Optimization of Cellular foams for Wearable Energy Harvesting: *Enhancing Electromechanical Coupling Coefficient k^2*

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INTRODUCTION

Wearable energy harvesting (or scavenging) devices are in the centre of attention the last decades, as there is a recognised need for autonomy in sensors and portable devices. Light weight, cost effective in terms of manufacturing, and efficacy are the three key characteristics that such a device needs to have.

Among the Piezoelectric materials used for wearable energy harvesting, Polymers seem promising candidates due to their compliance and low density having also comparable piezoelectric coefficient in thickness mode (***d_{33}***) to materials like PZT. As the electromechanical coupling coefficient ***k_{33}*** is the direct measure of the harvesters efficacy, the main aim of this work is to maximize it regarding the input properties. The material used for this investigation is **Cellular Polypropylene**.

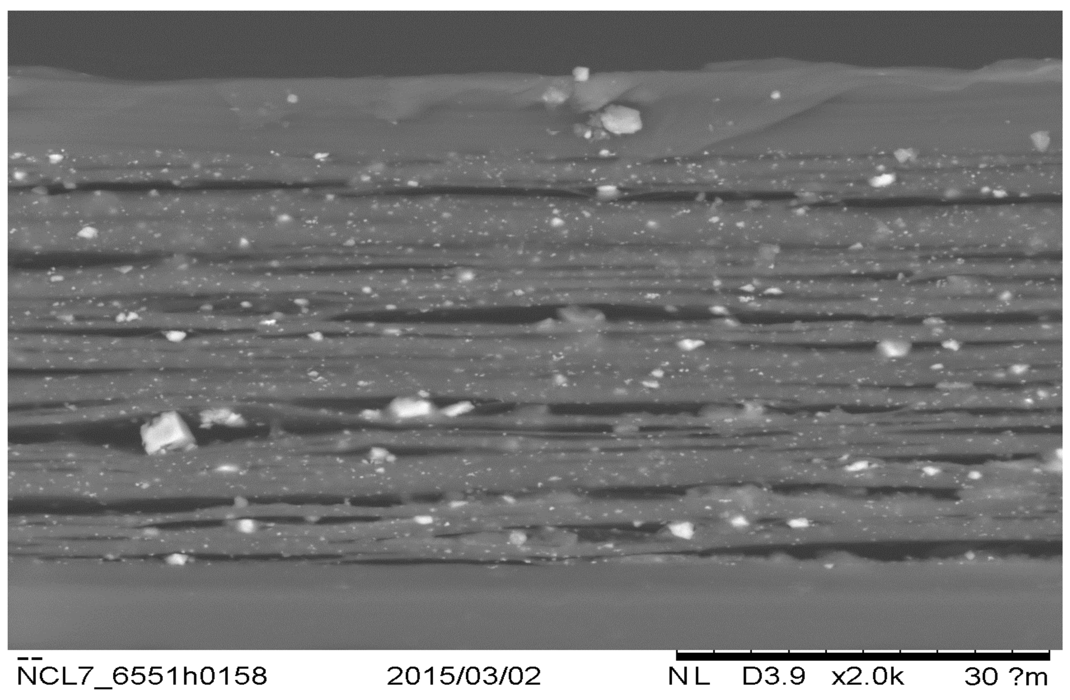

Figure1: Cross section of the virgin material with thickness of 80μm. Image taken with the aid of Scanning Electron Microscope TM3030

