# Mechanical Characterisation of Multi-Layered Ceramic Systems for SOC

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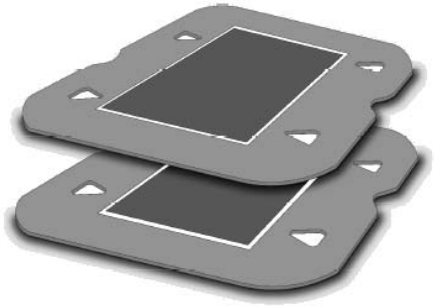
# Introduction

## Solid Oxide Cell (SOC) technology

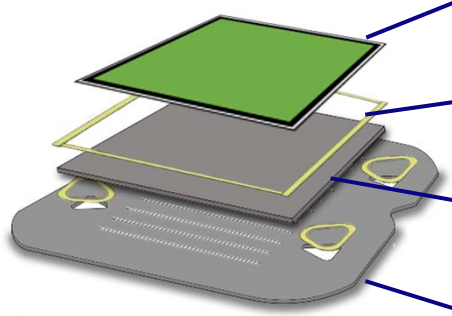
- MEA = Membrane Electrolyte Assembly

**Stack**

**Repetition Units**



**Components**




### Pros

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

### Weaknesses

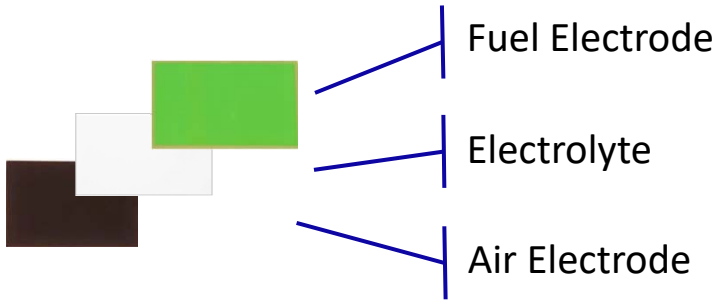
- High temperature
- Harsh operating conditions
- Elevated stresses

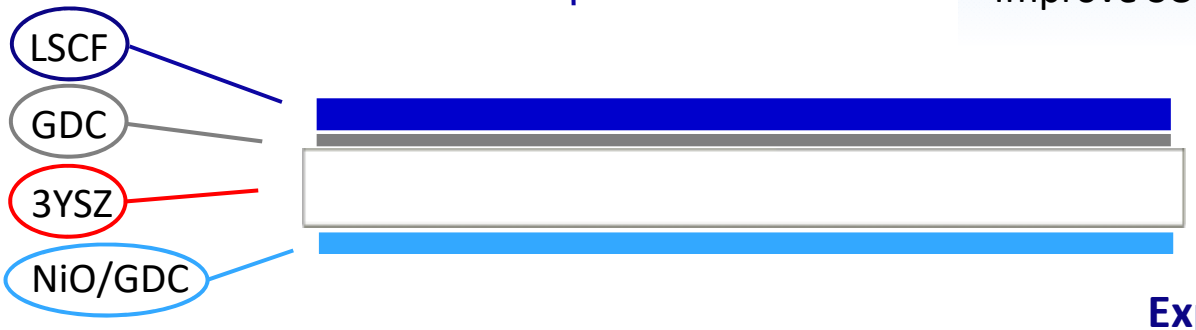
↑ Material degradation

↓ 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

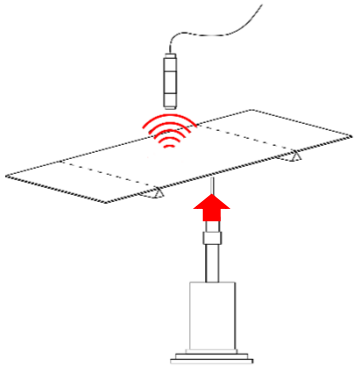
**SOC3** Electrolyte + Barrier + Fuel & Air Electrode

