

Mechanical Characterisation of Multi-Layered Ceramic Systems for SOC

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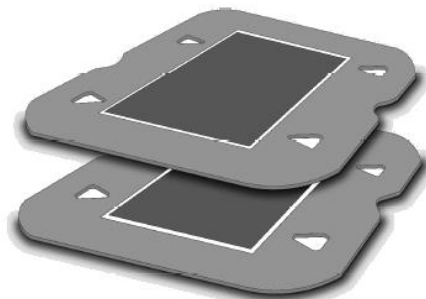
Introduction

Solid Oxide Cell (SOC) technology

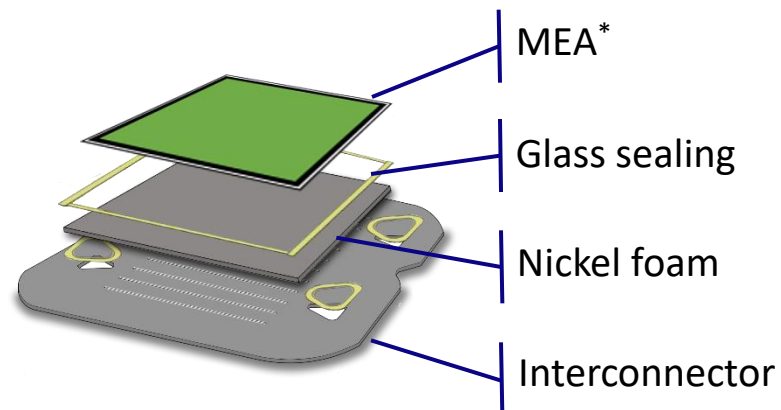
Stack



Repetition Units



Components



- MEA = Membrane Electrolyte Assembly

Pros

- High electric efficiency
- High power density
- Low pollutant emissions
- Multi-fuel compatibility