SAMPLE TREATMENT

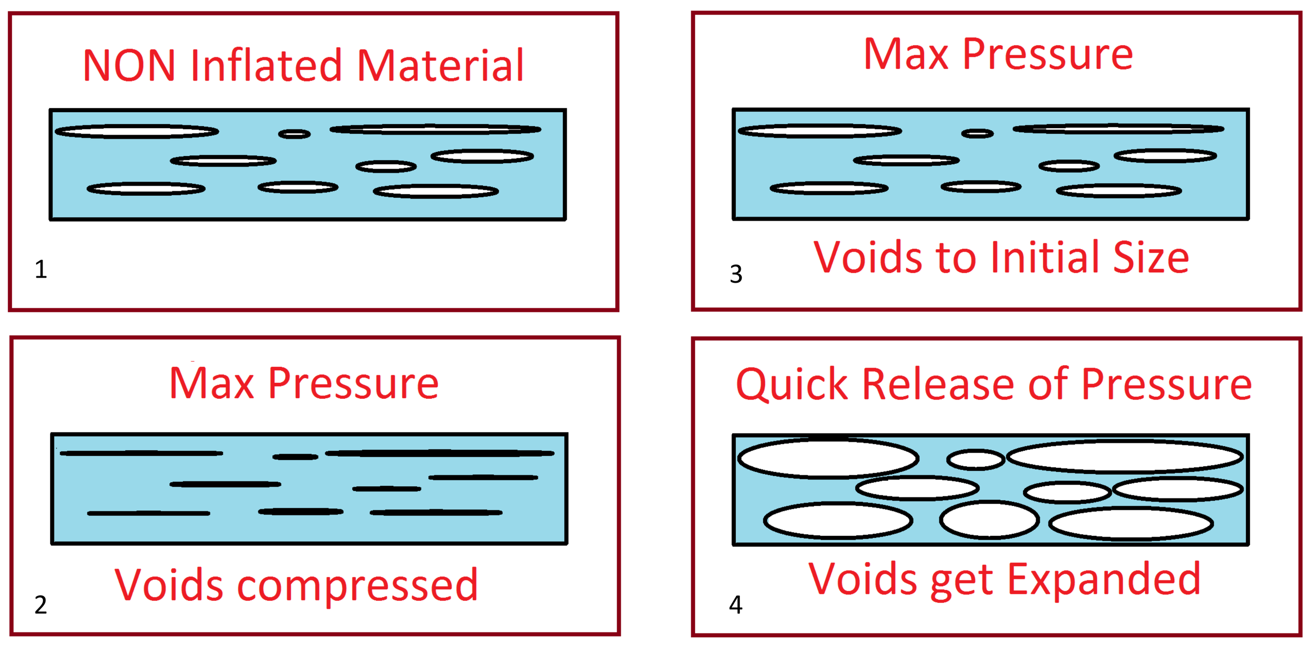

Figure2: Gas Diffusion Expansion (GDE) procedure. 1) Sample in its initial state 2) The voids get compressed 3) The pressure inside the voids gets equal to the external pressure 4) The voids get expanded

