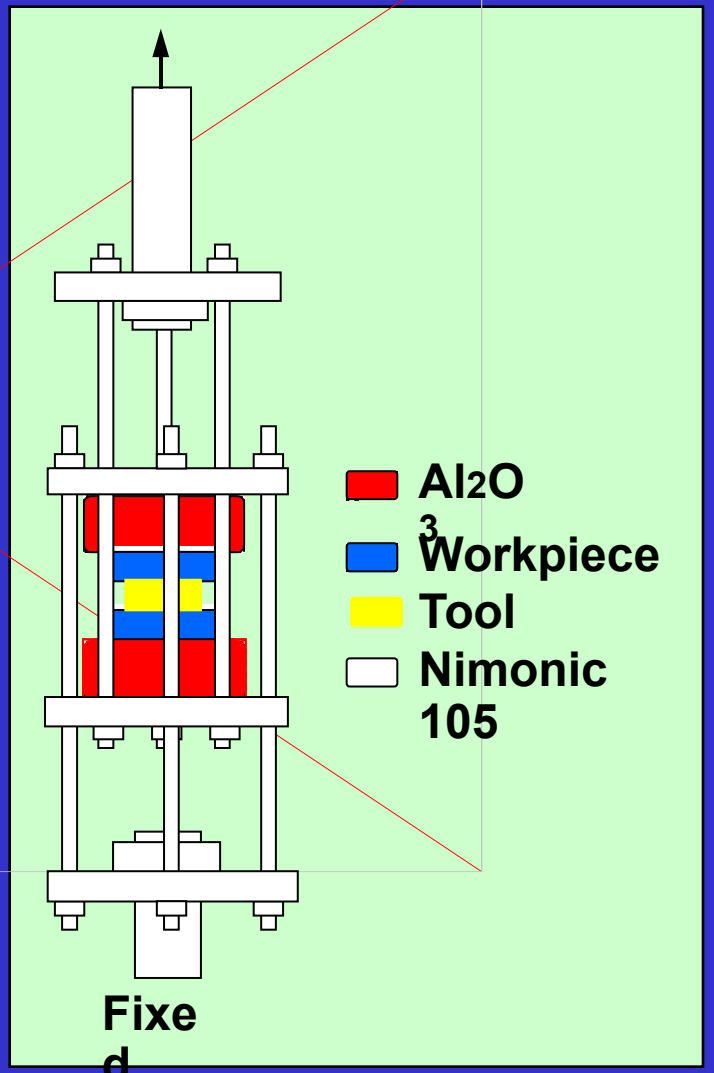
Dry machining of cast iron with ceramic composite tools

Dry drilling of cast iron at 450 m/min

Chemical compatibility assessment





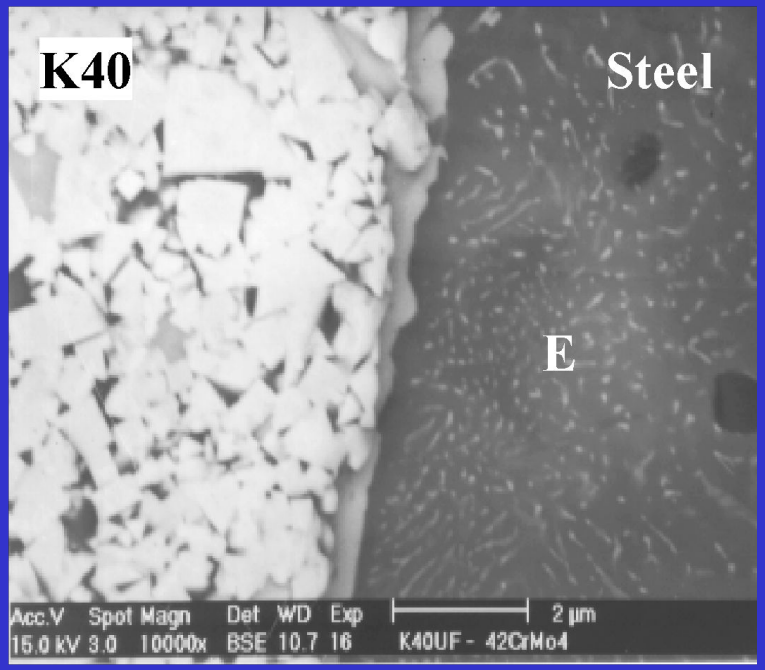


Experimental parameters

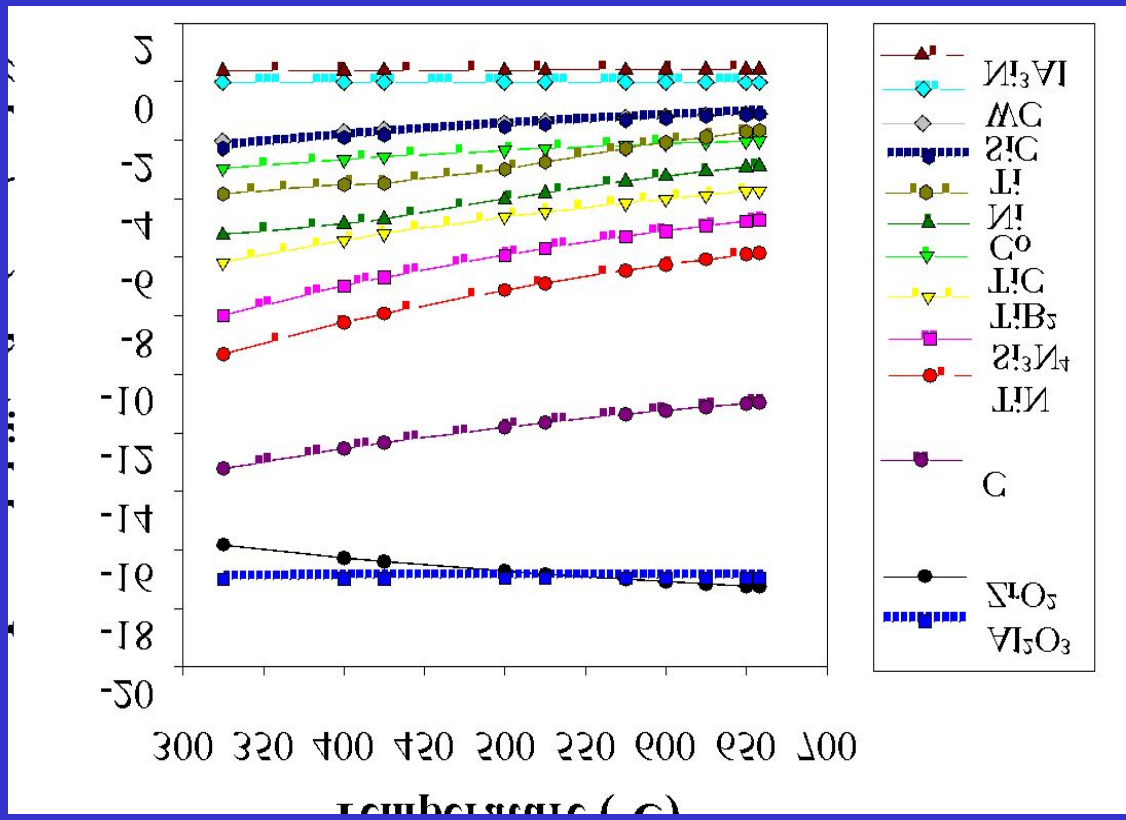
Temperature
Holding time
Mechanical load

Chemical compatibility assessment

Interaction couples

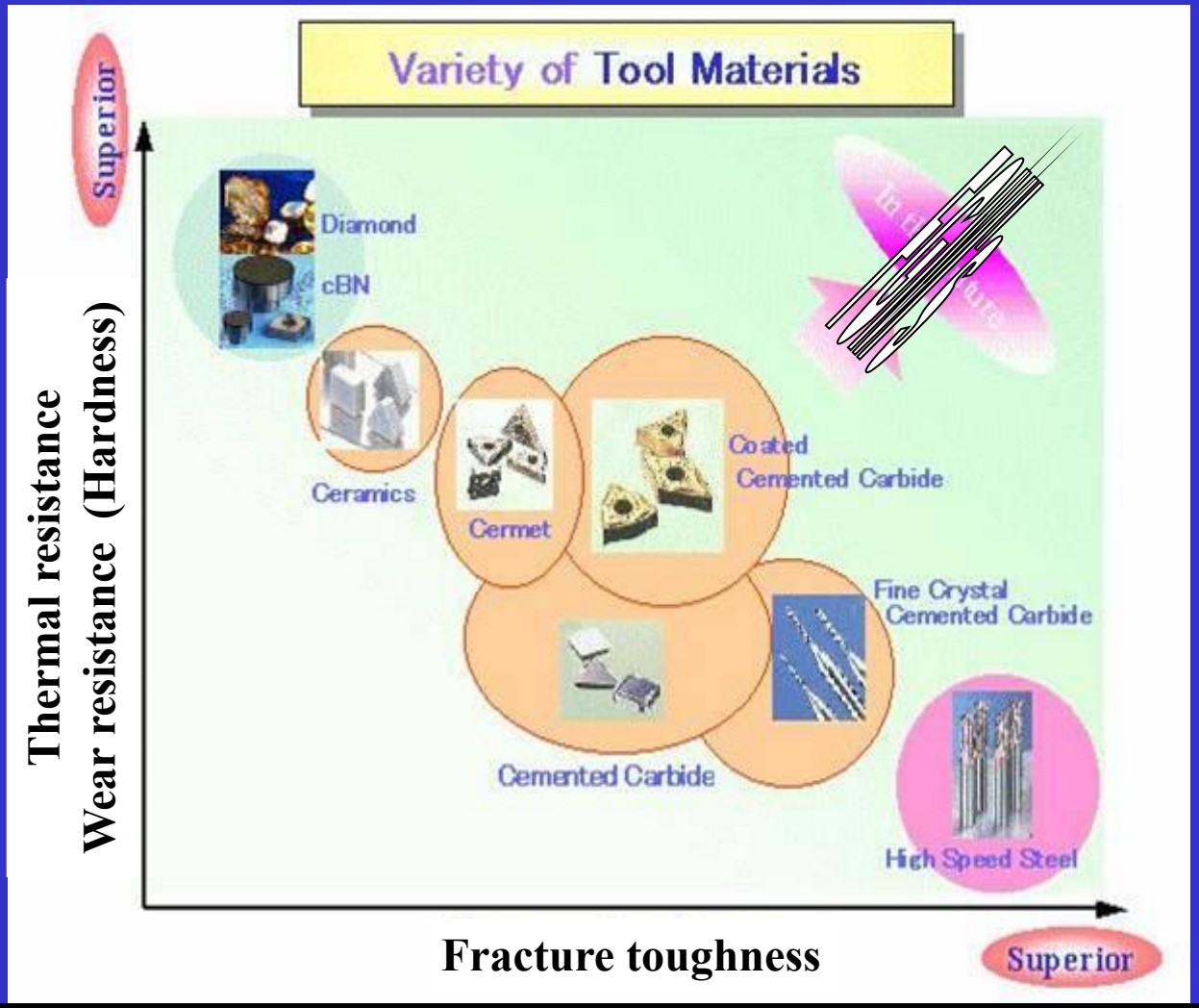


Equilibrium solubility calculations



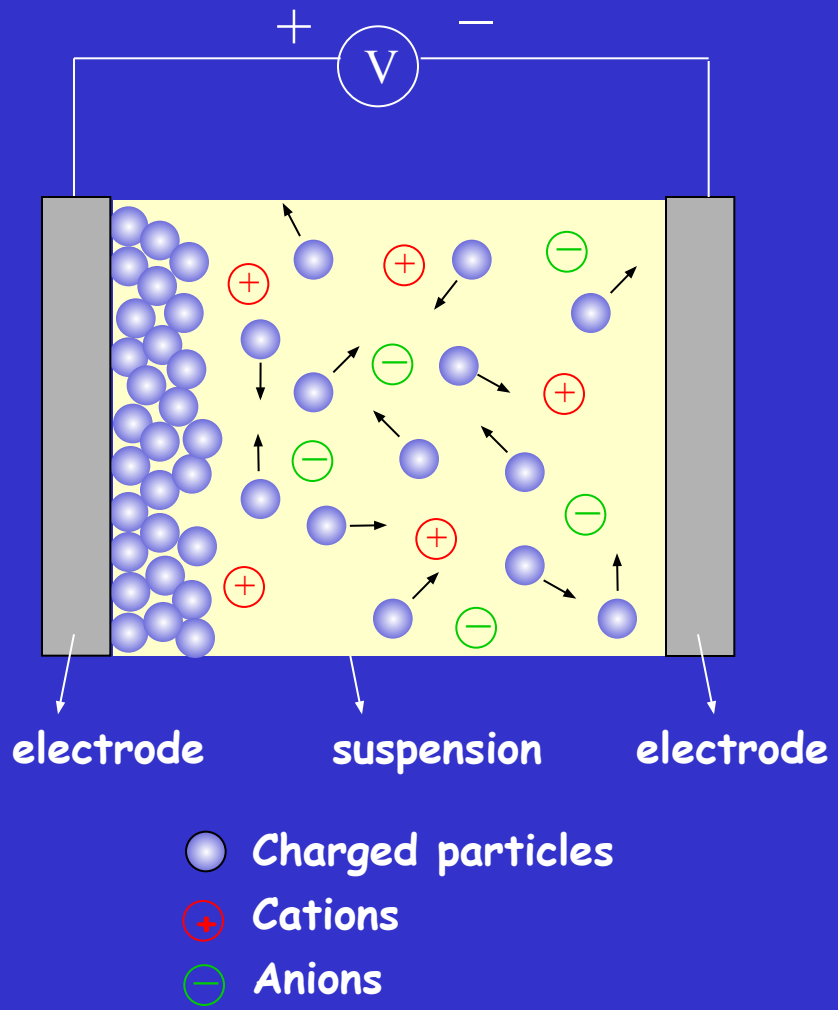
Functionally graded materials (FGM)