## Experimental Data Generation

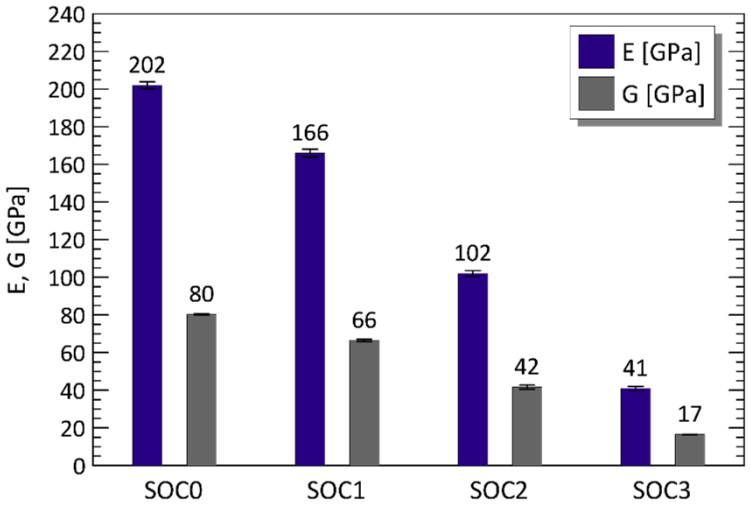
- Impulse Excitation Technique (IET)
- Three-point Bending (3PB) test
- Tensile test
- Numerical Calculations

# Results

## Impulse Excitation Technique



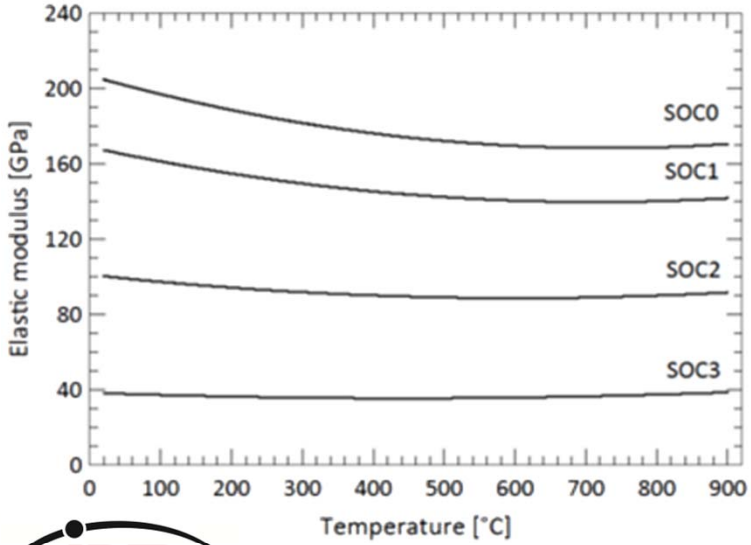
### Room Temperature

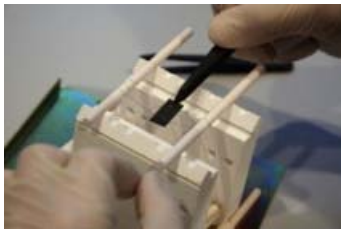



$$E = 0.9465 \cdot \left(\frac{m \cdot {f_f}^2}{b}\right) \cdot \left(\frac{L^3}{t^3}\right) \cdot T_1$$

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

### High Temperature

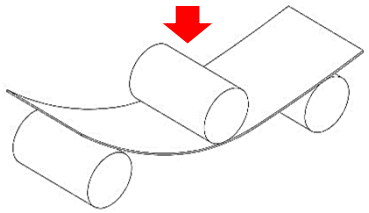


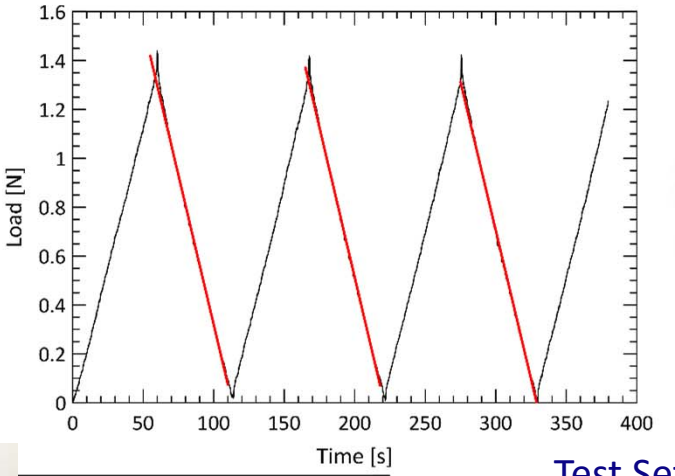
- Continuous **decrease** in the Elastic and Shear moduli
- Biggest relative drop when adding the air electrode layer (SOC3)
- Decreasing behaviour with increasing temperature
- Rather **constant behaviour vs temperature** with increasing number of layers