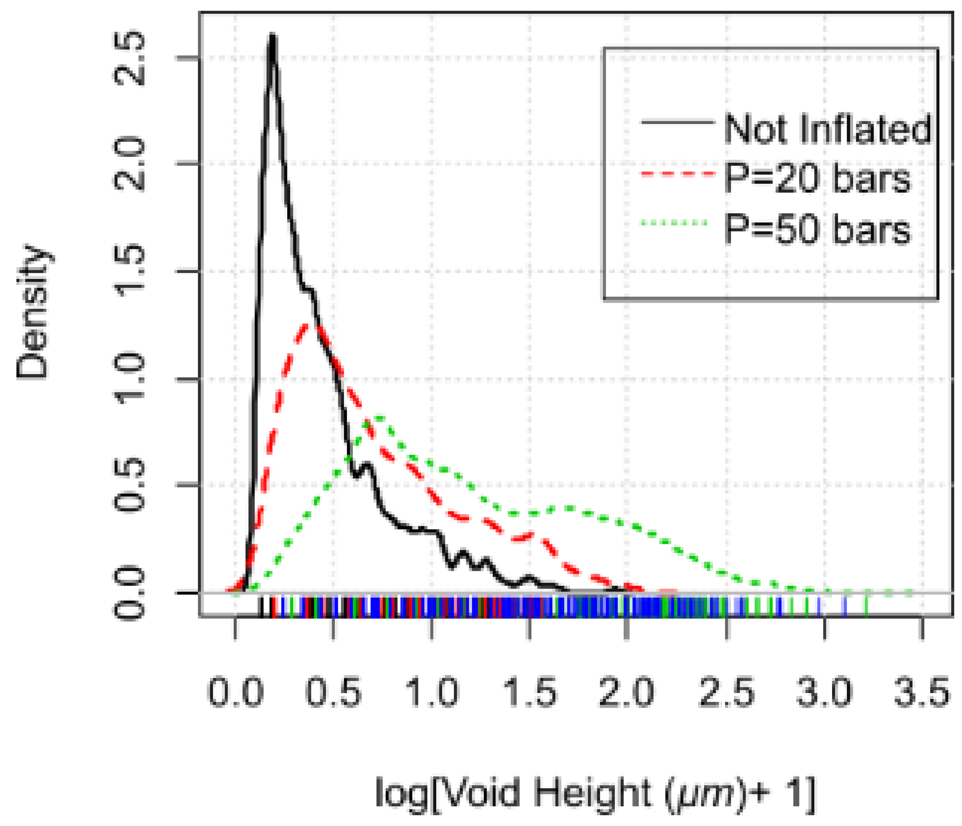

Figure3: Density of voids height distribution within the material for different inflations

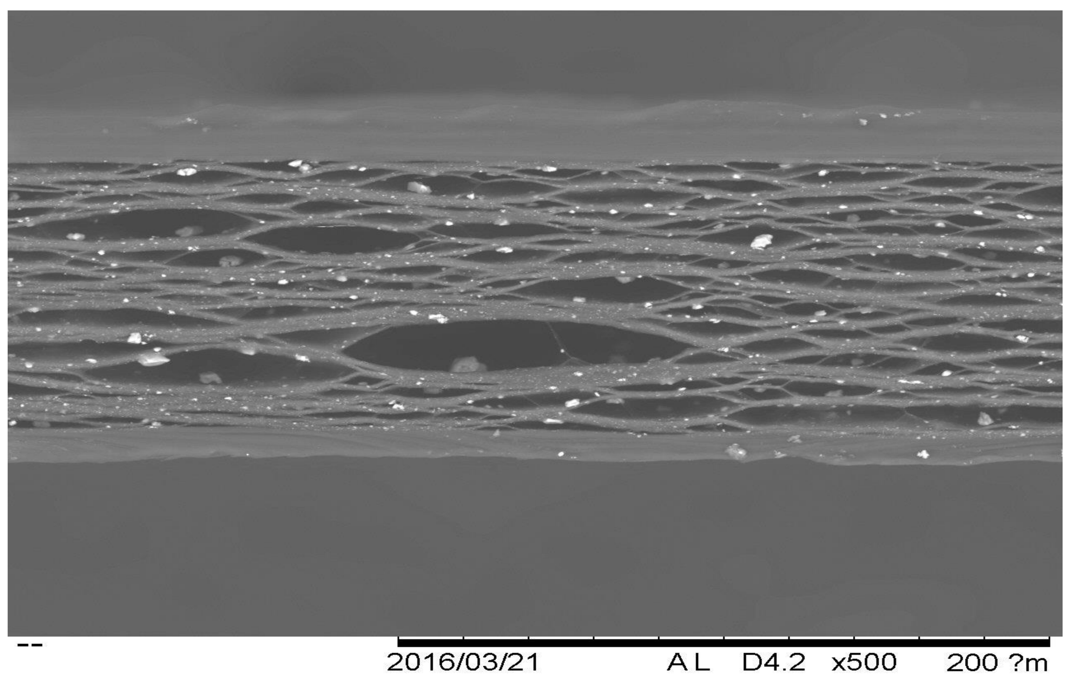

Figure4: Cross section of an inflated material. The inflation was done via GDE procedure with max pressure time of 20 minutes and pressure release of 1.5 minutes. Resultant thickness of 125μm. Image taken with the aid of Scanning Electron Microscope TM3030