To combine irreconcilable properties in the same component
by engineering a gradient in composition and concomitant properties



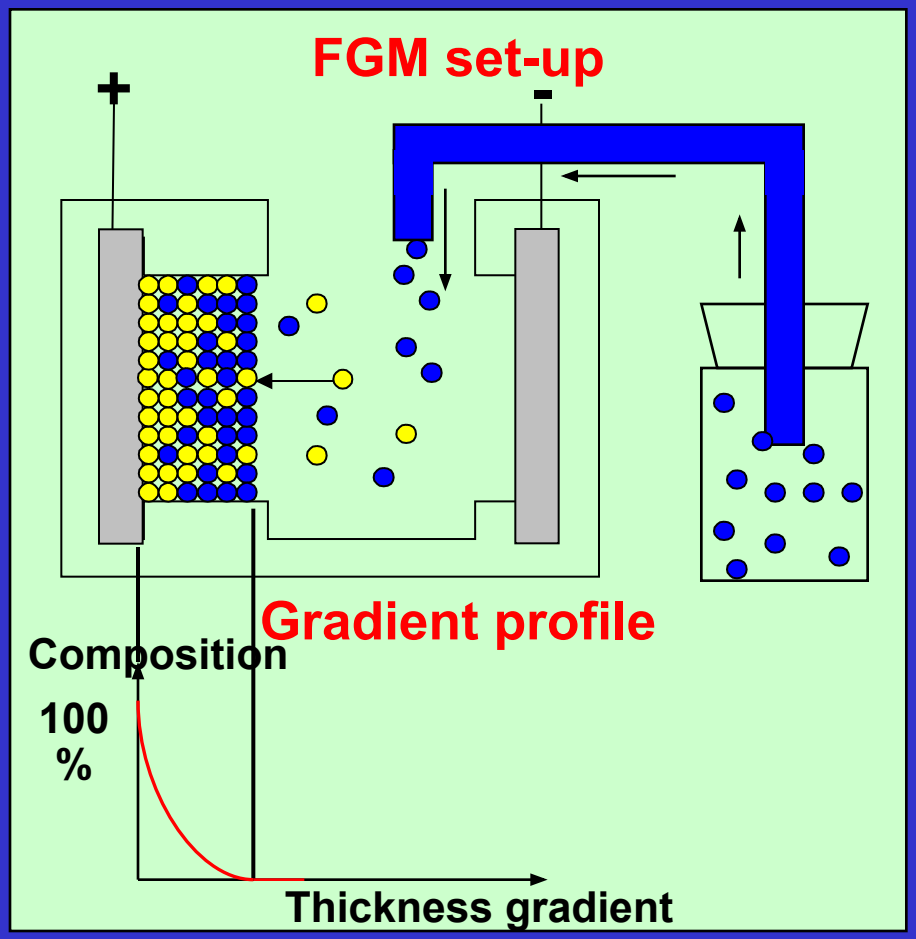
Electrophoretic deposition (EPD)

Colloidal processing technique in an electric field



- Particles are charged by interaction with the solvent and additives
- Charged particles move under the influence of an applied electric field (electrophoresis)
- Partices form a growing deposit on the deposition electrode (deposition)

Electrophoretic deposition (EPD) of FGM



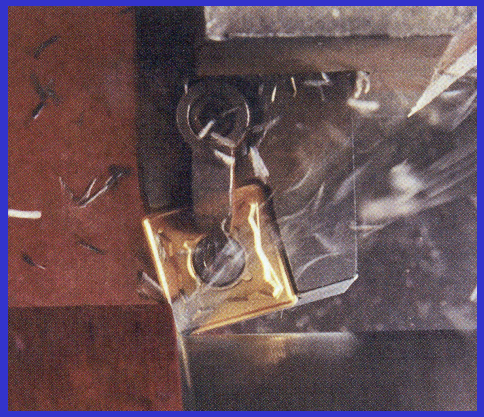
Applications:

- Gradient materials
- Laminates
- Coatings (nm-mm)
- Infiltration
- Textured materials
- Save processing of nanopowders

Graded Tribological Materials Formed by Electrophoresis

EPD of FGM and coatings

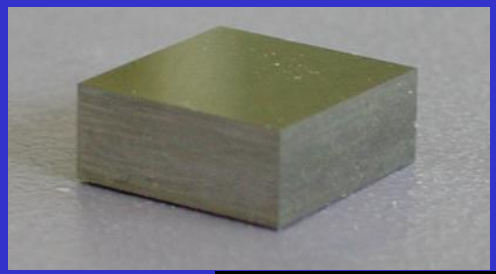
Cutting tool inserts : WC-Co-Ti(C,N)/ WC-Co/ WC-Co-Ti(C,N)

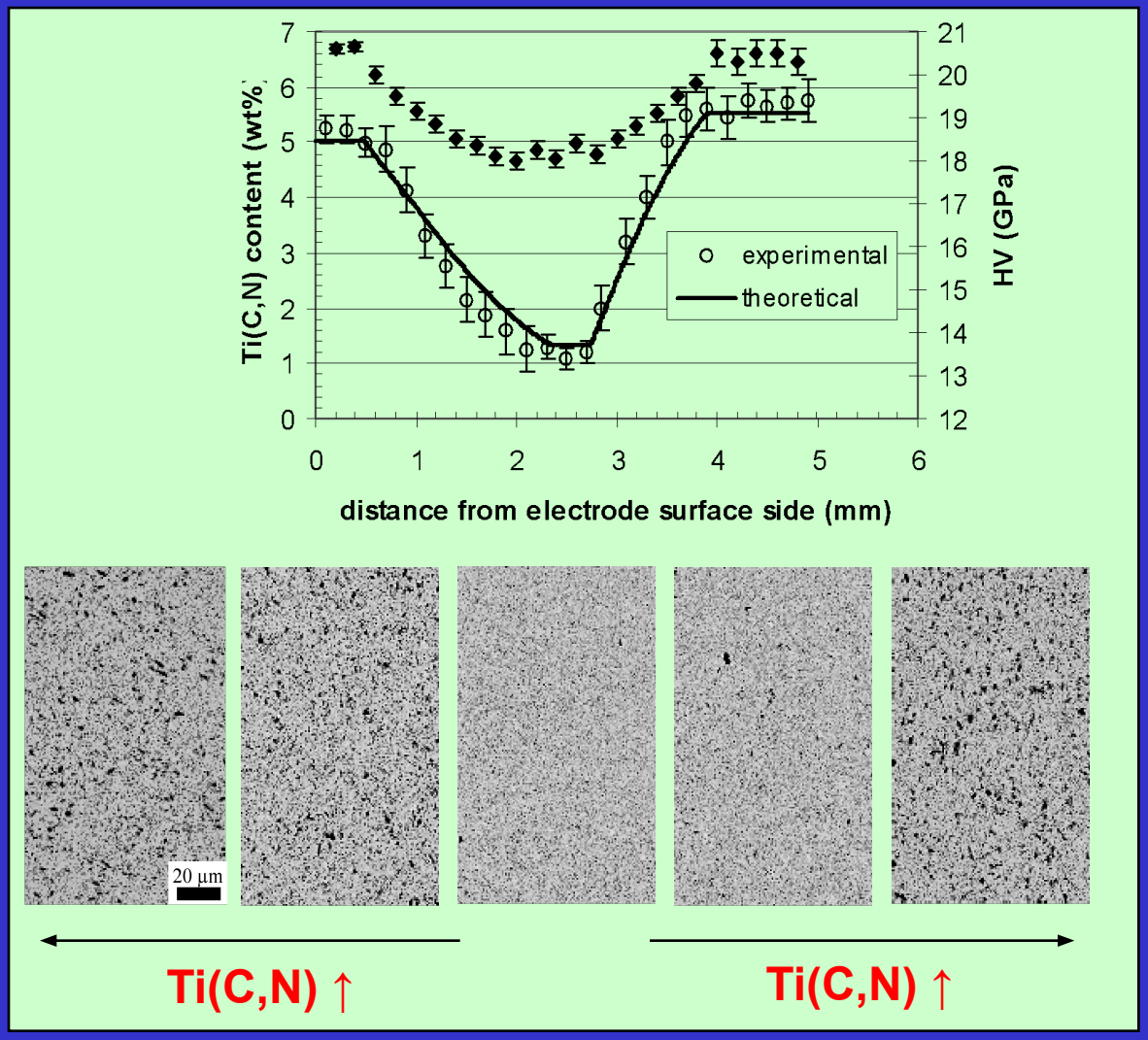


WC-Co-Ti(C,N)

WC-Co

WC-Co-Ti(C,N)





EPD of FGM and coatings

HSS substrate

EPD-coated

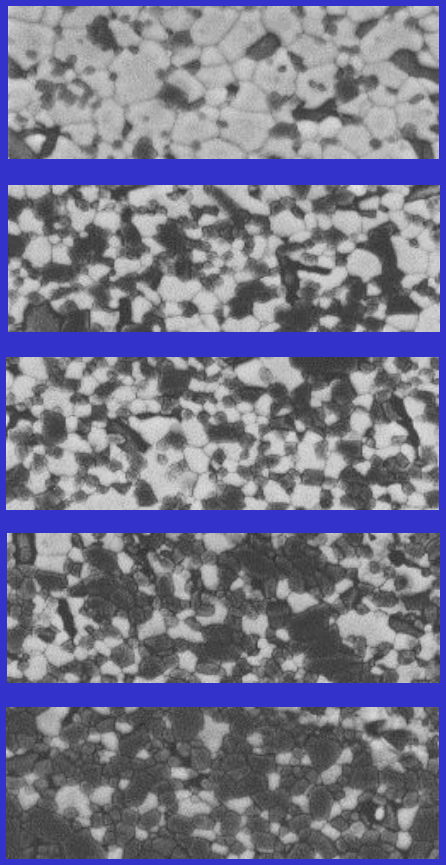
Sintered

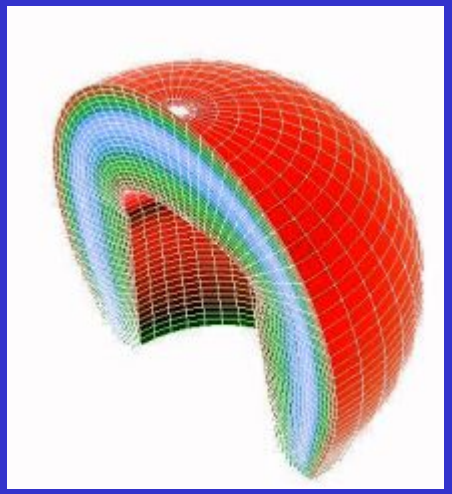
Final machined

HSS taps with carbide coating

EPD of FGM

Increasing the Performance of Total Hip Replacement Prostheses through Functionally Graded Material Innovation and Design