# Results

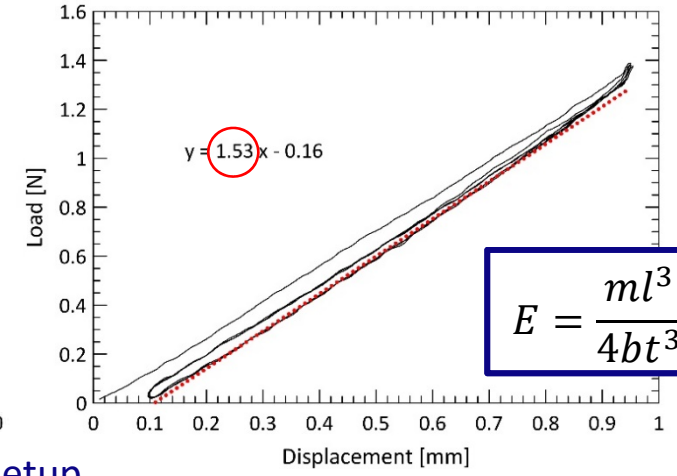
## Three-Point Bending Test



### Load VS Time

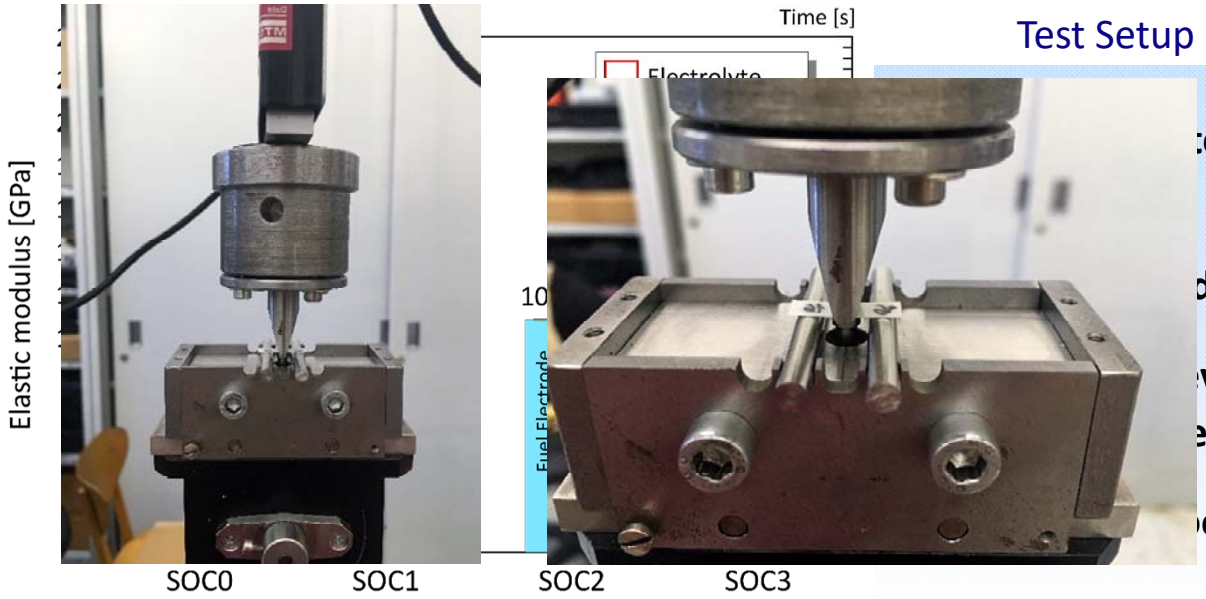



### Load VS Displacement




$$E = \frac{ml^3}{4bt^3}$$

### Elastic modulus




### Test Setup



**tested** due to the non-symmetric

**decrease** in the Elastic modulus

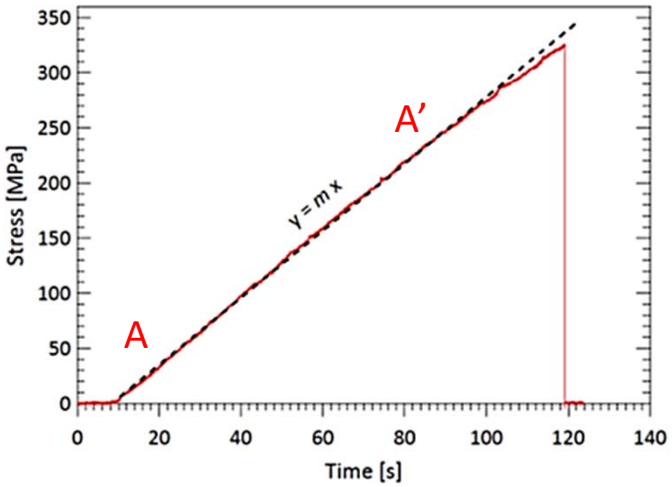
