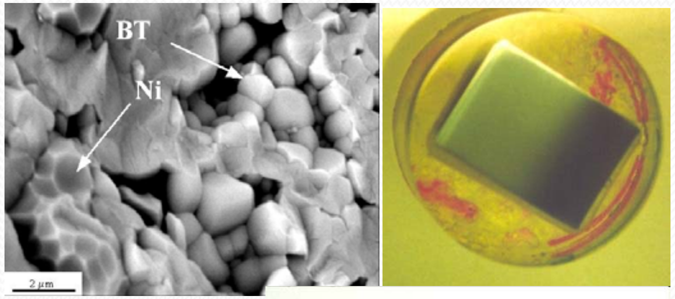
Robust ceramic composites with tunable electric properties

Miguel Morales
Carlos Pecharromán
cpg@icmm.csic.es
Instituto de Ciencia de Materiales de Madrid, CSIC Spain.

CSIC
Consejo Superior de Investigaciones Científicas
Instituto de Ciencia de Materiales de Madrid (ICMM)

ICMM Ceramic Composites Research:

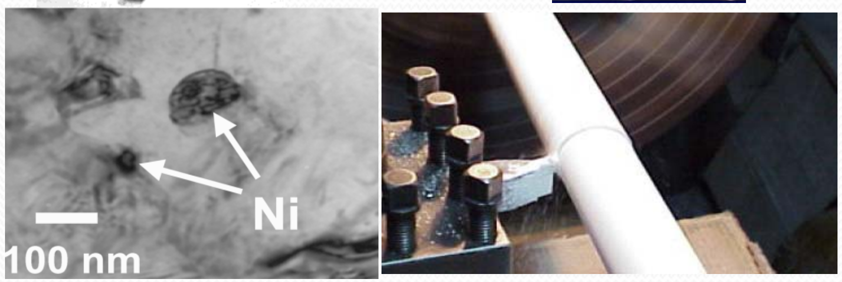
- Percolative ceramic/metal composites



- Plasmonic materials:

- Biomedical applications

- Cutting tools

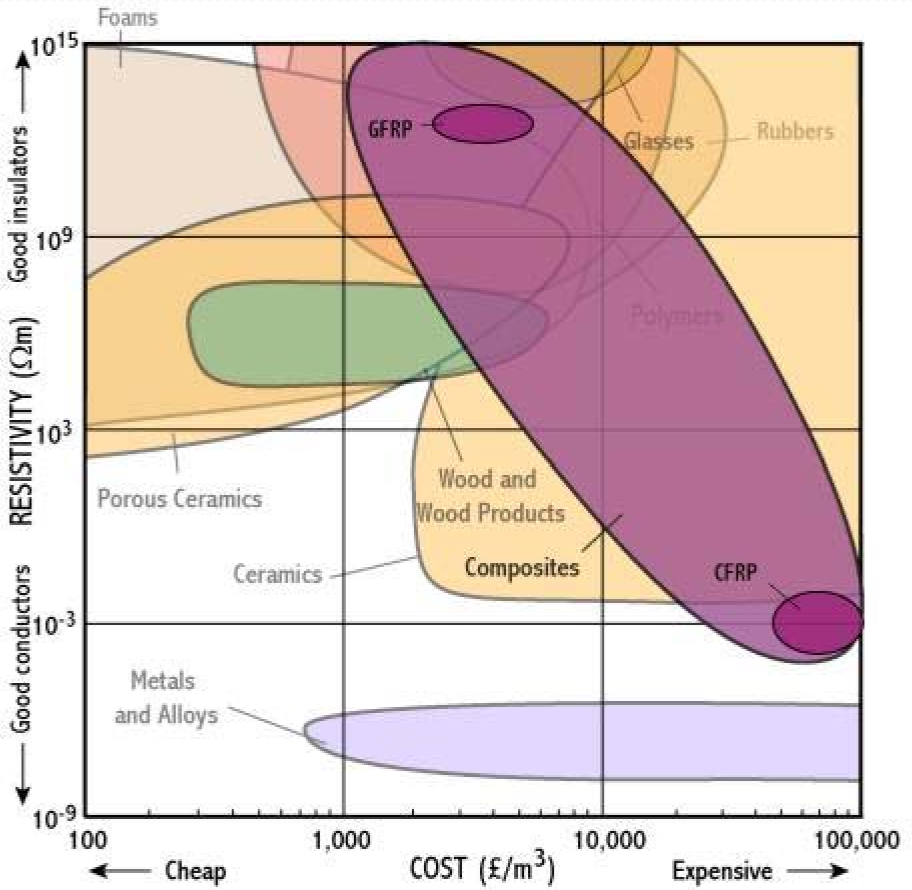


Defining the ceramic composites.

