

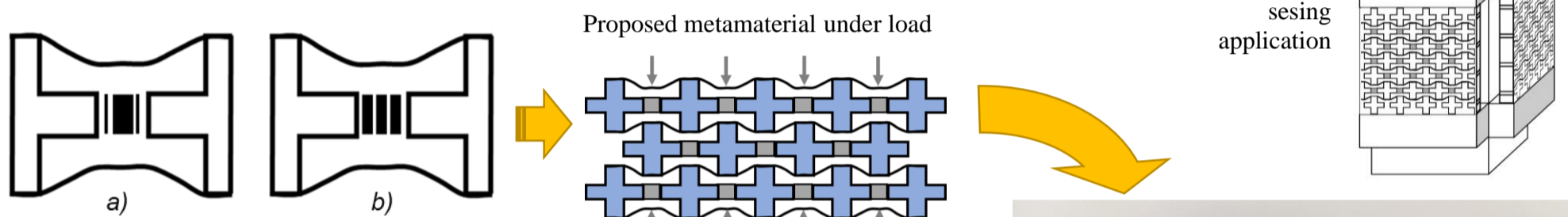
# CONCEPT OF METAMATERIAL WITH PIEZOELECTRIC ELEMENTS FOR CYBER-PHYSICAL SYSTEM APPLICATIONS

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*This paper deals with a metamaterial for sensing purposes under Industry 4.0 applications. The presented of metamaterial is based on an auxetic structure which is made by Direct Metal Laser Sintering technology. The stain steel auxetic structure could integrate smart material elements or systems for electromechanical conversions. The proposed concept of metamaterial uses the auxetic structure with piezoelectric elements or stacks to transduce external load of structure into electric signal. The auxetic structure could provide uniform mechanical load on several smart piezoelectric elements in middle layers due to negative Poisson ration. The paper presents a FEM simulation of this concept and analysis of coupled electromechanical system under harmonic excitation. Deformation of auxetic structure with piezoceramic PZT plates is presented and the voltage response is analyzed.*

*The assembly of metamaterial system with piezoelectric PVDF in case of soft application is also presented and voltage response was measured. This application it will be tested under future development.*

## Auxetic Structure of Proposed Metamaterial with Piezoelectric Elements

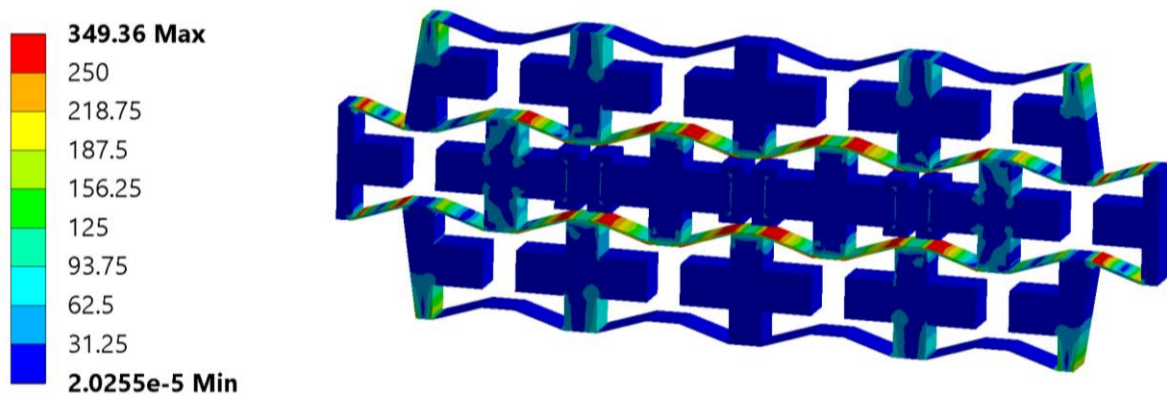


Patterns of structure with smart elements in form of  
a) isolated piezoceramic plates,  
b) piezoceramic or piezopolymer stack.