**vere drop** in the presence of the

**od agreement** with the **IET data**

# Results

## Tensile Test

Stress VS Time

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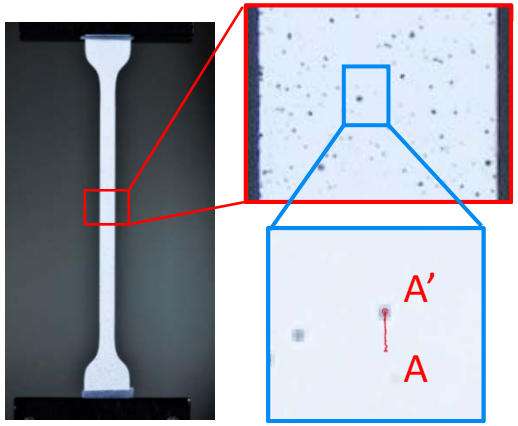
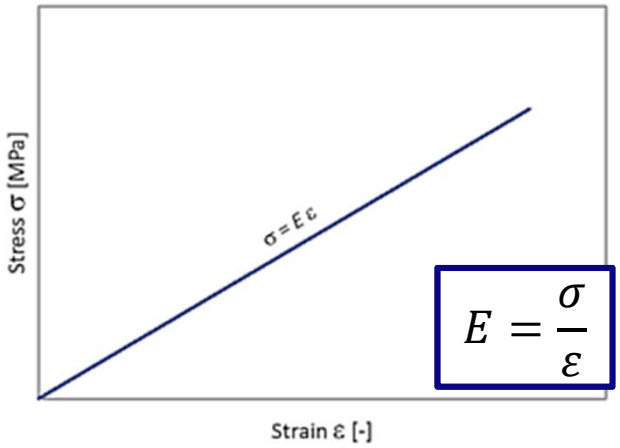
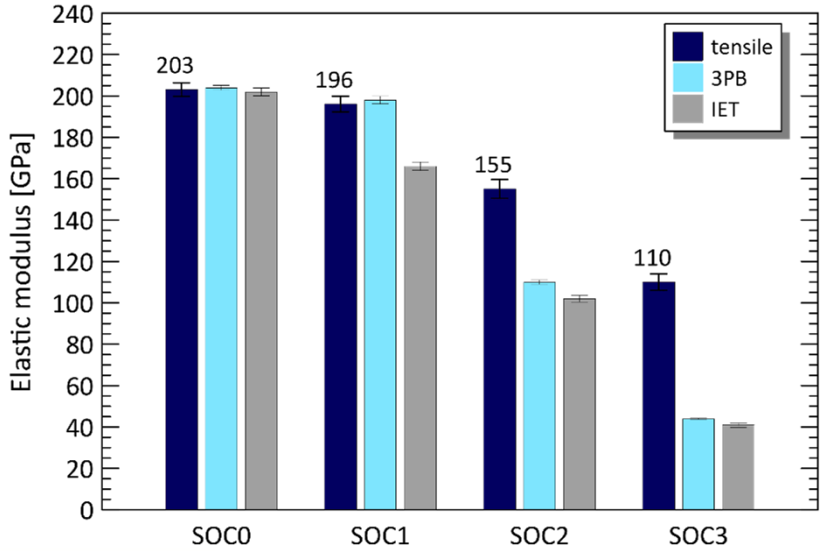