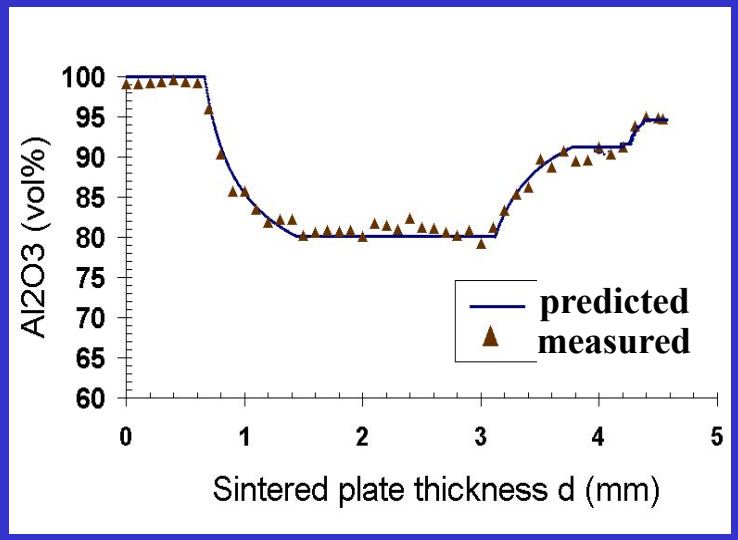


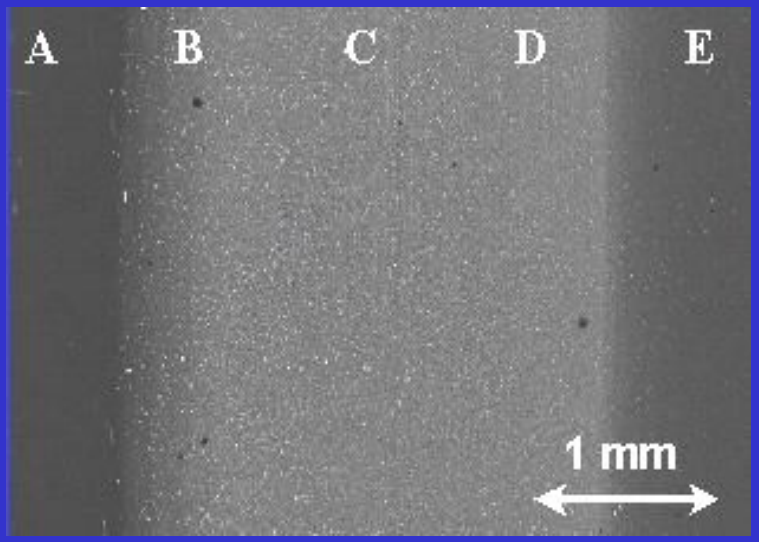
Gradient in composition resulting in:

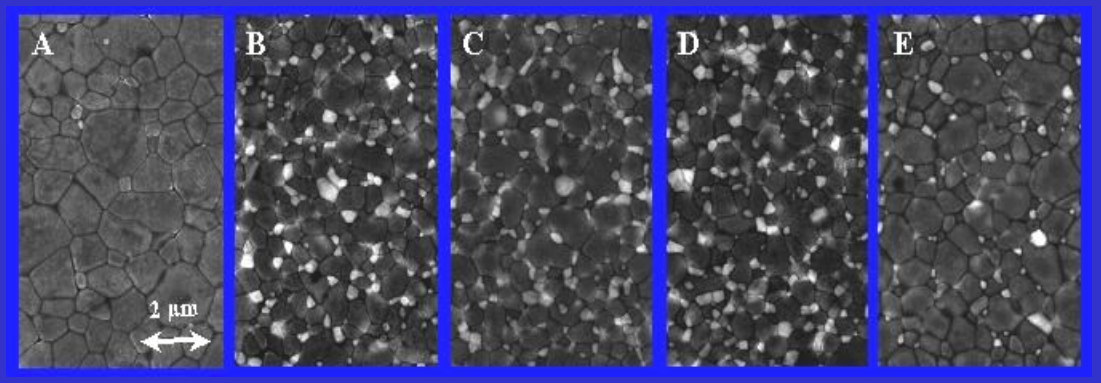
- Gradient in properties
- Residual thermal stresses
- improved strength and wear resistance

EPD of plate shaped FGM

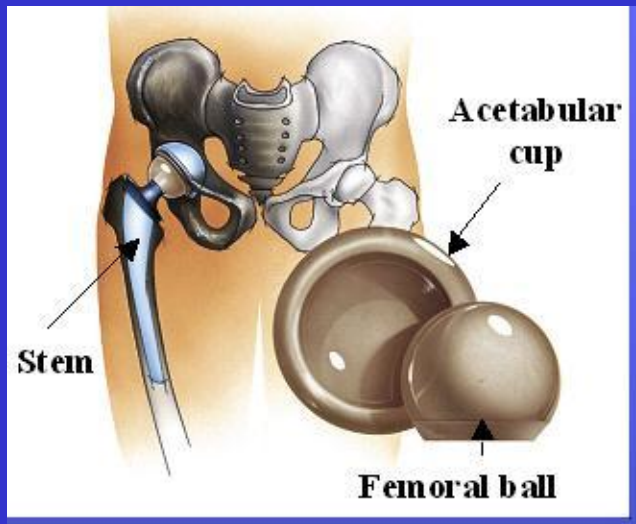
Symmetrical Al_2O_3/Al_2O_3-ZrO_2/Al_2O_3 FGM

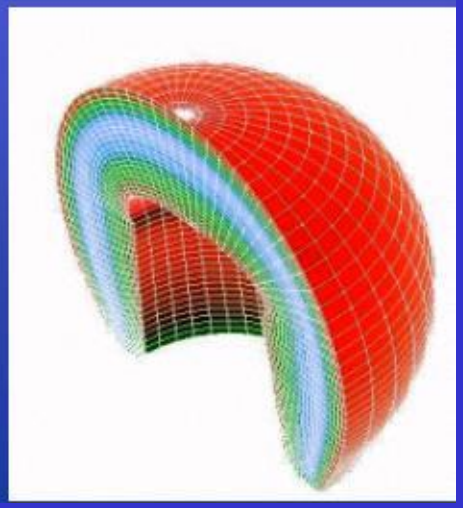






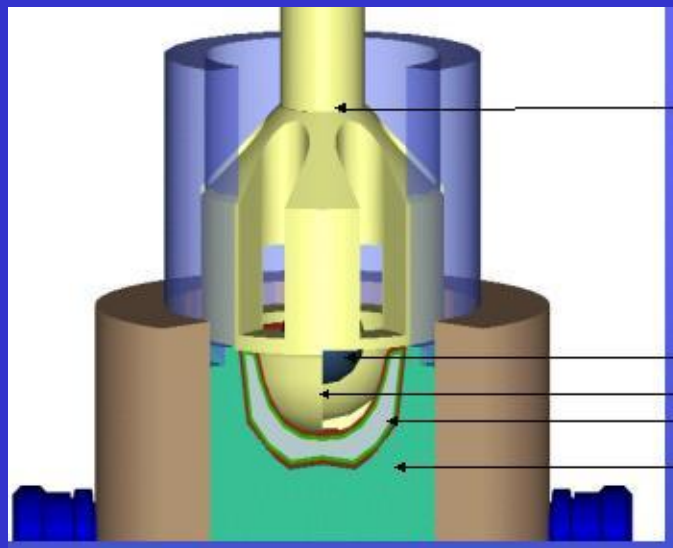
EPD of complex shaped FGM

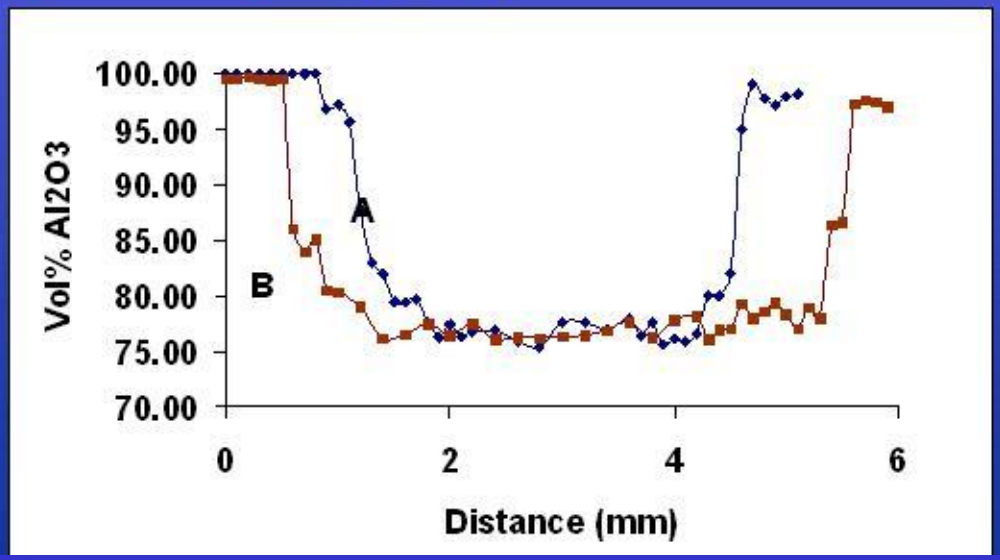


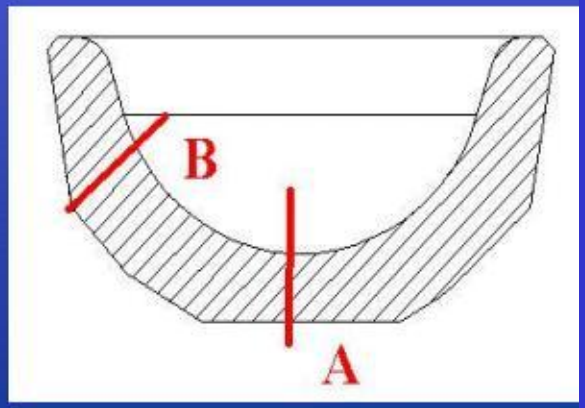


Near-net-shape processing (max + 100 µm)

EPD of complex shaped FGM



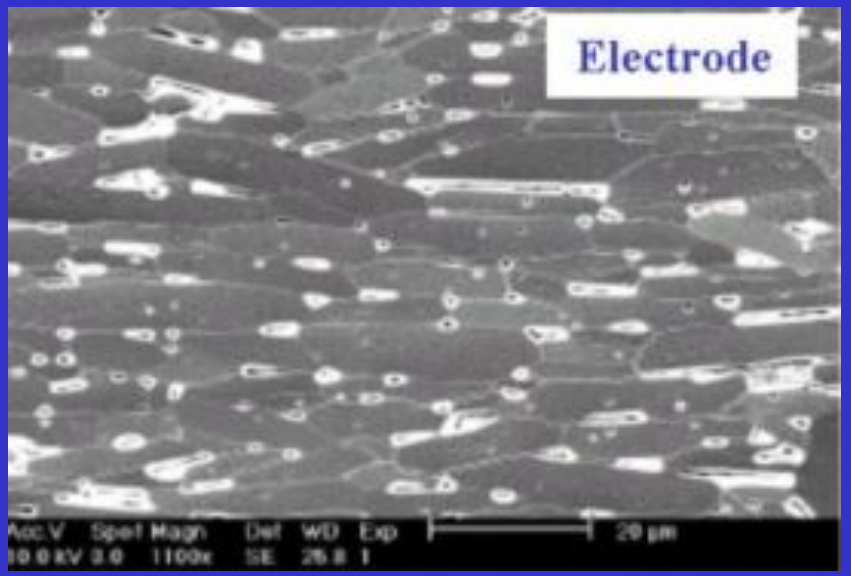




EPD of coatings

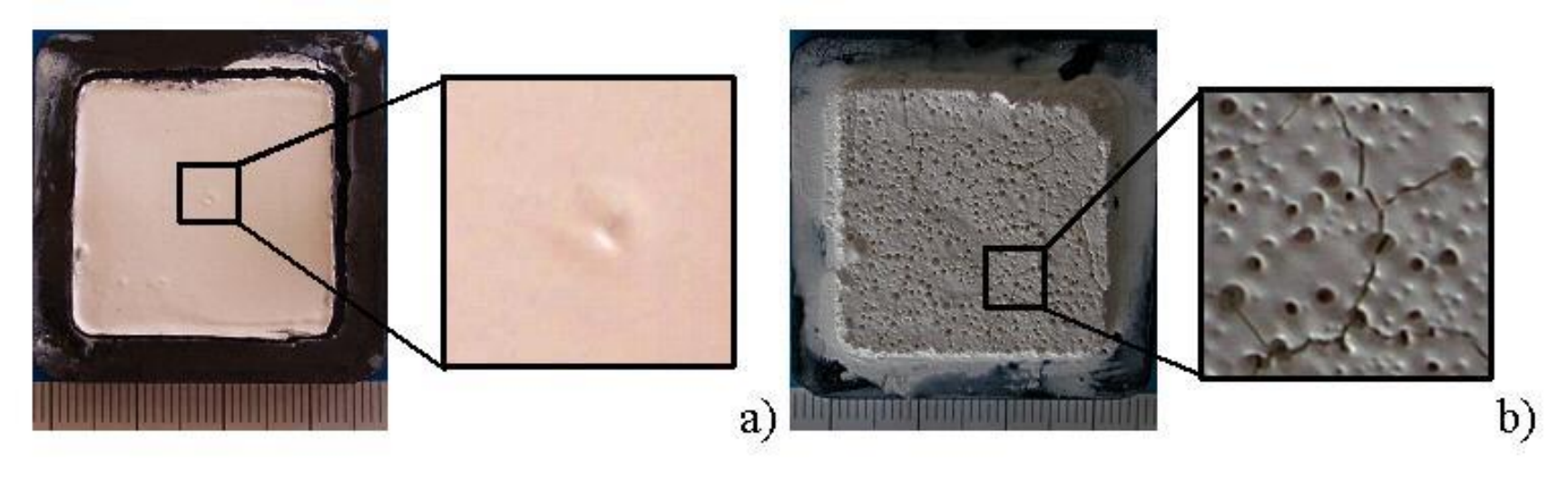
ZrO_2 coating on metal substrates

Texturing of materials



Fundamentals of AC electrophoretic deposition (AC-EPD)