- Conductivity around 10^{-10} Sm^{-1}. Lossy material.
    - Matrix-> bad insulator.
    - Inclusions-> bad conductor.
- Stability against high fields, ageing and atmosphere.
    - Electronic conductivity. (Ion conductivity should be avoided in the conductive phase due to ageing related to faradaic conductivity)
    - Water condensation (porosity) produces inhomogeneity and sparks. (Porous ceramics must be rejected)
    - Excellent homogeneous microstructure.
- Ability for tuning the conductivity.
- Good mechanical properties.
- Not very expensive. The material can be scaled-up for industrial production.

Creating a new material with specific values of electric properties from scratch:

http://www-materials.eng.cam.ac.uk/mpsite/interactive_charts/resistivity-cost/basic.html



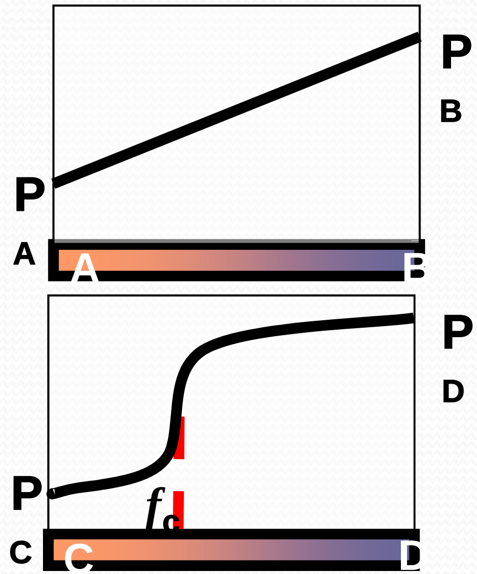
Composites

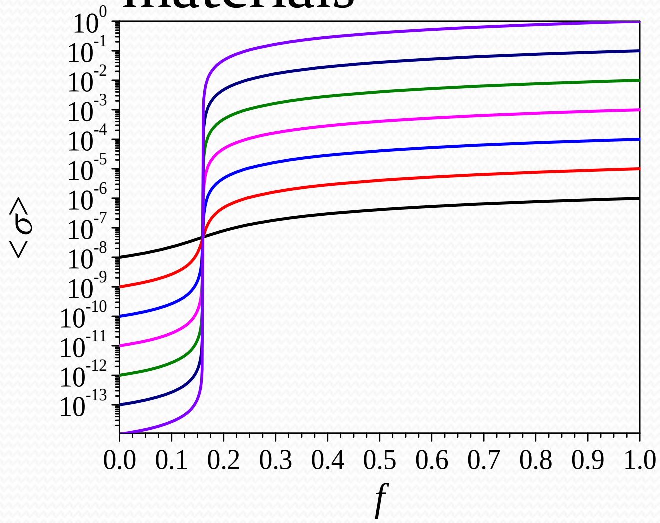
Polymers

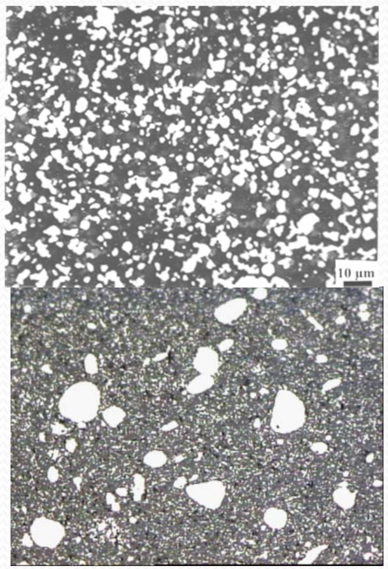
Ceramics

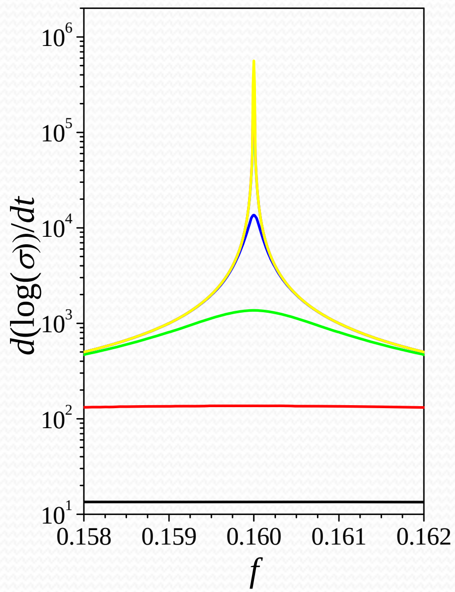
Percolation and conductivity:

- To create new materials with a specific value of conductivity we use two materials with larger and smaller value.
- The effective property does not follow the “rule of mixtures”.
- Combining dissimilar materials in combination with heterogeneous aggregation produce “out of specification” materials





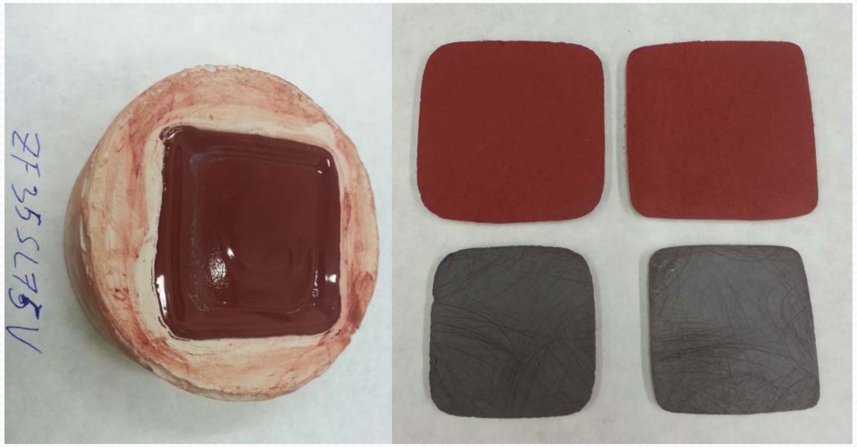


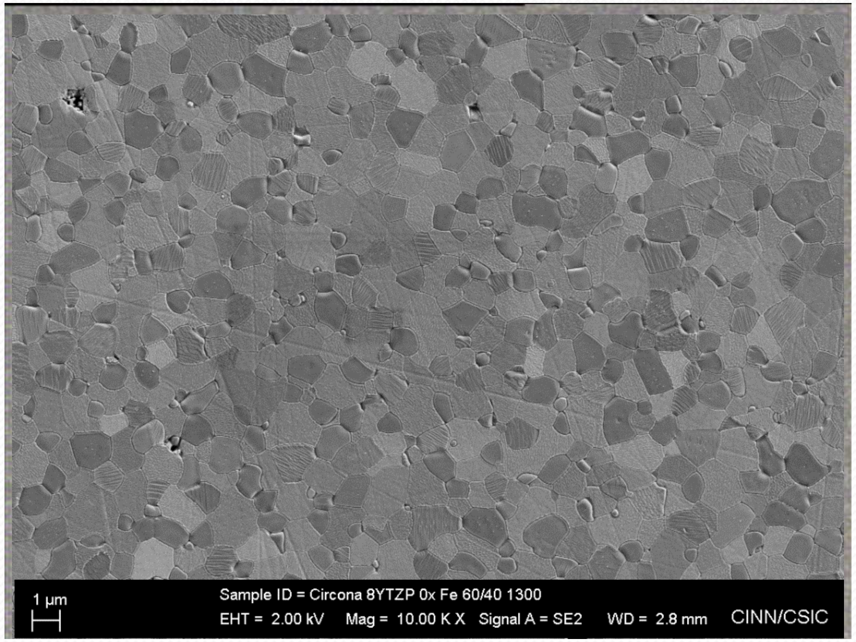


ZF materials.

- Composites are made by poor electron conductive inclusions embedded into a poor insulating matrix.
- Both components are good oxygen conductors at T>300ºC. Thermal treatments under oxidizing or reducing atmosphere can reversibly modify the composite conductivity.
- Powder processing are relatively simple and can be easily scaled up to produce large or thin plates (10 μm) by standard industrial procedures.
- Large Z's
- Relatively high ε
- Good chemically stability.

