

Stress cycle on a ZnO nanowire-based nanogenerator: a phenomenological study

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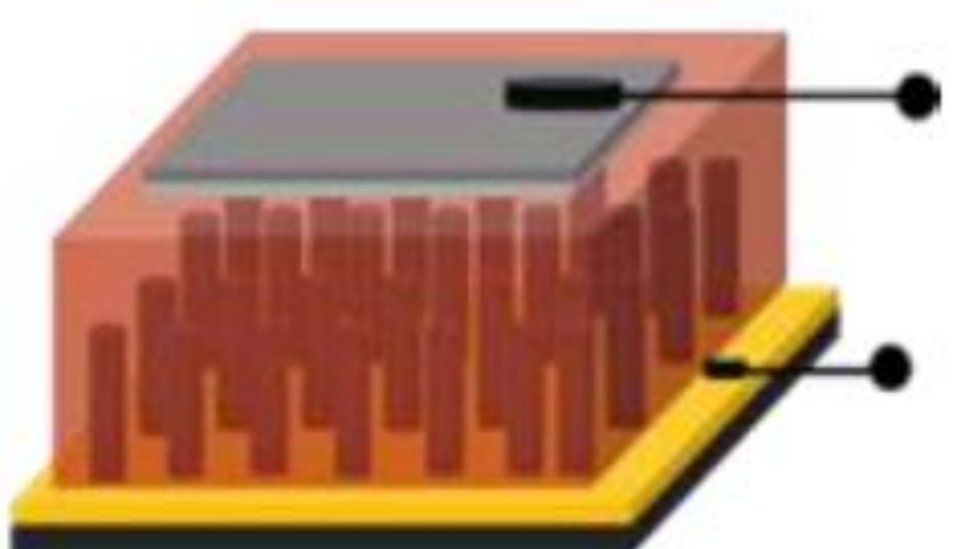
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Introduction: The aim of this work is to search influent parameters on the energy conversion in a ZnO nanowire-based nanogenerator and transfer to the external load during a quasi-static stress cycle. The studied parameters are: mechanical excitation characteristic times, ZnO doping level, polymer dielectric permittivity and external load resistance.

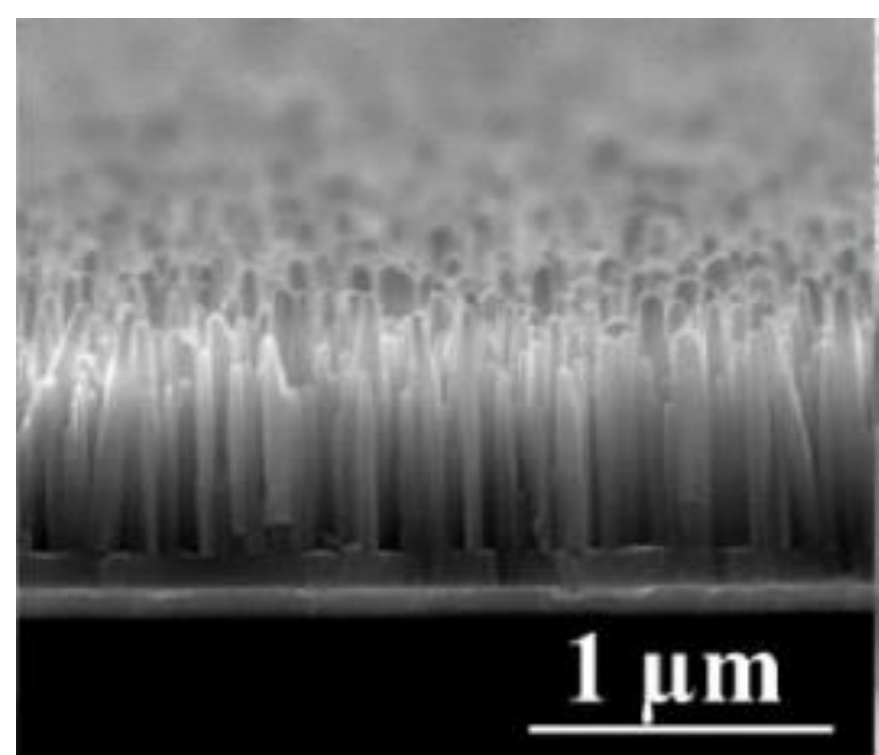
Context: Mechanical energy harvesters are promising devices to make integrated sensors or actuators autonomous, by scavenging free energy from the environment. Piezo-nanogenerators use direct piezoelectric effect to harvest an external mechanical energy and convert it into electrical one. For this purpose, ZnO nanostructures are used as piezoelectric material and are embedded within a polymer matrix.