Aqueous electrophoretic deposition in asymmetric AC electric fields

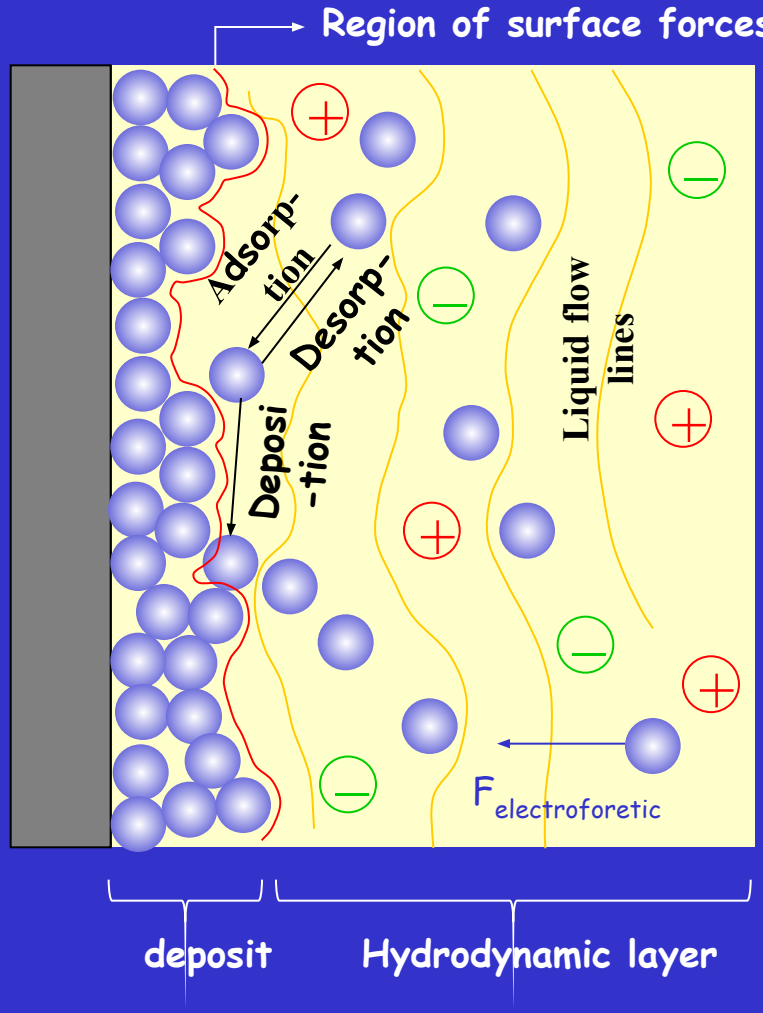


Alumina powder deposit formed by unbalanced AC (a) and DC (b) electric fields from a water-based suspension

How does this work ?

Basic science on EPD

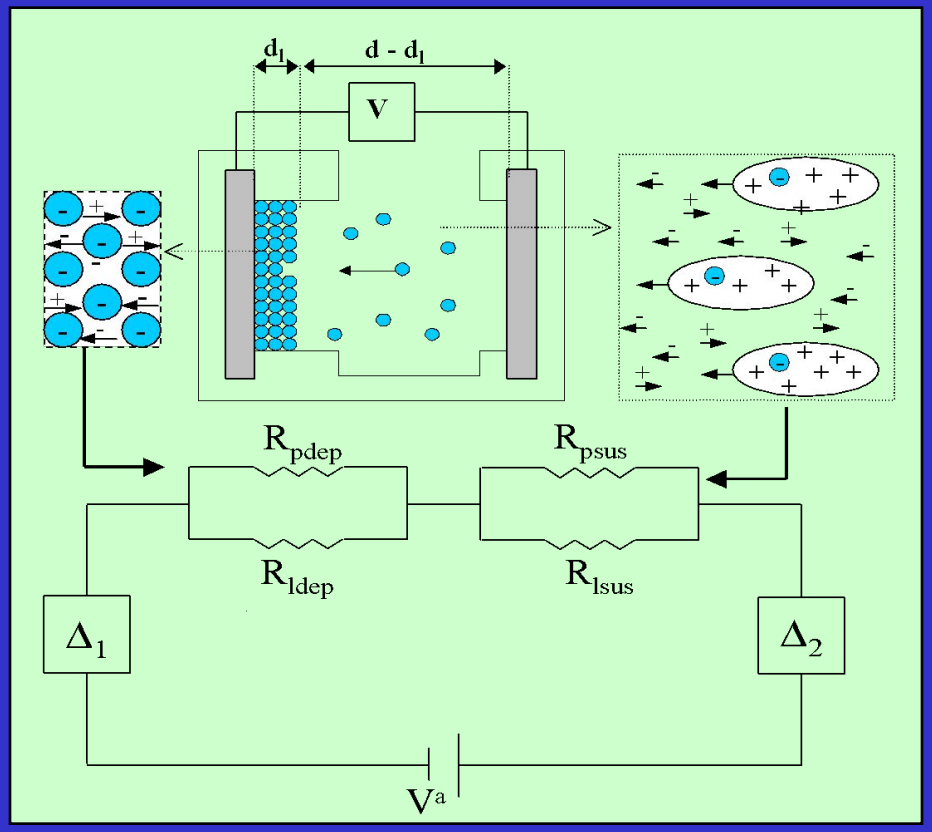
Electrophoretic forming of functionally graded materials and coatings



- Suspension stability studies
- Charging mechanisms and particle-additive interactions
- Electrophoretic mobility and zeta potential measurements
- Study of the deposition process
- AFM of particle-electrode interaction
- Electrochemical reactions
- Fluid dynamic interactions during EPD
- Modelling of the EPD kinetics

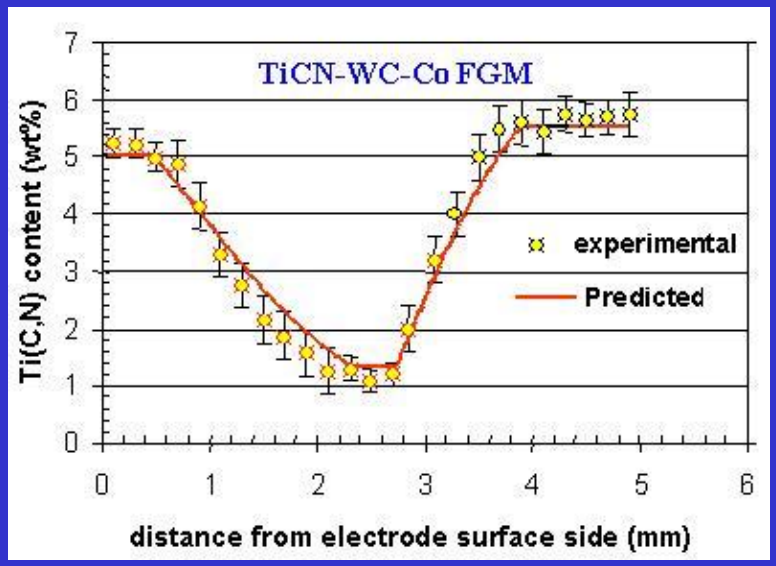
GOA-TBA 2005-2008 K.U.Leuven

Modelling of EPD



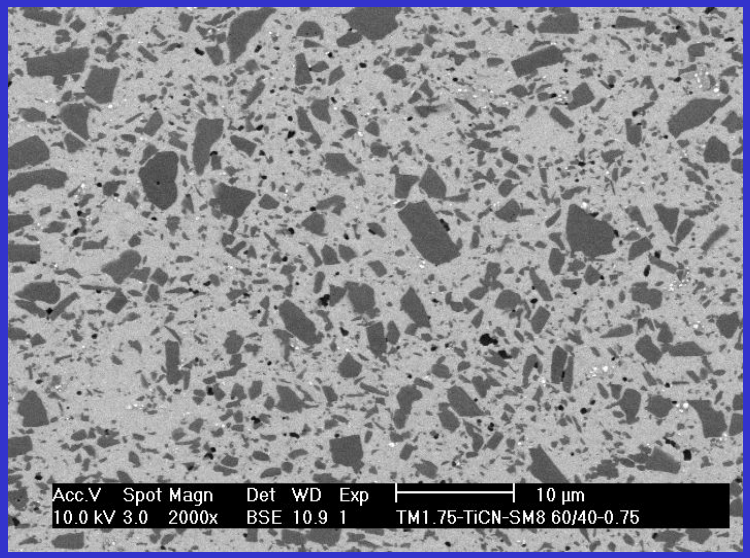
The currents and voltages during EPD are calculated from the equivalent electric circuit shown

To calculate the composition gradient in the FGM material from the starting composition of the suspensions, the EPD operating parameters and the powder-specific EPD characteristics.



Nanomaterials and Nanocomposites

Conventional composite



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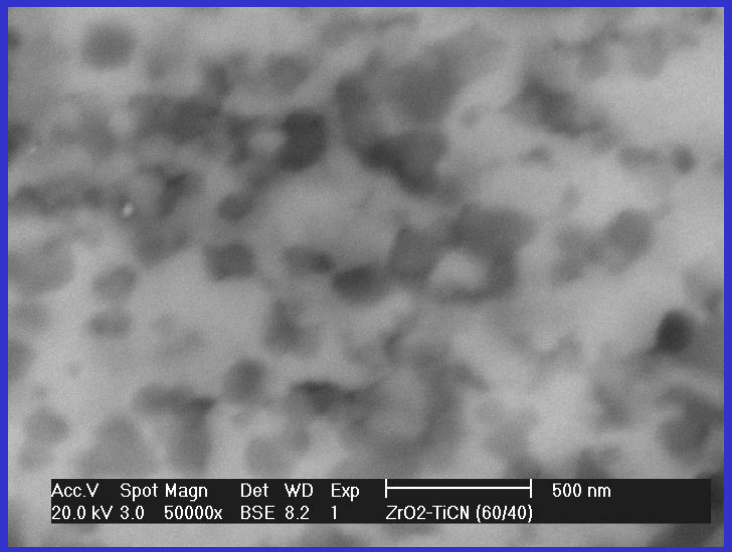
Nanocomposite < 100 nm !