CORONA CHARGING

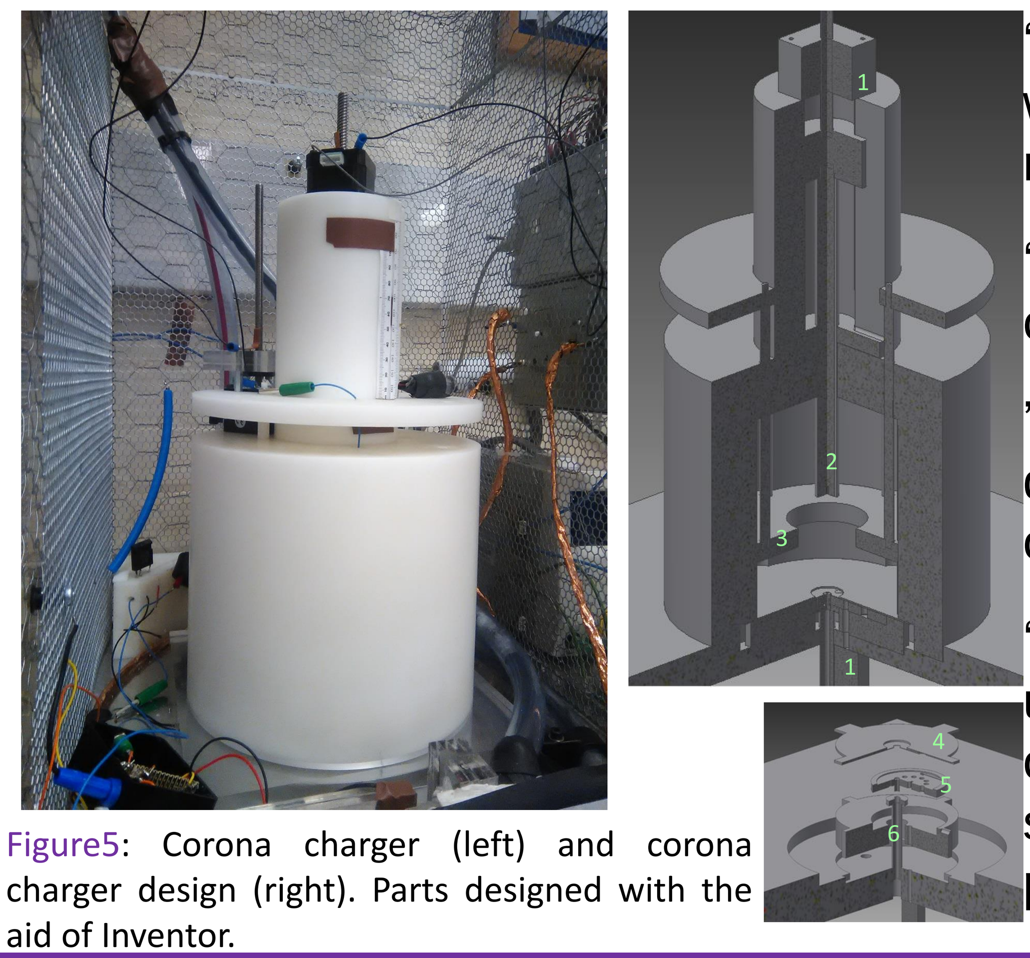

Figure5: Corona charger (left) and corona charger design (right). Parts designed with the aid of Inventor.

"2" 8.9um diameter tungsten wire (corona tip) attached to a rod

"3" Metallic grid attached to a circular holder

"1" Tip and Grid are able to displace in Z axis via means of stepper motors

"5" Samples are placed underneath a grounded piece of metal "4" exposing one sample per charging procedure

Corona Charging Process

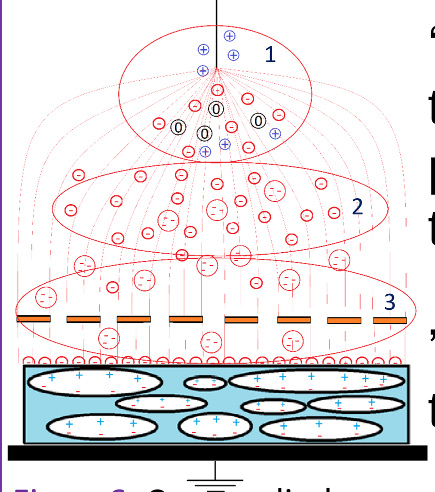

Figure6: Corona discharge process. The process consists of three regions:
1) Ionizing plasma
2) Non Ionizing plasma
3) Unipolar region