Weaknesses

- High temperature
- Harsh operating conditions
- Elevated stresses



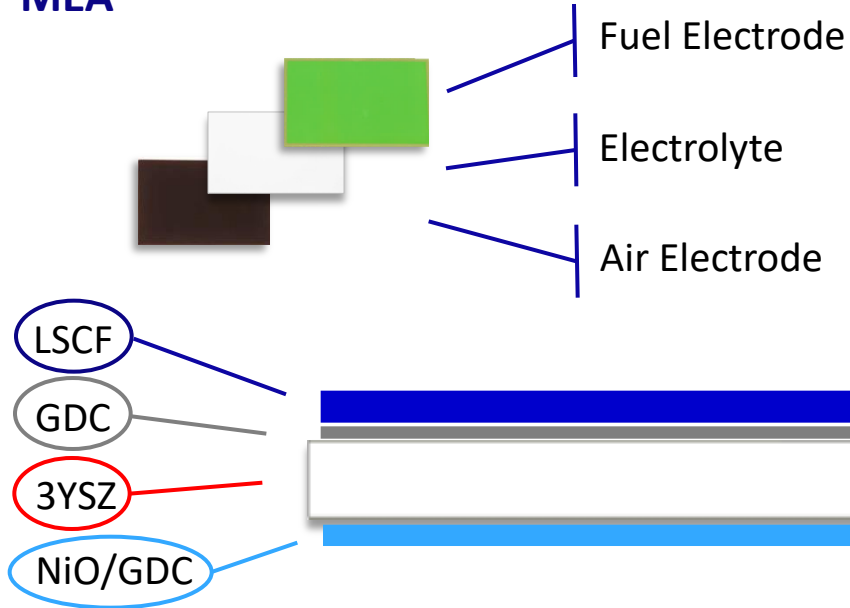
Material degradation



Mechanical stability

Methodology

MEA



Mechanical characterisation of the **MEA**

Overall elastic behaviour of MEA

Interactions between layers

Improve SOC **reliability**

SOC0 Electrolyte

SOC1 Electrolyte + Barrier

SOC2 Electrolyte + Barrier + Fuel Electrode

SOC3 Electrolyte + Barrier + Fuel & Air Electrode

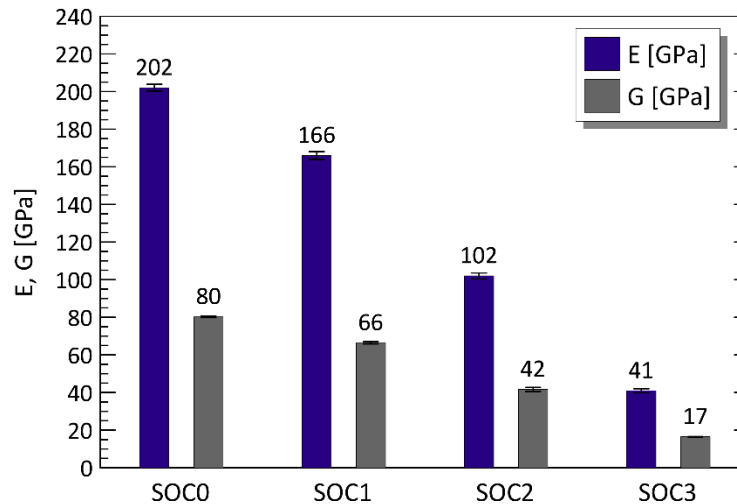
Experimental Data Generation

- Impulse Excitation Technique (IET)
- Three-point Bending (3PB) test
- Tensile test
- Numerical Calculations

Results

Impulse Excitation Technique

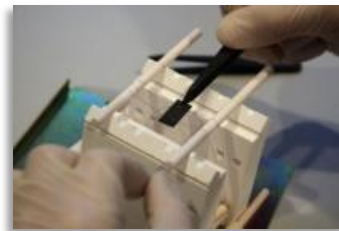
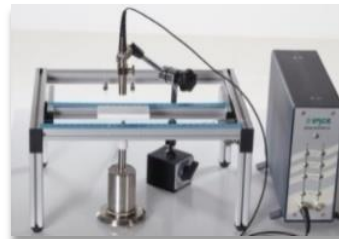
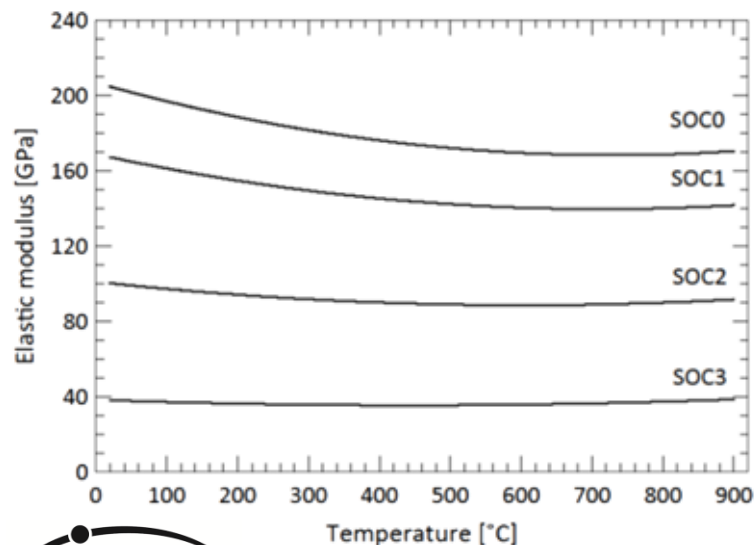
Room Temperature



$$E = 0.9465 \cdot \left(\frac{m \cdot f_f^2}{b} \right) \cdot \left(\frac{L^3}{t^3} \right) \cdot T_1$$

$$G = \frac{4Lmf_t^2}{bt} \cdot \left(\frac{B}{1+A} \right)$$

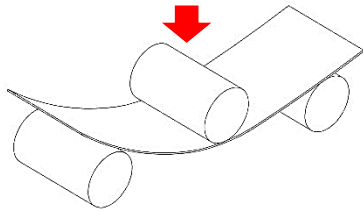
High Temperature



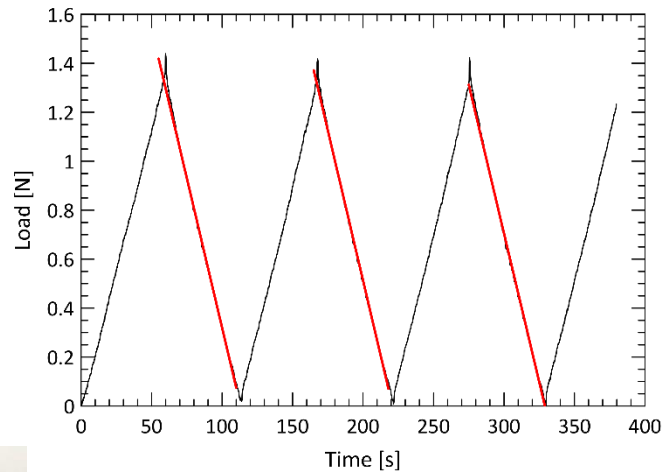
- Continuous **decrease** in the Elastic and Shear moduli
- Biggest relative drop when adding the air electrode layer (SOC3)
- Decreasing behaviour with increasing temperature
- Rather **constant behaviour vs temperature** with increasing number of layers