Stress VS Strain



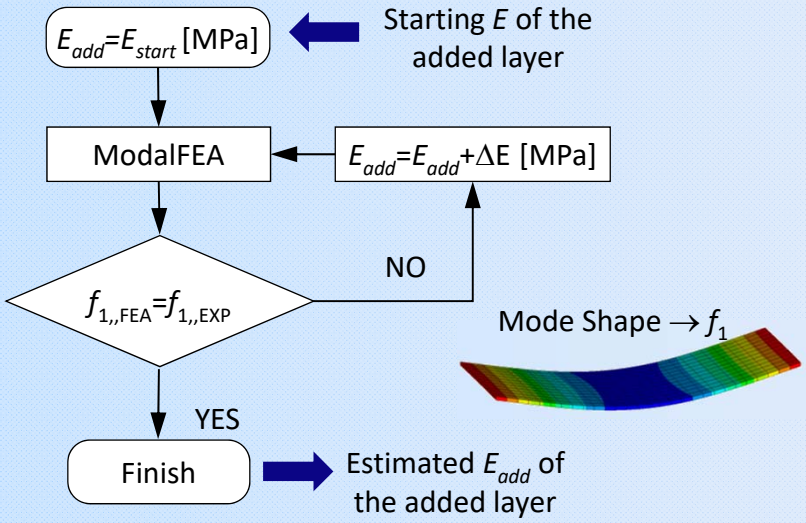

- Continuous **decrease** in the Elastic modulus
- Good agreement between IET and 3PB results (flexural loading)
- **Higher values** in uniaxial (tensile) loading

# Results

## Numerical Calculations

### Finite Element Analysis

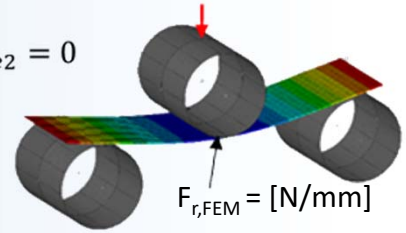
#### Impulse Excitation Technique




#### Three-Point Bending

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

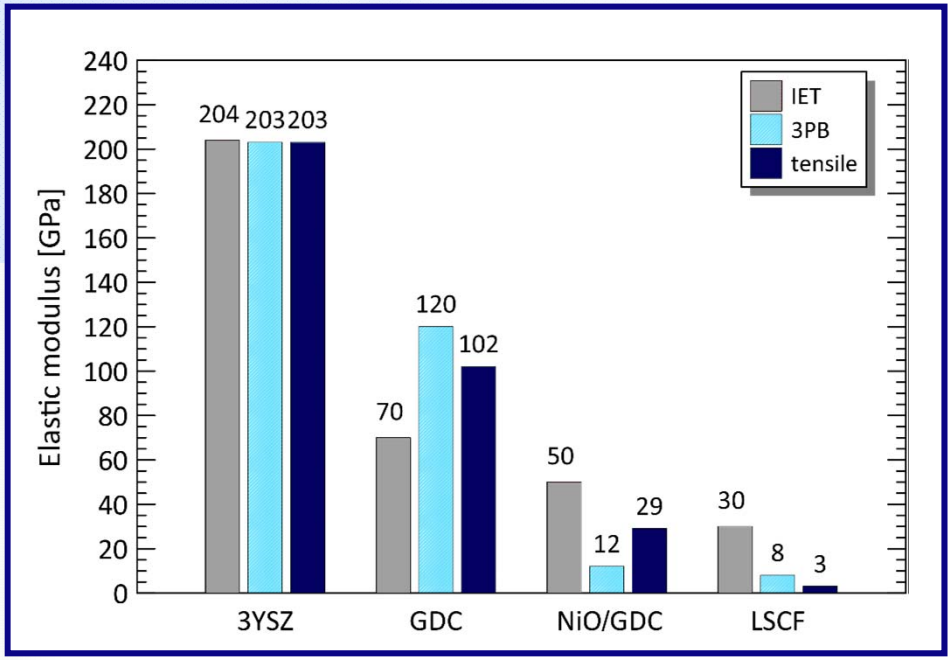
$\alpha_{add}$, $E_{add}$




### 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 flexural 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**.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# Thanks for your attention