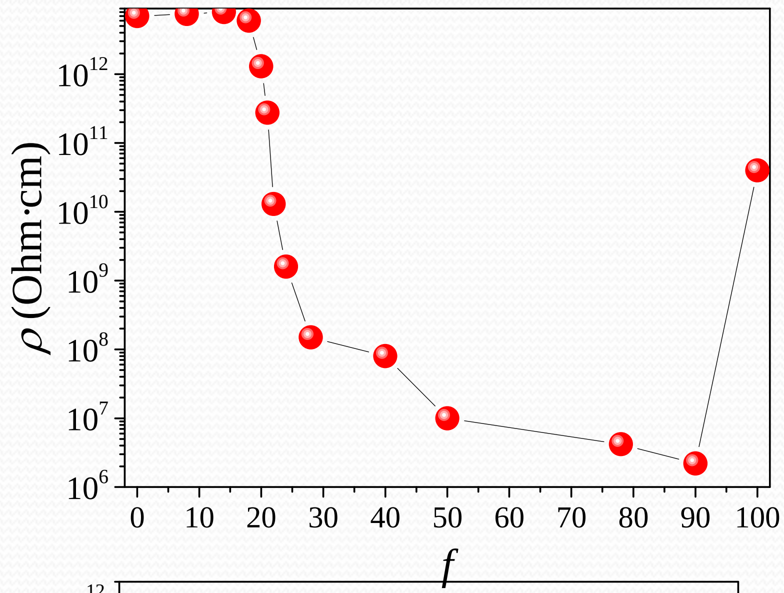
ZF Composites: Experimental Set-up and Microstructure



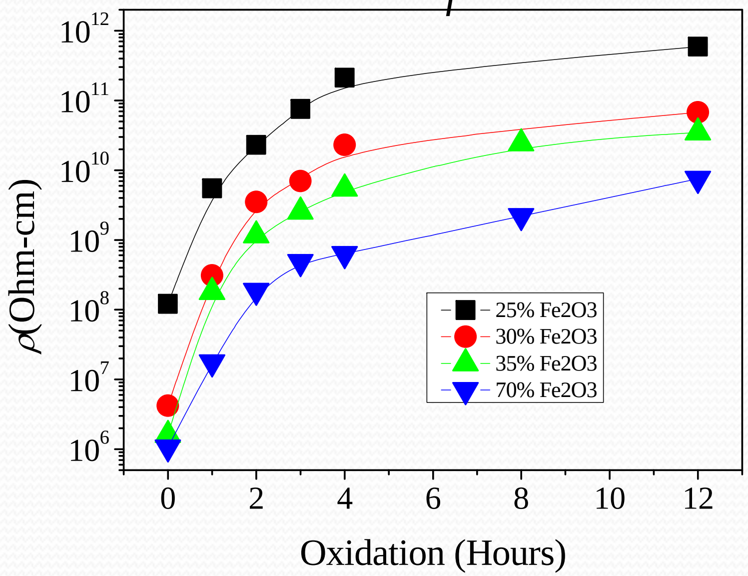


Electrical properties of ZF electrodes conductivity tuning

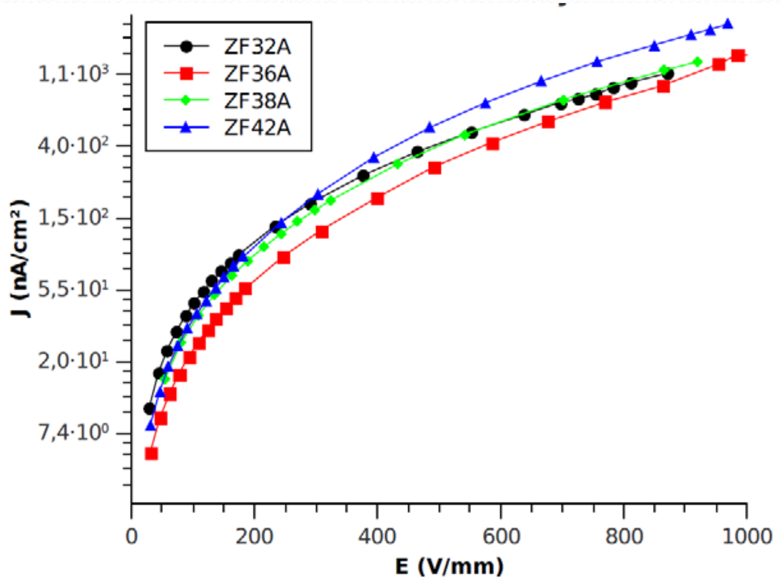
- Tuning of conductivity is a crucial feature for a composite.
- The percolation threshold of this system is f_c~0.23: ρ varies from 10^{13} to 10^8 Ω·cm