Colloidal processing of nanopowders

Shaping of Coatings Composites Gradient materials

Densification with limited grain growth

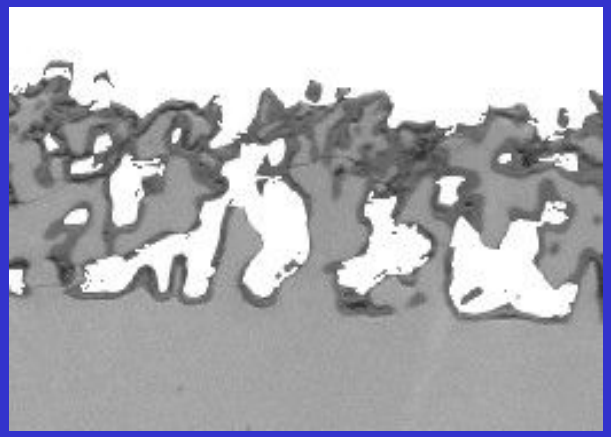
Characterisation: microstructural physical mechanical

Processing flowchart

GOA 2008-2011 K.U.Leuven

Development of biocompatible coatings

Multifunctional bioresorbable biocompatible coatings with biofilm inhibition and optimal implant fixation



www.meddelcoat.eu

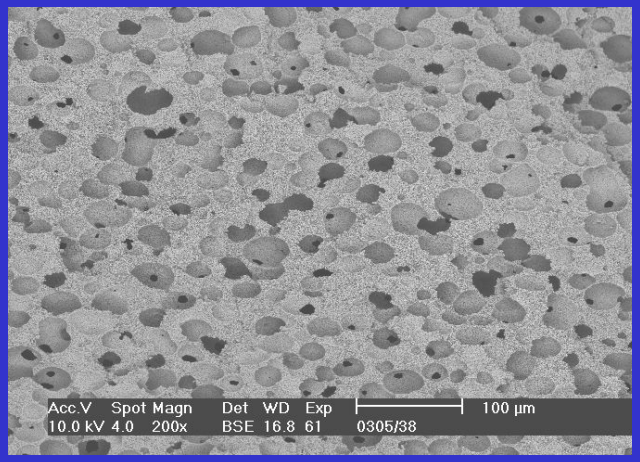
6th Framework Project

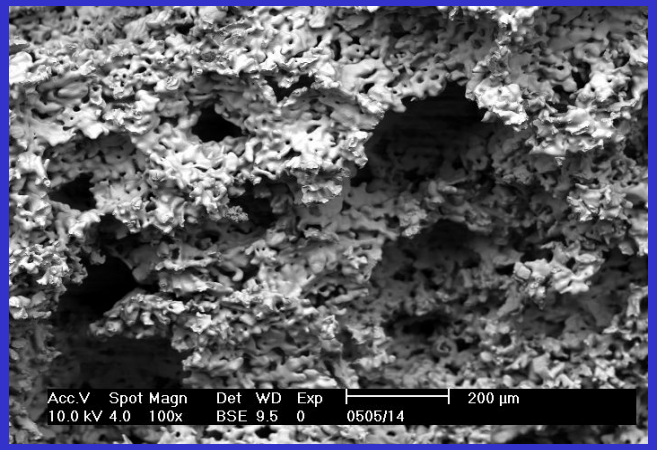
Meddelcoat

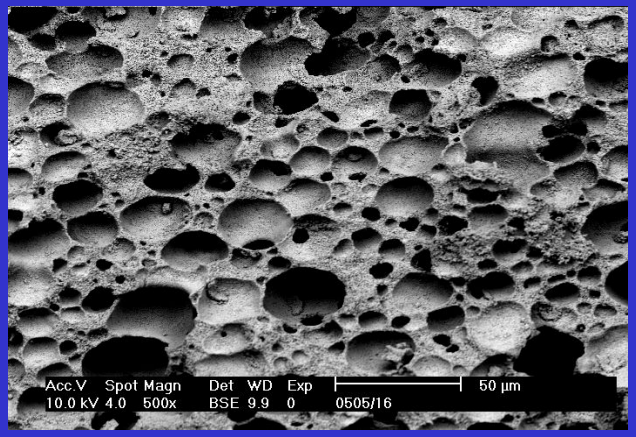
2006-2010

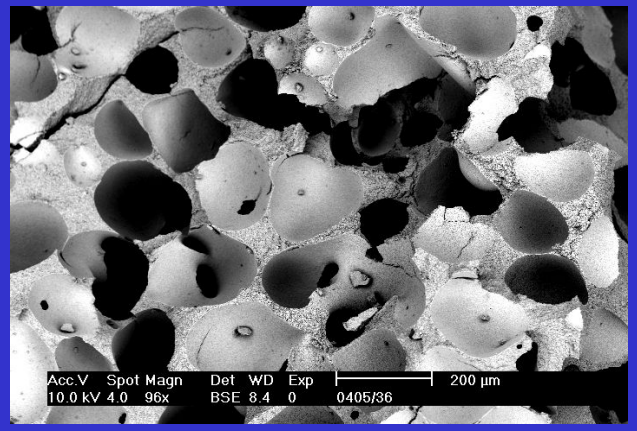
Project Coordinator:
K.U.Leuven

Development of Porous Materials





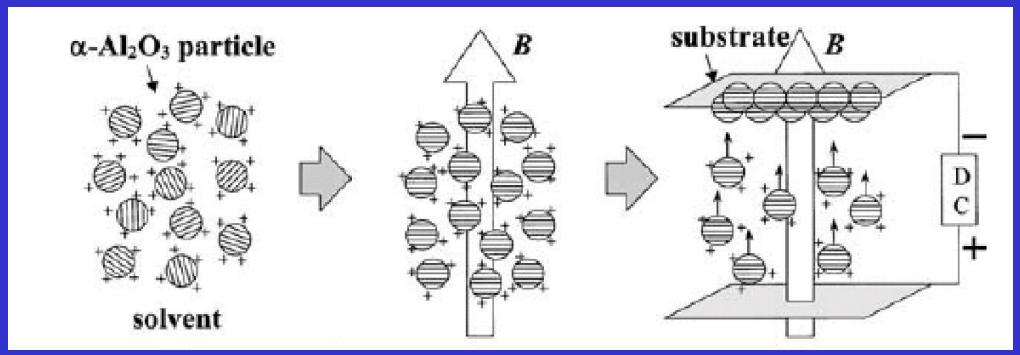


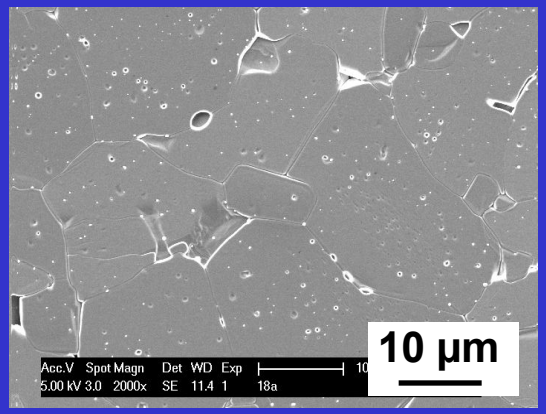


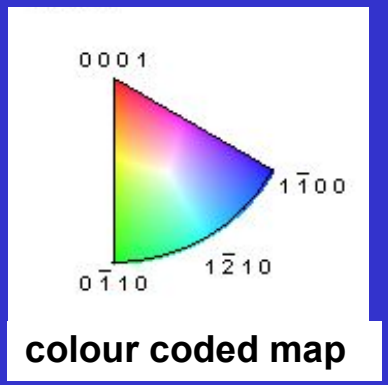
Development of porous glass, ceramic and metal structures and coatings

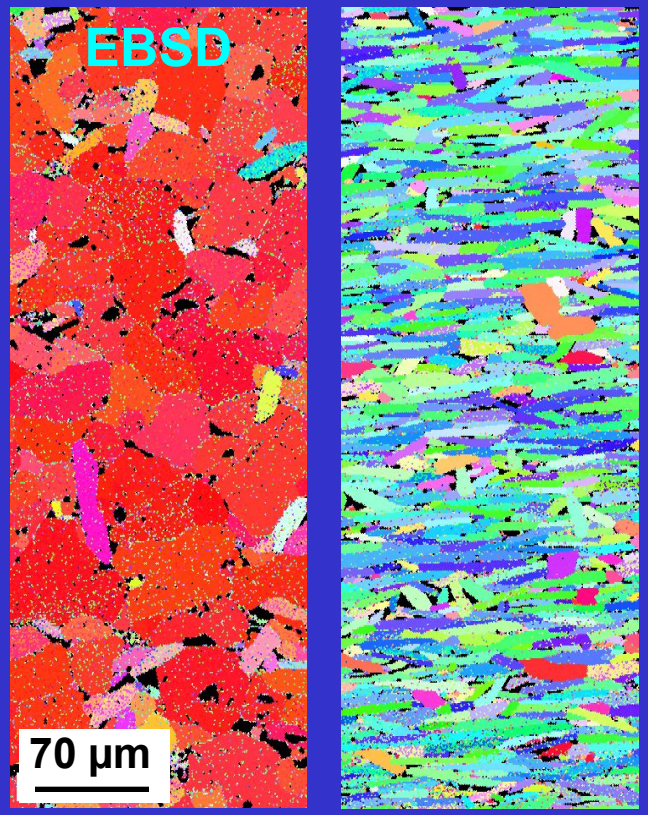
Development of textured materials by EPD

Processing of materials using a strong magnetic field









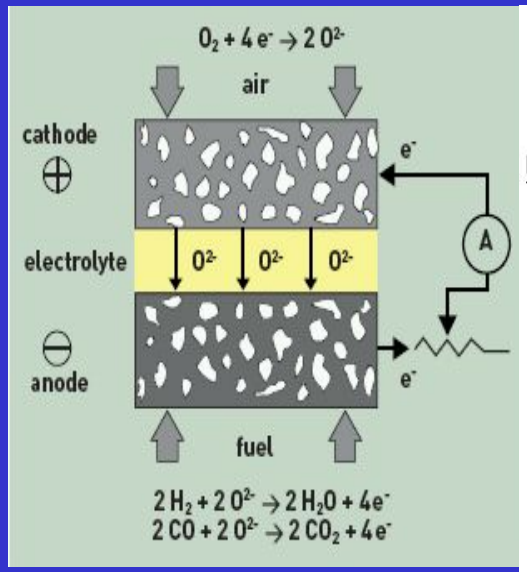
Plane parallel and perpendicular to electrode

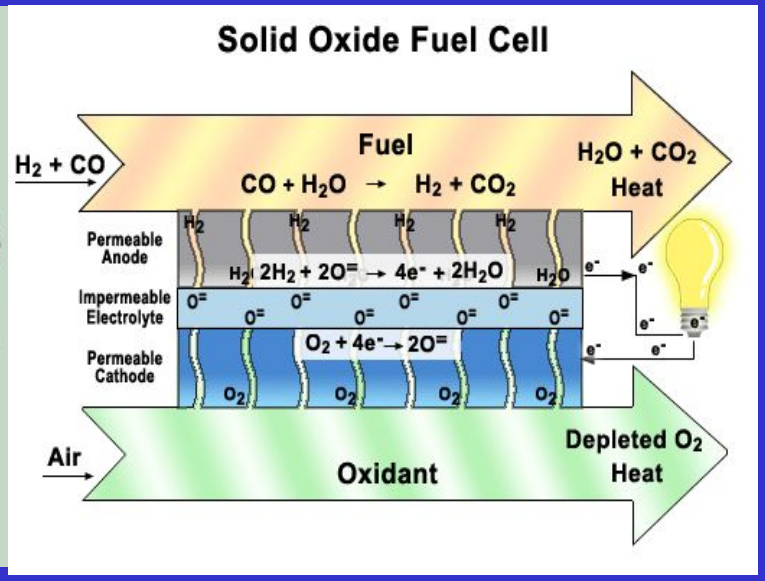
PROMAG 2007-2010

Project Coordinator
K.U.Leuven

EPD of SOFC

Novel Materials for Silicate-Based Fuel Cells



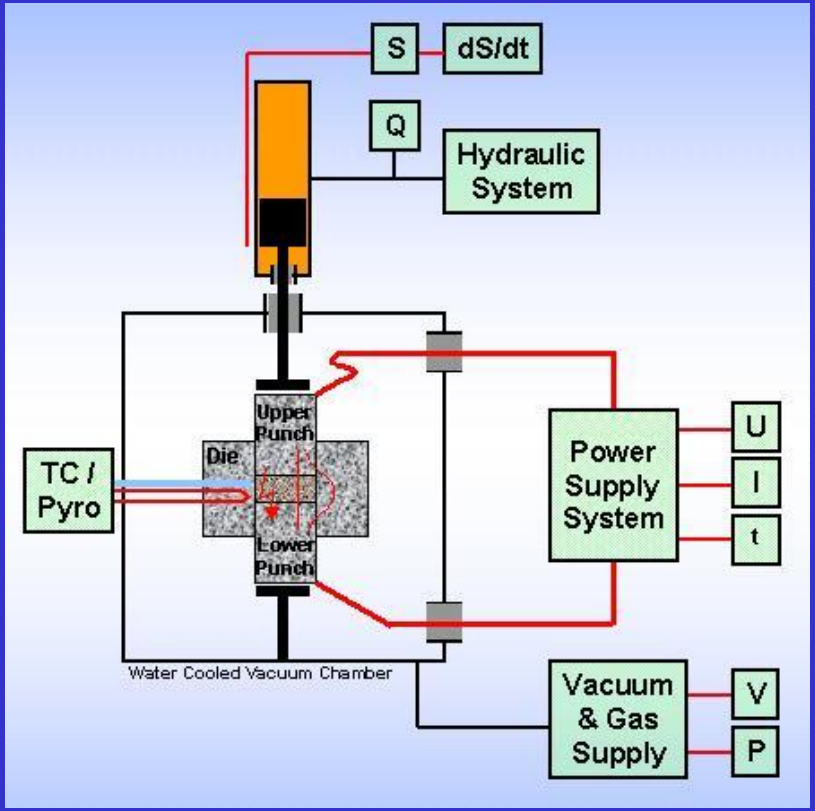


Processing of Solid Oxide Fuel Cells

- Nanopowder synthesis
- Colloidal processing of half cells
- Sintering of half cells