Results

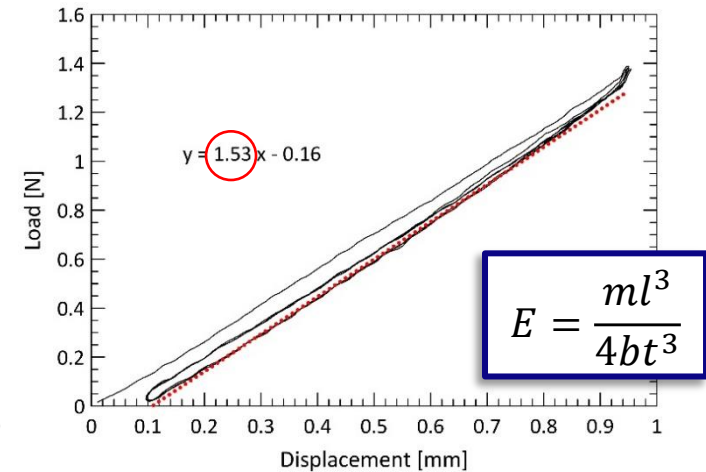
Three-Point Bending Test



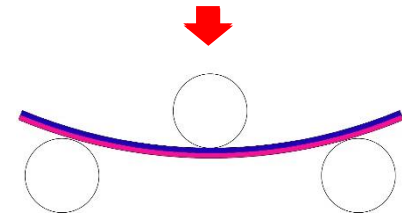
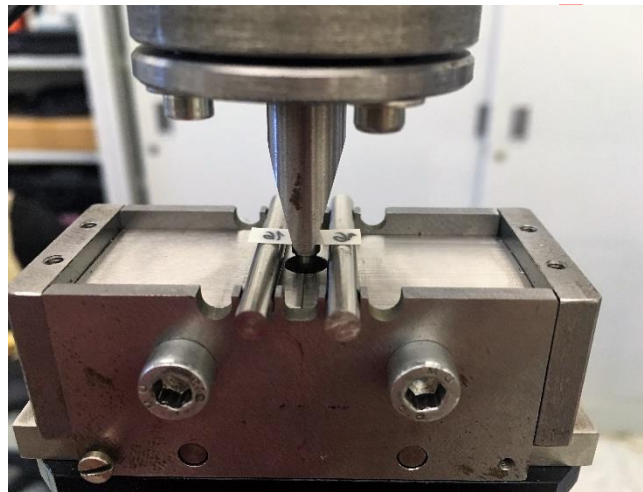
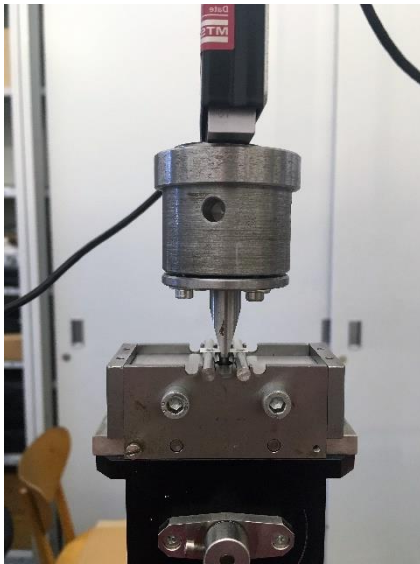
Load VS Time