"1" The tip is brought to highly negative potential for electrons to be freed

"2" Electrons combine to form negative Ions

"3" Negative Ions continue their way towards the sample

Charging mechanism

Criteria for functionalization $E_V > E_b$

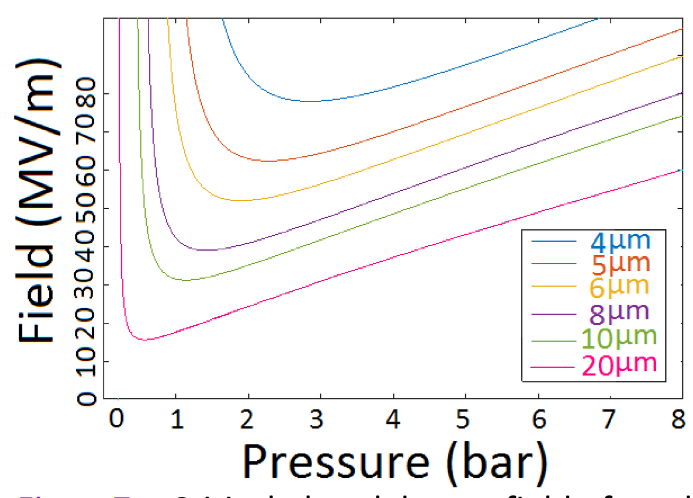

Figure7: Critical breakdown field for different void heights as predicted from Paschen's law

$$E_V = \frac{V_{surface}}{h} \qquad E_b = \frac{Ap}{B + \ln(ps)}$$

Smaller voids, in terms of height, require larger fields to get charged

PRELIMINARY RESULTS

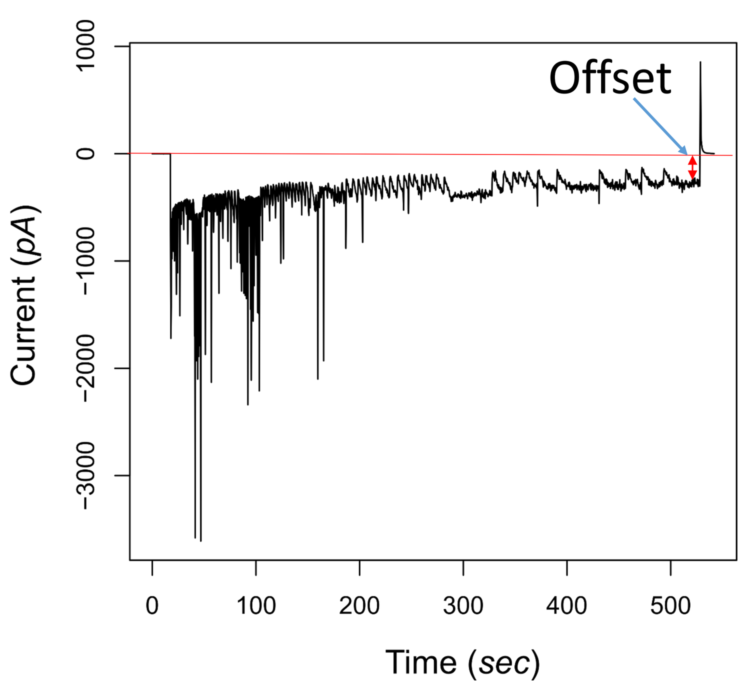

Figure8: Current flowing from the sample during charging process. Data obtained with the aid of Electrometer Keithley 6517b