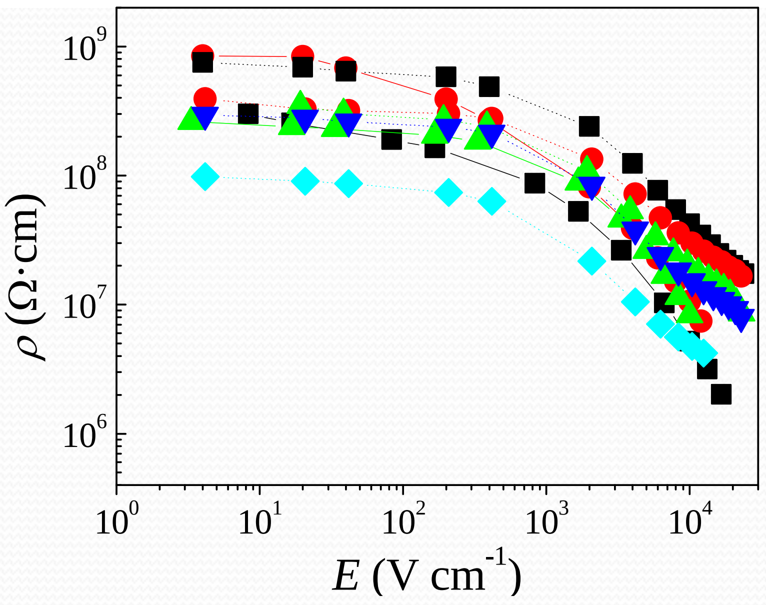
- Fine tuning (2 orders of magnitude) can be done by a thermal treatment at T>300ºC in air ($\rho\downarrow$) or in neutral or reducing atmosphere ($\rho\uparrow$)