Field Assisted Sintering Technology (FAST)

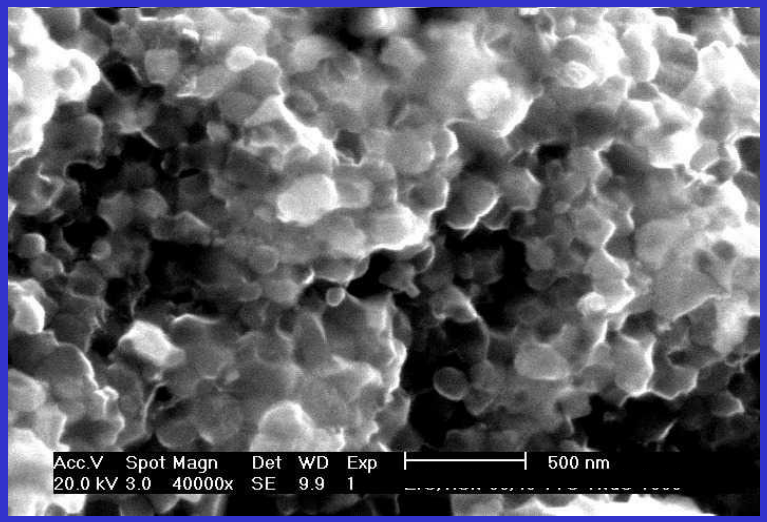
Field assisted sintering technology for the densification of nanostructured powders and fabrication of functionally graded materials

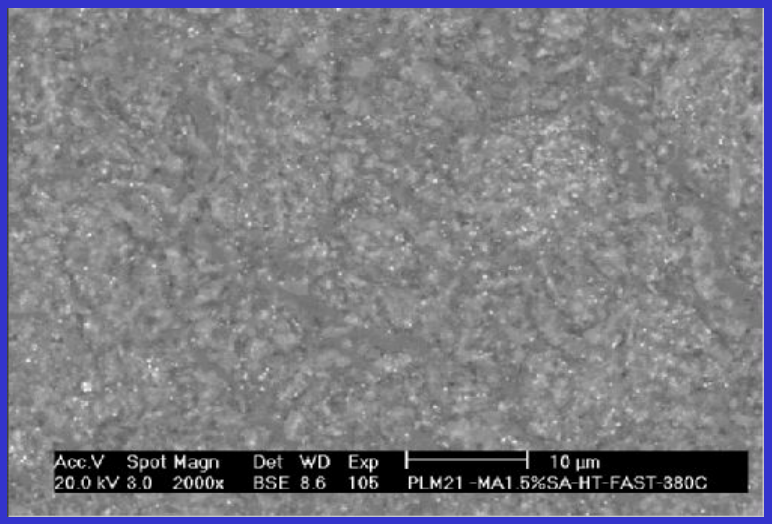


- Technology development
- Experimentation
- Thermo-electrical modelling
- Thermo-electrical-mechanical modelling
- Superplastic deformation

Field Assisted Sintering Technology (FAST)

Ceramic and ceramic-metal nanocomposites (cermets) fabricated from nanopowders

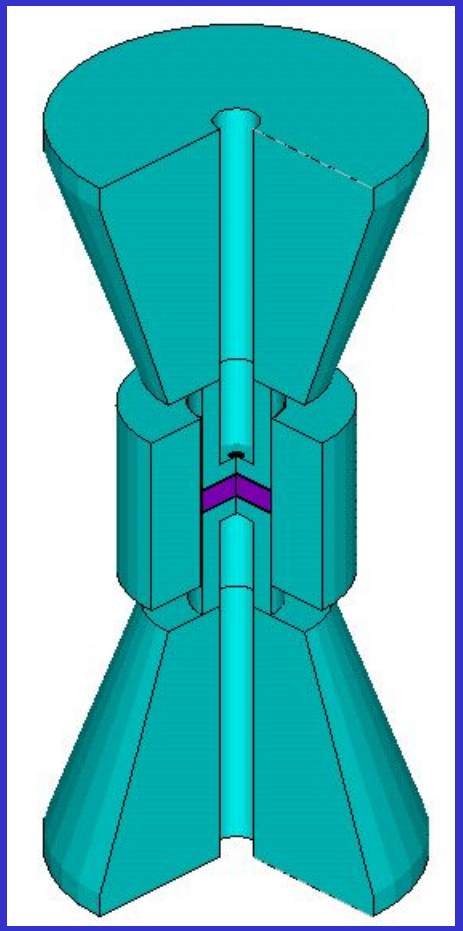


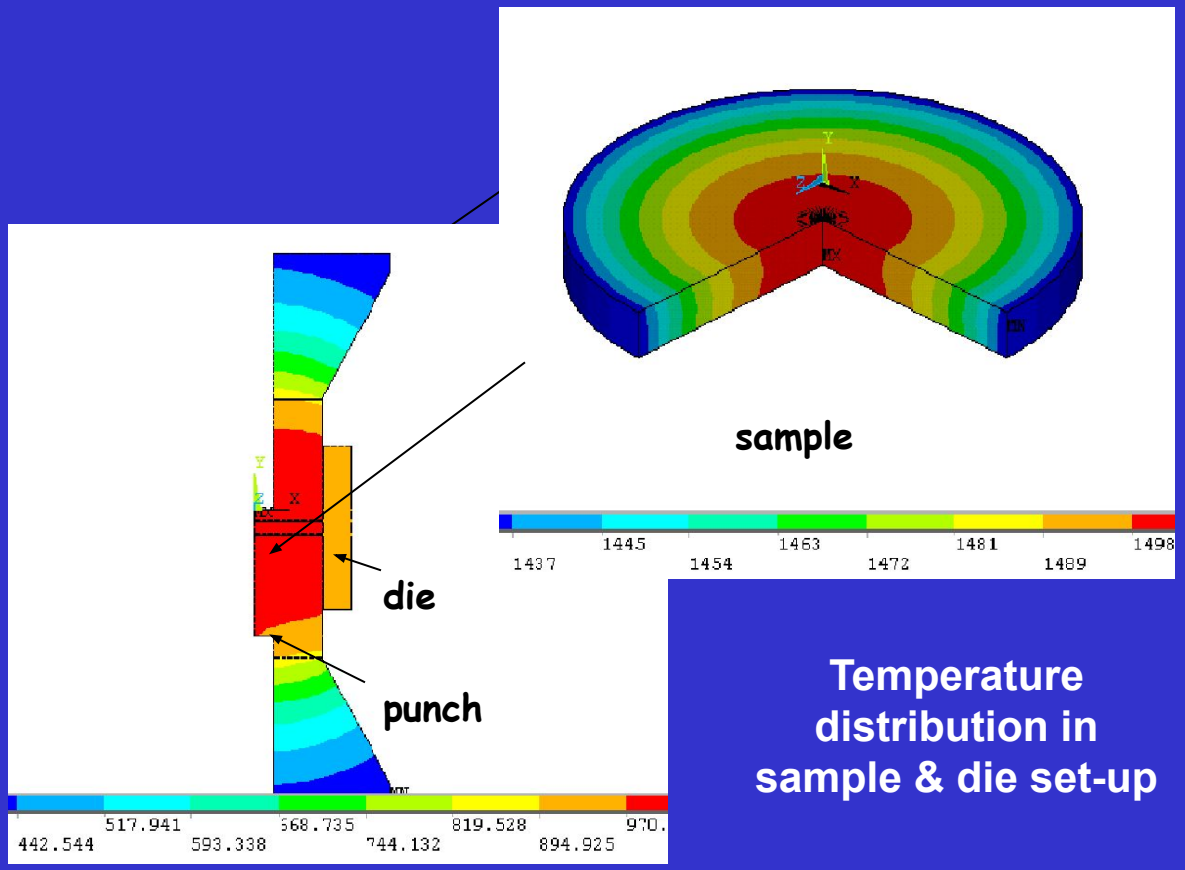


Nanostructured aluminium based alloys from rapid solidification or mechanical alloying

Field Assisted Sintering Technology (FAST)

FE-modelling of the temperature distribution during FAST





Temperature distribution in sample & die set-up

High temperature equipment

SPS

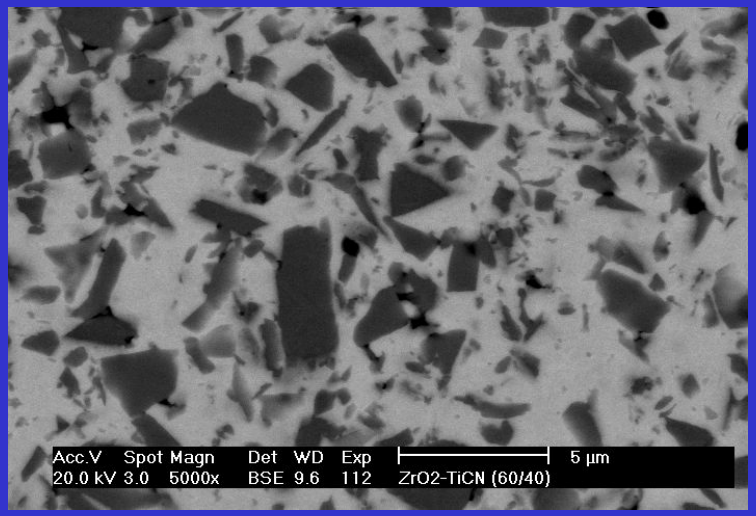
Equipment Properties:

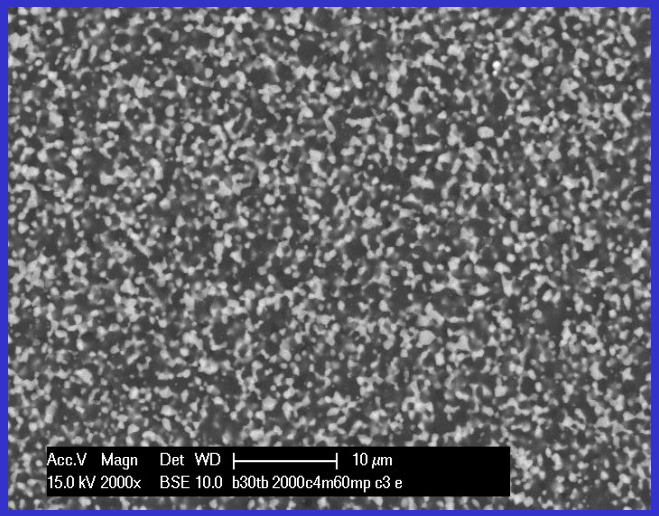
pulsed electric current: 0 – 8000 A
pulse/pause time combinations:
0 - 255 ms
force: max. 250 kN
heating rate: up to 1000°C/min
heating cycle duration: 10 -30 min
(incl. heating-cooling)
max temperature > 2200°C
min controllable temperature = 150°C

Materials : **Al-alloys, intermetallics, steel, ZnSe, ITO, borides, carbides, nitrides, Cu_3Sn, oxides, electroceramics, $BaTiO_3$, cermets, cemented carbides, ceramic composites, tungsten, etc.**