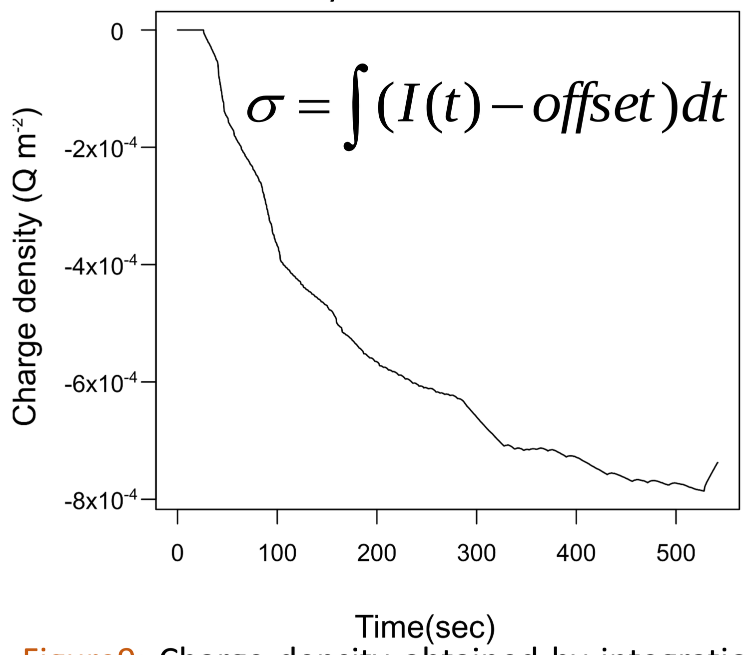

Figure9: Charge density obtained by integration of the current slope (figure 8)

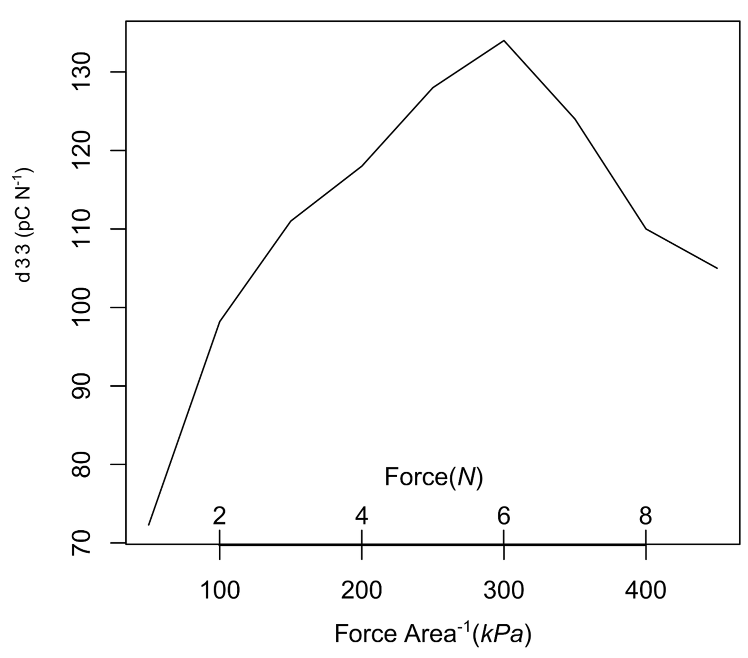

Figure10: Static ***d_{33}*** value measured at different loads. n=3

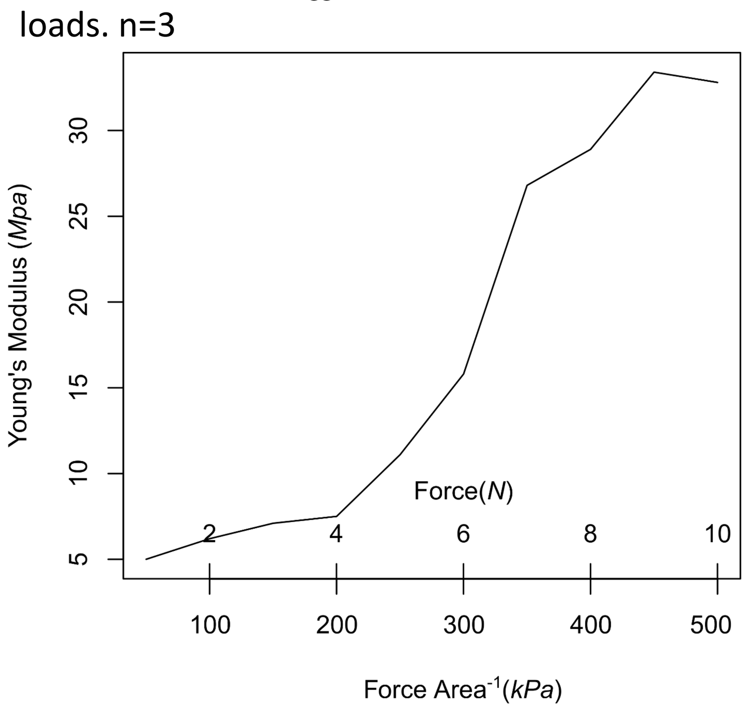

Figure11: Modulus of elasticity during compression at different loads. Data taken with the aid of Dynamic Mechanical Analyzer "DMA8000"