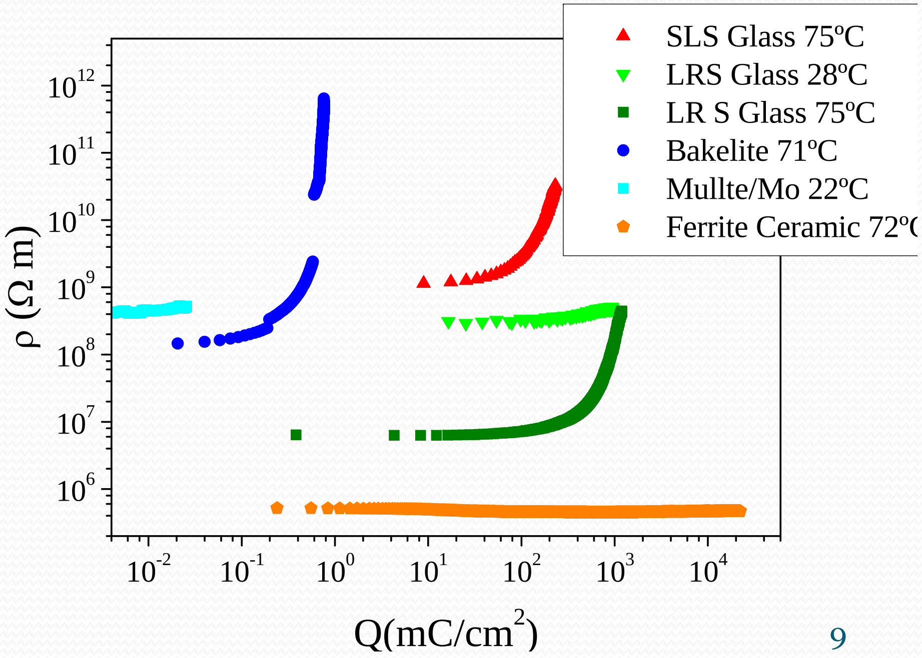


Electrical properties: Stability



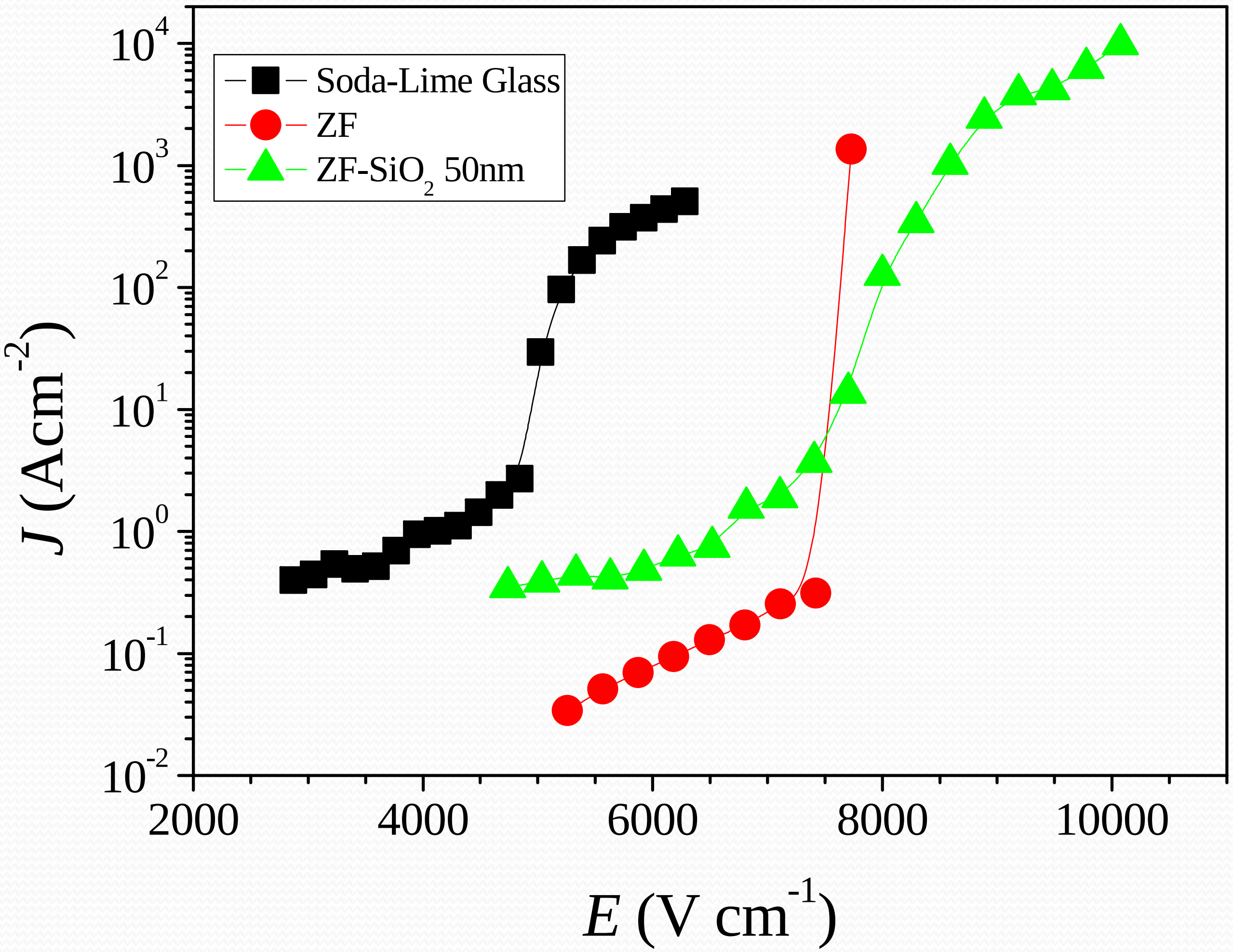
- Ceramic composites present a non-linear I/V behavior.
- Resistance fall around an order of magnitude for high E fields.
- This composites **do not present ageing** at all.





Gas-Ceramic Electrode Interaction

- Although the excellent electrical properties of ZF composites, the behavior as anode in a gas (freon) detector is odd.
- However, a surface treatment allows them to be used in gas chambers.



Conclusions.

- Composite ceramic materials with previously specified electrical properties can be produced from scratch.

- Conductivity can be tuned by changing concentration and by thermal treatments.

- They present optimal electrical stability even under high voltages for indefinite time periods.

- Epitaxial surface treatments make them suitable to be employed in gas detector electrodes.


Thank you for your attention.