Load VS Displacement

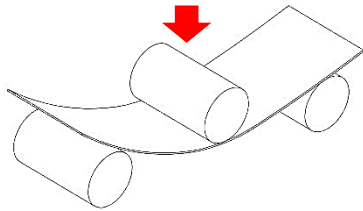


Test Setup

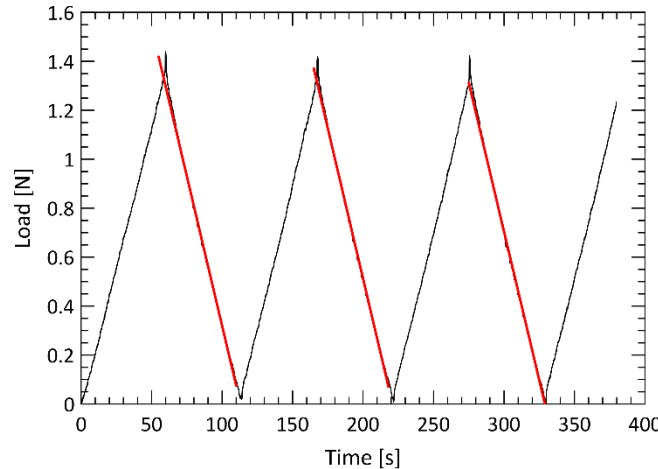


Results

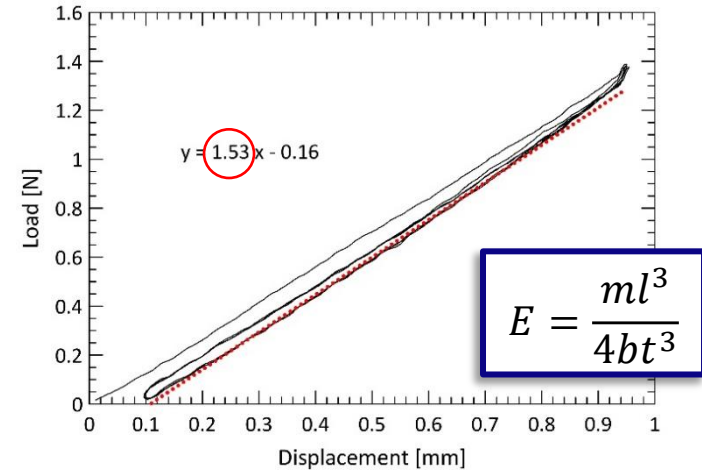
Three-Point Bending Test



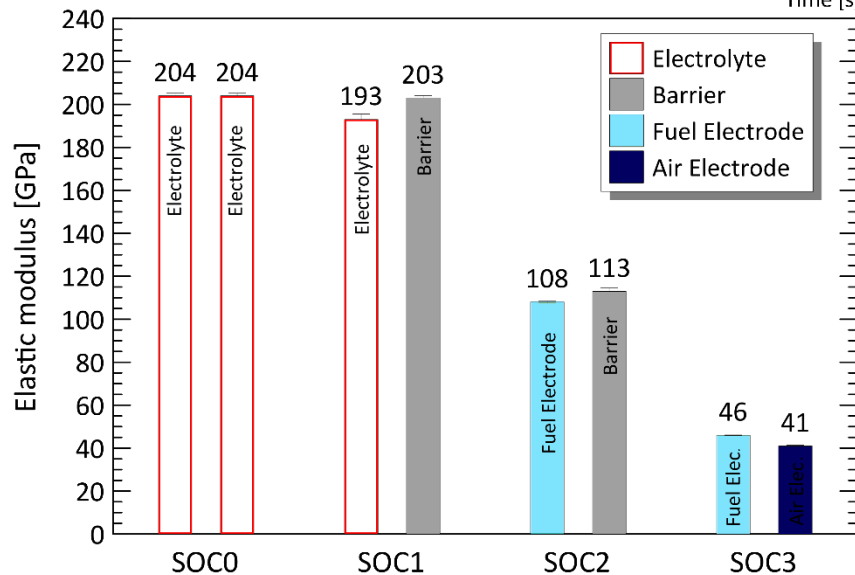
Load VS Time



Load VS Displacement



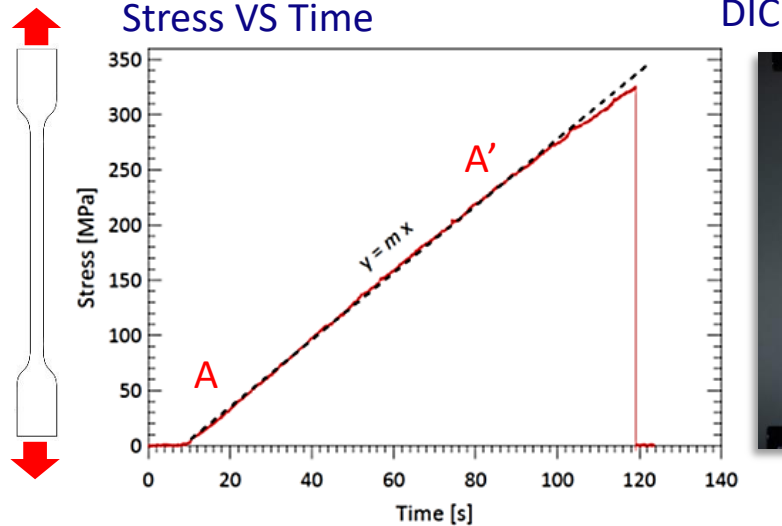
Elastic modulus