Electro-conductive ceramic composites

For electrical discharge machining (EDM) and wear applications



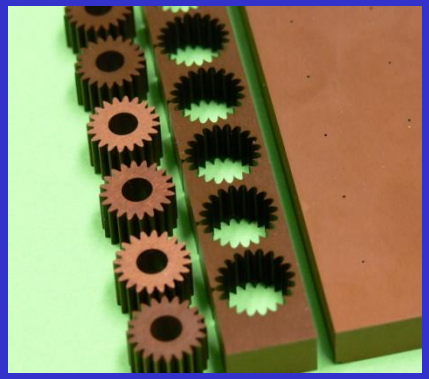


http://www.mtm.kuleuven.be/Research/GBOU-IWT/spark/index.html

http://www.moncerat.org

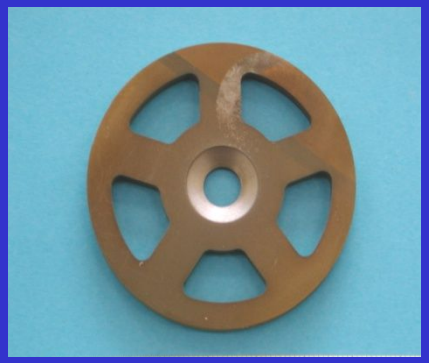
Development of ceramic composites

Electrical discharge machined new composites



Gears

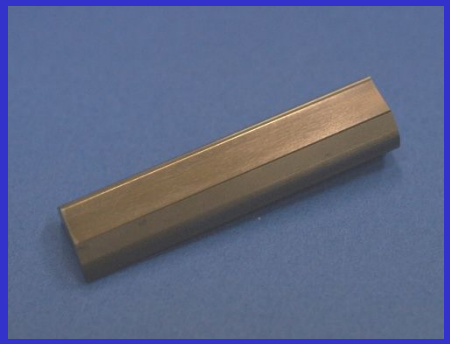
Extrusion die insert



Attritor disc

Lens mould insert

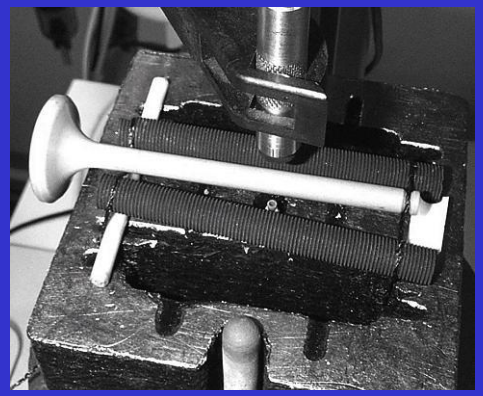
Injection moulding tool

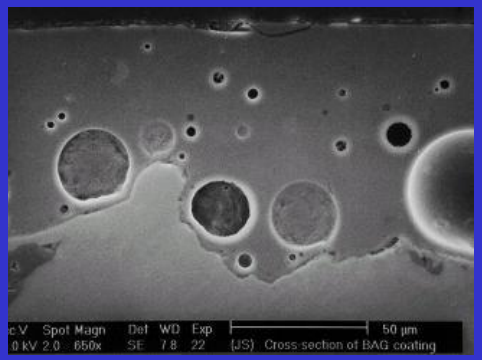


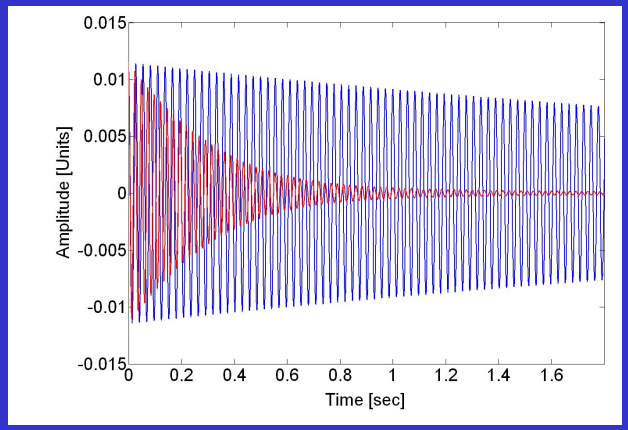
Fine blanking tool

Elastic and internal friction properties of materials

Measuring of resonance frequency and damping







Impulse Excitation Technique (IET)

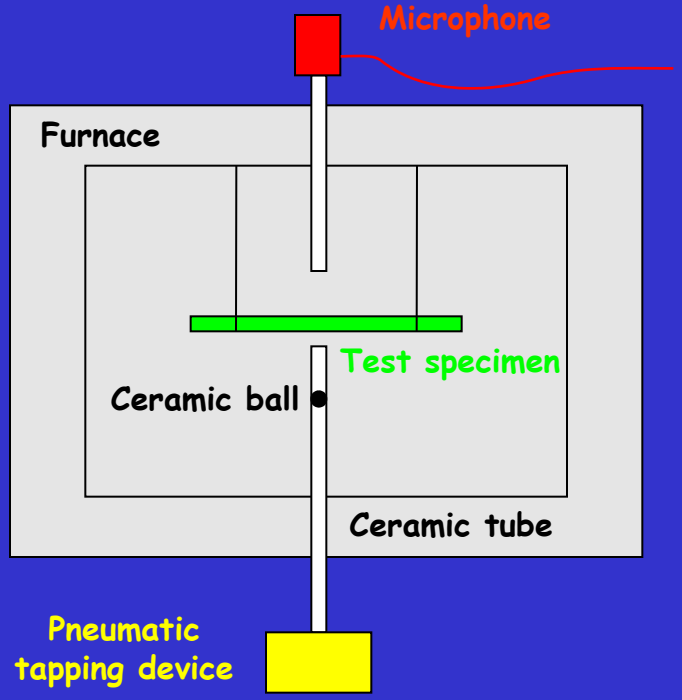
⇒ Measurement of E, G, ν, and Q^{-1} at RT

⇒ Measurement of E and Q^{-1} at elevated temp.

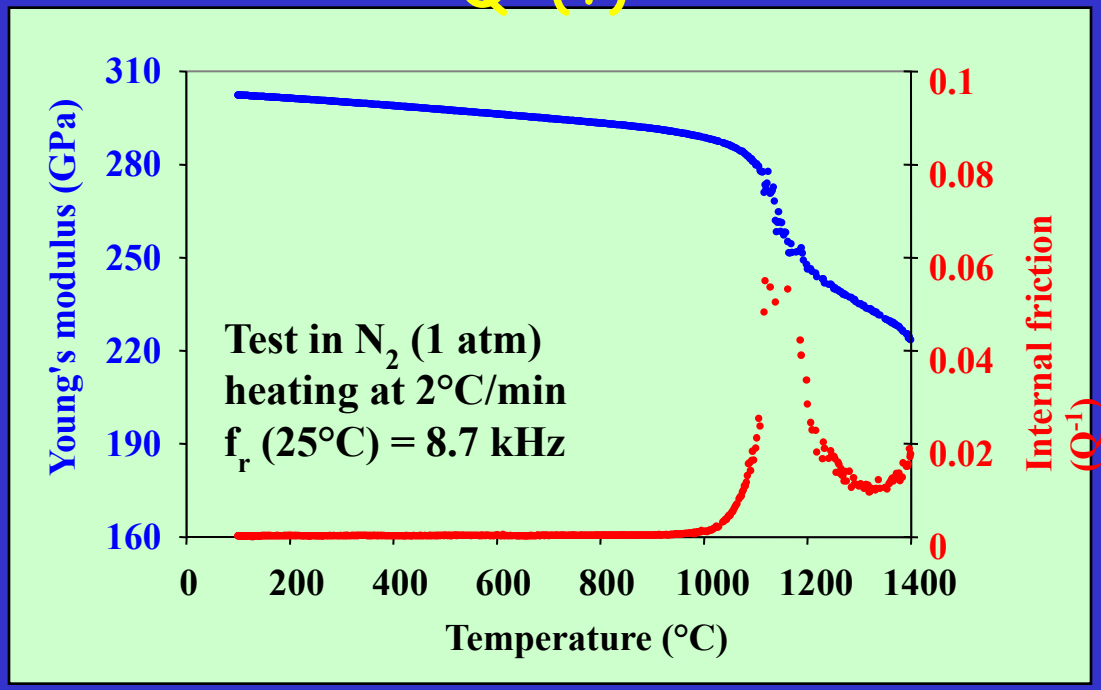
⇒ Applicable to monoliths, coatings and laminates