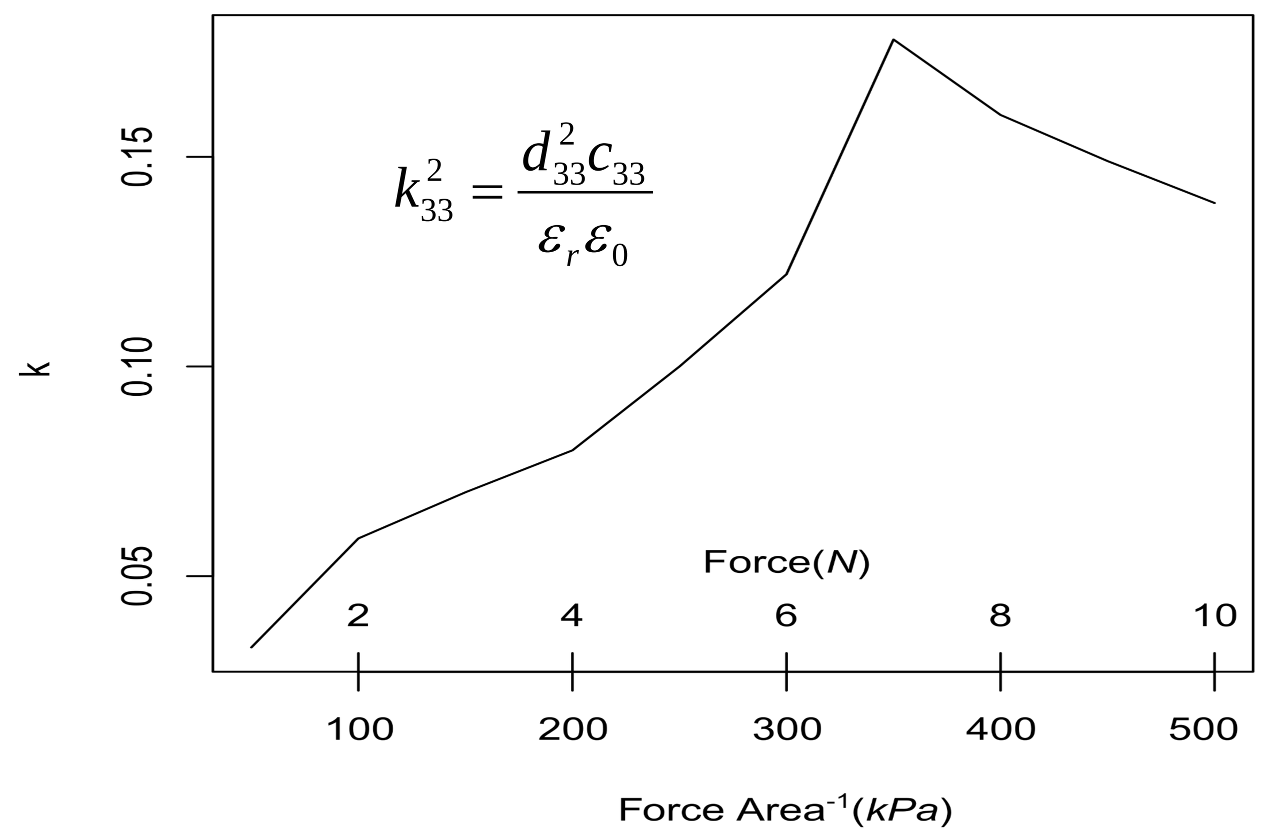

Figure12: Calculated k for different loads based on the data from figures 10 and 11

DISCUSSION

- The material is non homogenous and its response is non linear
  Its response differs based on different compression stresses applied as In higher compressive stresses, the material gets stiffer
- The morphology of the bulk plays a key role to the response
  By changing the morphology of the voids (void height distribution) the material can give its highest response at different compressive loads

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