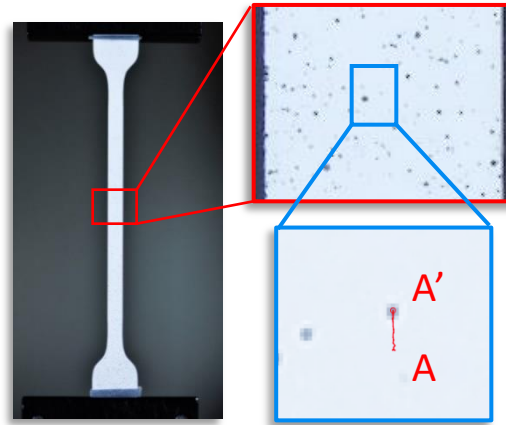
- **Both sides tested** due to the non-symmetric layout
- Continuous **decrease** in the Elastic modulus
- The most **severe drop** in the presence of the **air electrode**
- Results in **good agreement** with the **IET data**

Results

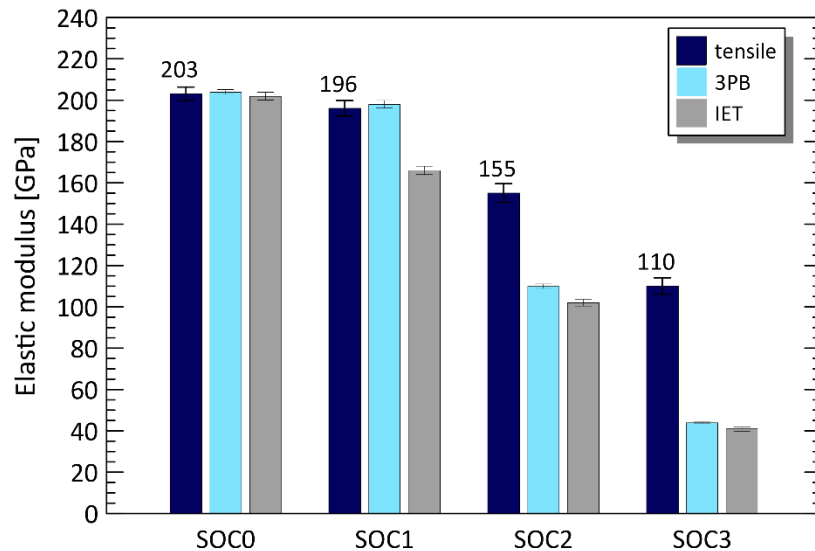
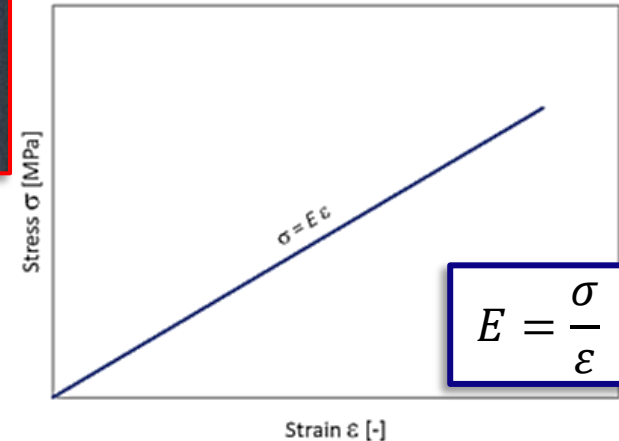
Tensile Test