Elastic and damping properties of materials

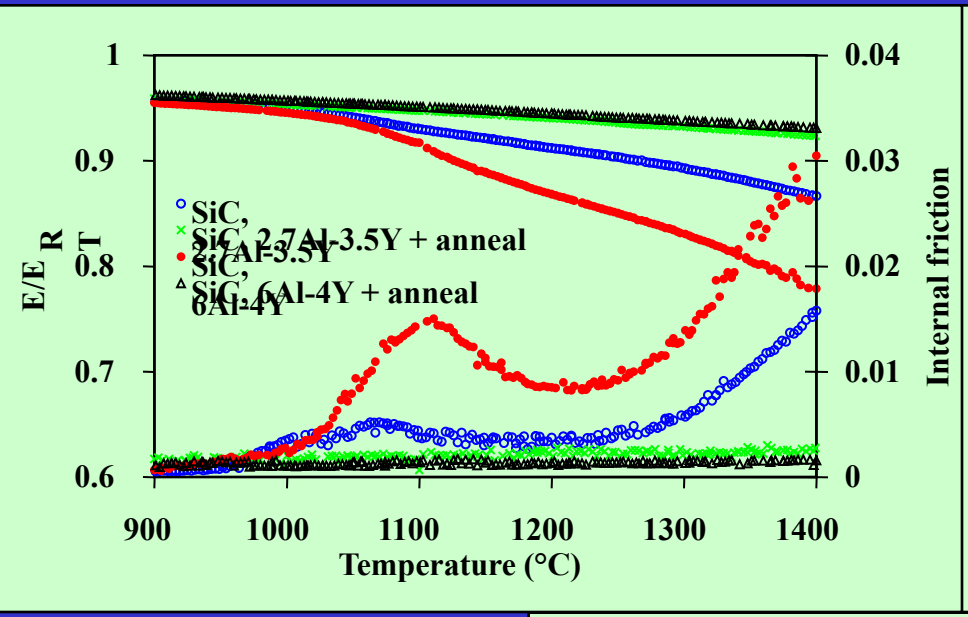
Schematic of an IET-furnace

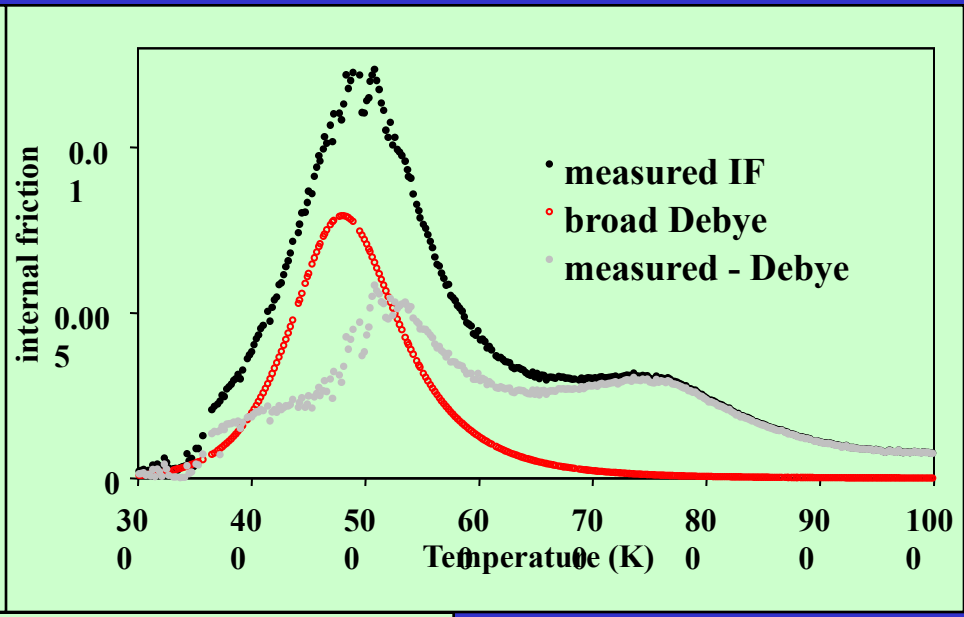


Si_3N_4 result : f_r or E (T) and $Q^{-1}(T)$

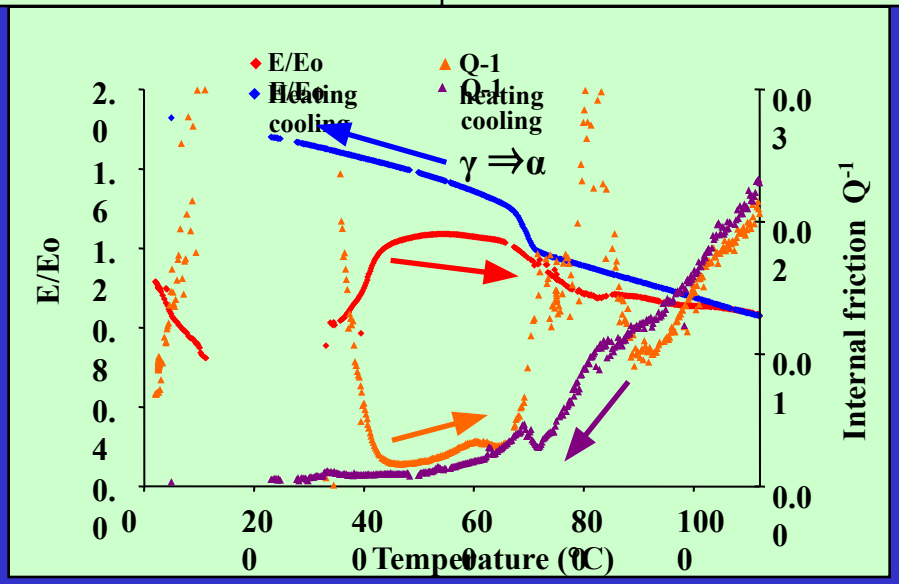


Elastic and damping properties of materials





Hot pressed SiC

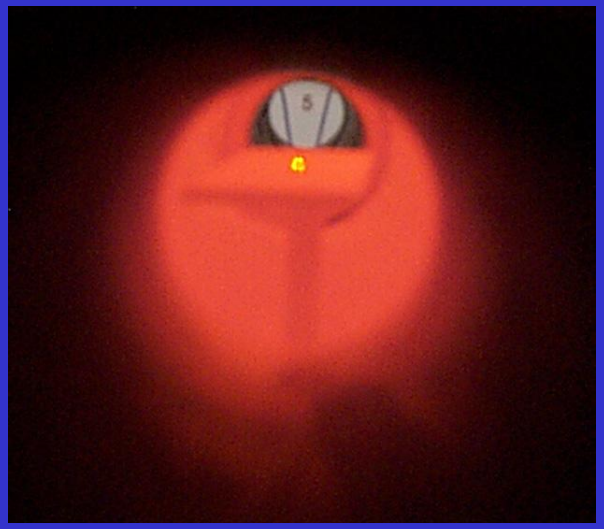


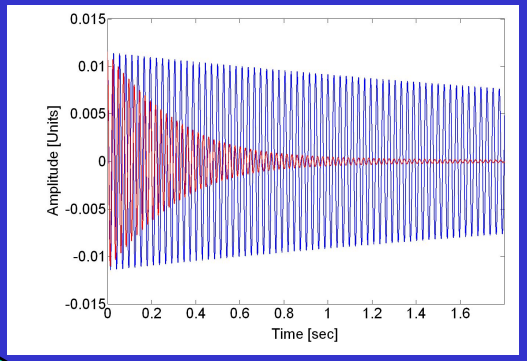
Sintered 2Y-TZP

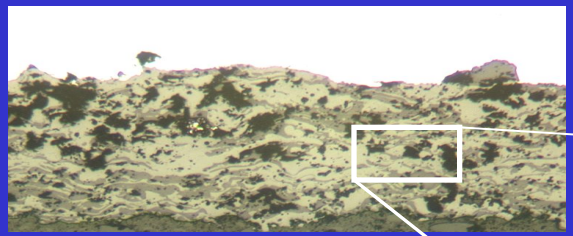
Sintering PM steel

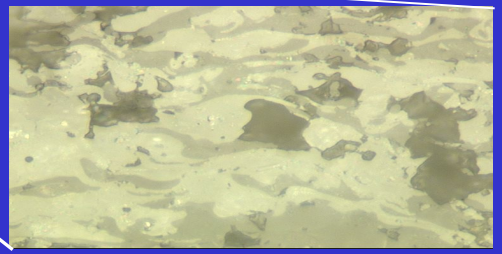
Elastic and damping properties of materials

Structural Integrity of Ceramic Multilayers and Coatings”



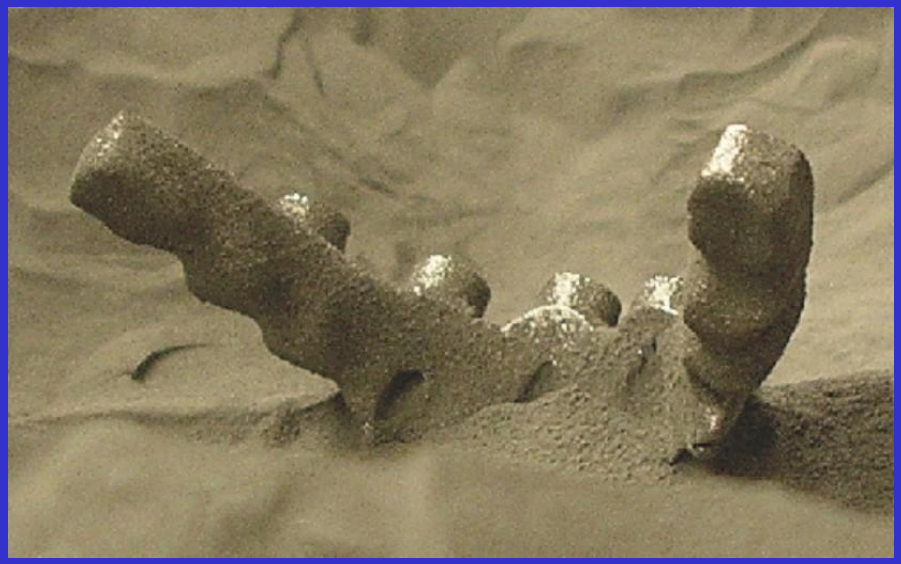






Selective laser sintering and melting

Direct rapid manufacturing of metallic and ceramic parts

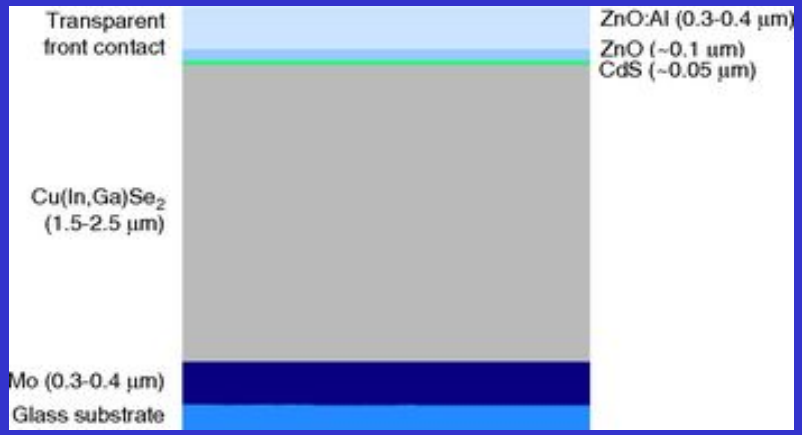


SBO project: DiRaMaP (2008-2012)

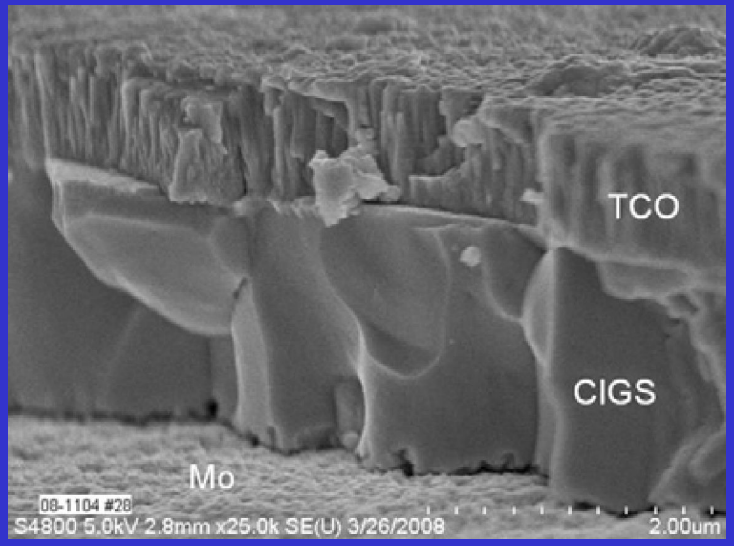
Project Coordinator:
PMA, K.U.Leuven

Solution Deposition Technologies for CIGS and TCO

- Powder-based opposed to vacuum sputtered photovoltaics
- Selenisation studies of Cu(In,Ga)-Selenides
- Assessment of fast selenisation processes
- Rapid annealing processes of transparent conductive oxides (TCO)

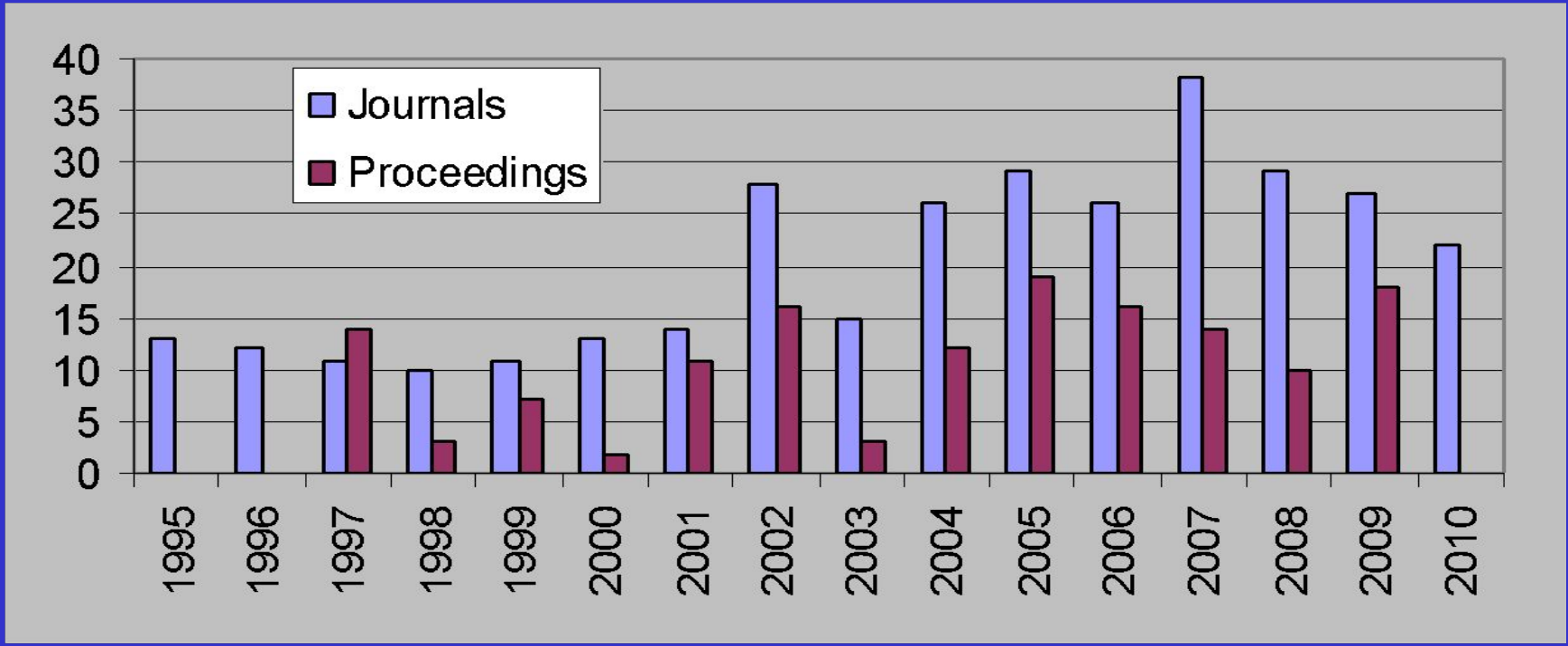


Cross-section of $Cu(In,Ga)Se_2$ solar cell



SIM project: SoPPoM (2010-2014)

Publications ceramics research group



Ceramics research group