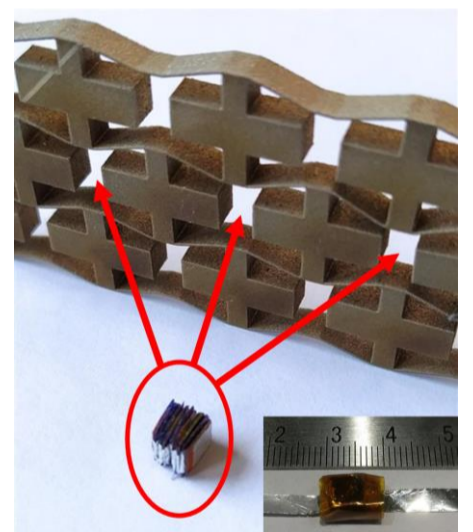


Prototype of stain steel auxetic structure

## FEM Simulation of Metamaterial with Piezoelectric PZT Plates

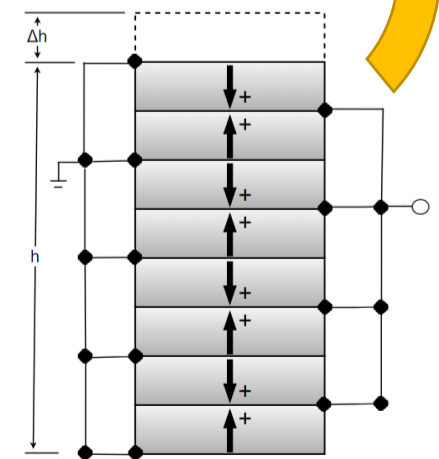
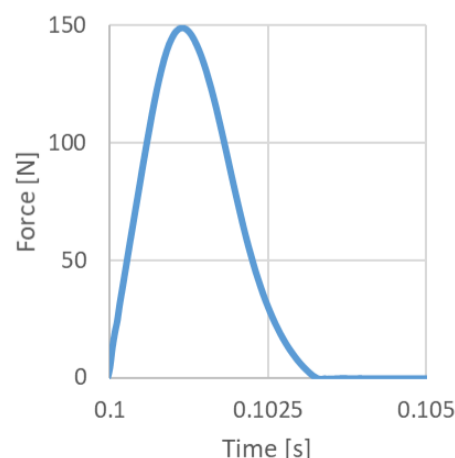
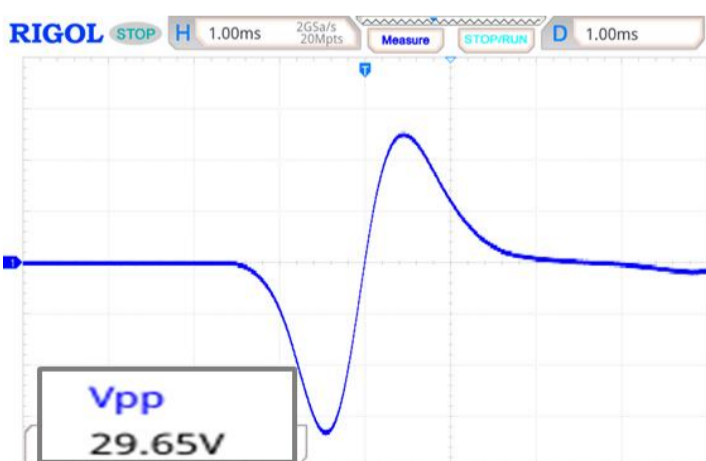


Equivalent stress [MPa] of metamaterial structure with piezoceramic PZT plates under excitation with amplitude 0.1 mm



## Concept of Metamaterial with PVDF Piezoelectric Stack

The assembled piezoelectric PVDF stack was tested in lab conditions and the voltage response of this sensing system was analyzed. The voltage response is proportional with a rate of stack deformation. The piezoelectric stack assembly was loaded by force impulses, which were created by modal hammer and the force impulse was recorded.



**Conclusion:** The proposed metamaterial provides smart solution of design for future devices and machines which could integrate design and sensing function together. A combination of additive technologies, smart material manufacturing and printed electronics allows to provide modern cyber-physical system for Industry 4.0 application.

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