DIC



Stress VS Strain



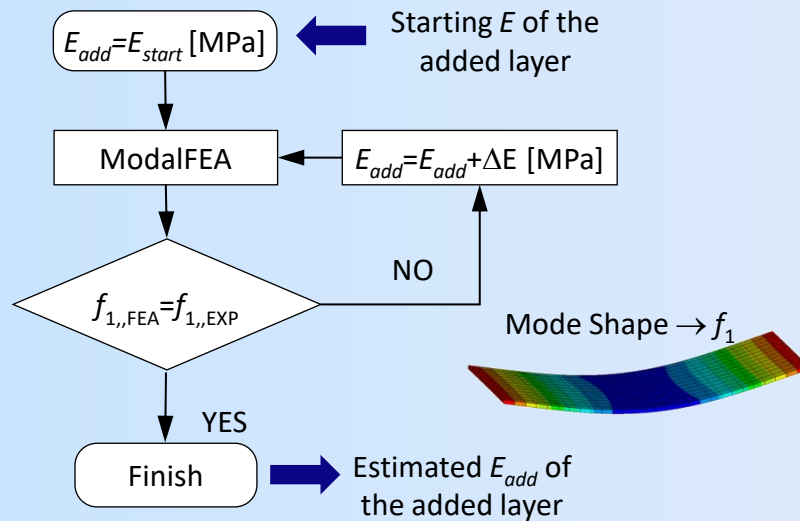
- Continuous **decrease** in the Elastic modulus
- Good agreement between IET and 3PB results (flexural loading)
- **Higher values** in uniaxial (tensile) loading

Results

Numerical Calculations

Finite Element Analysis

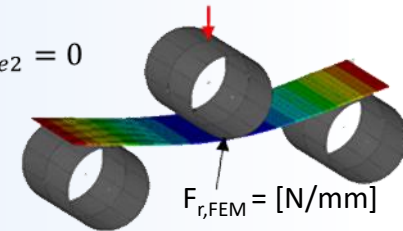
Impulse Excitation Technique



Three-Point Bending

$$\begin{cases} F_{r,FEM,side1}(\alpha_{add}, E_{add}) - F_{r,FEM,side1} = 0 \\ F_{r,FEM,side2}(\alpha_{add}, E_{add}) - F_{r,FEM,side2} = 0 \end{cases}$$

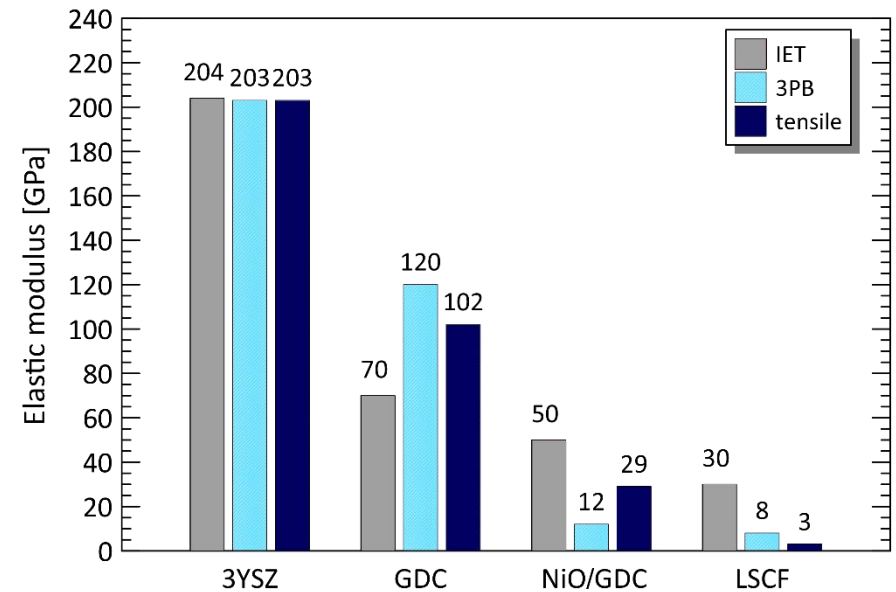
α_{add}, E_{add}



Rule of Mixture

Tensile

$$E_{add} = \frac{1}{t_{add}} \left(h \cdot E_{app} - \sum_{i=1}^{n-1} E_i \cdot t_i \right)$$



Conclusions

- **E (stiffness) decreases** with the addition of layers to the electrolyte;
- **Good agreement** between the results of IET and bending test (3PB) due to the application of the same flexural loading mode;
- All the techniques yielded to the **same value of E** for the **electrolyte (SOC0)**;
- **MEA** is a **non-symmetrical laminate** and the homogenization is not applicable;
- **FEA** can provide indicative values of elastic modulus for **individual layers**;
- Results are really **sensitive to thickness**.



European Training Network



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**Thanks for
your attention**