System description

- Connections
- Ti / Al
- Parylène C
- ZnO Nanowires
- Bottom electrode + seed layer
- Si or Glass or PDMS



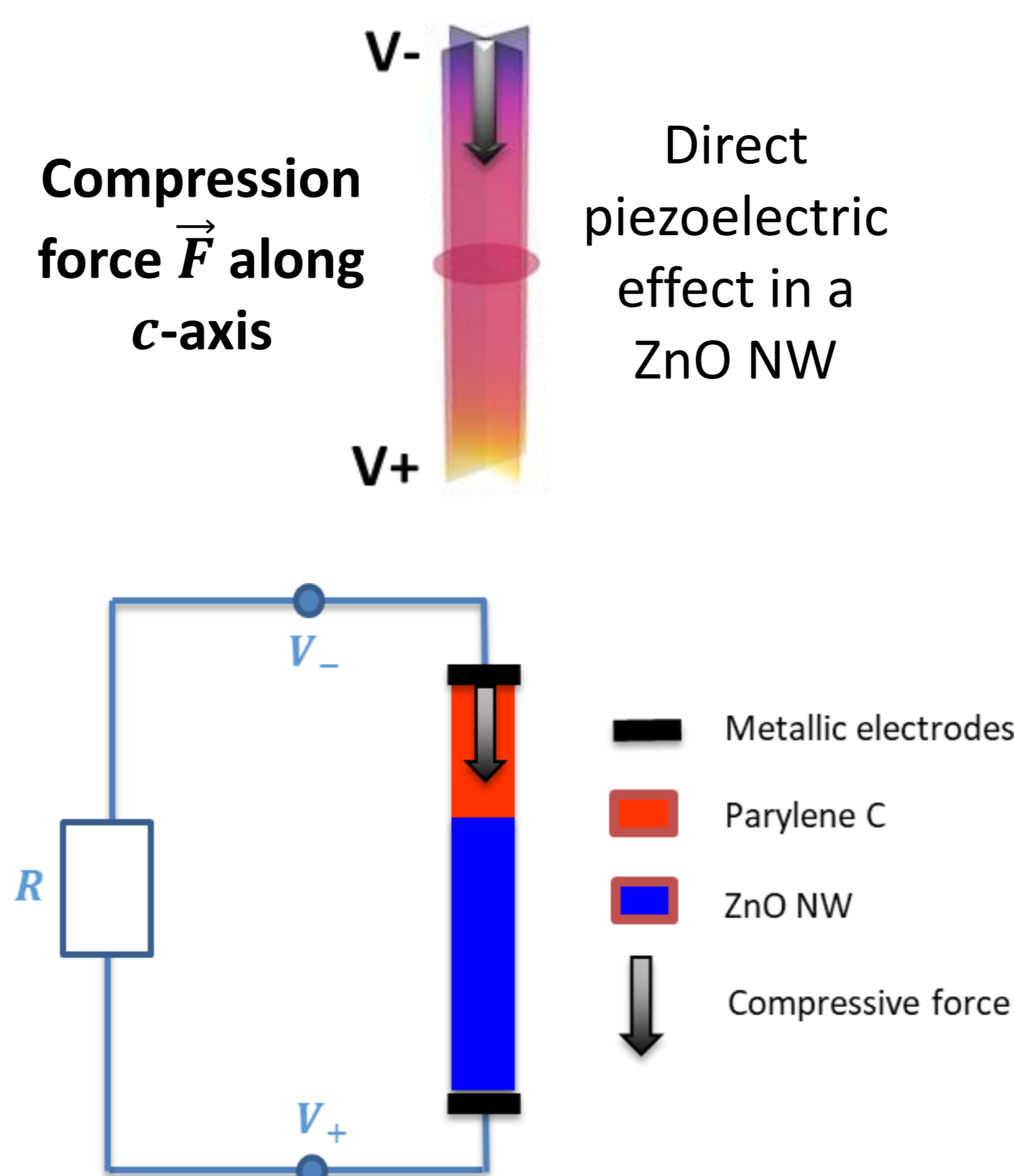
Design of a nanogenerator with ZnO NWs [1]



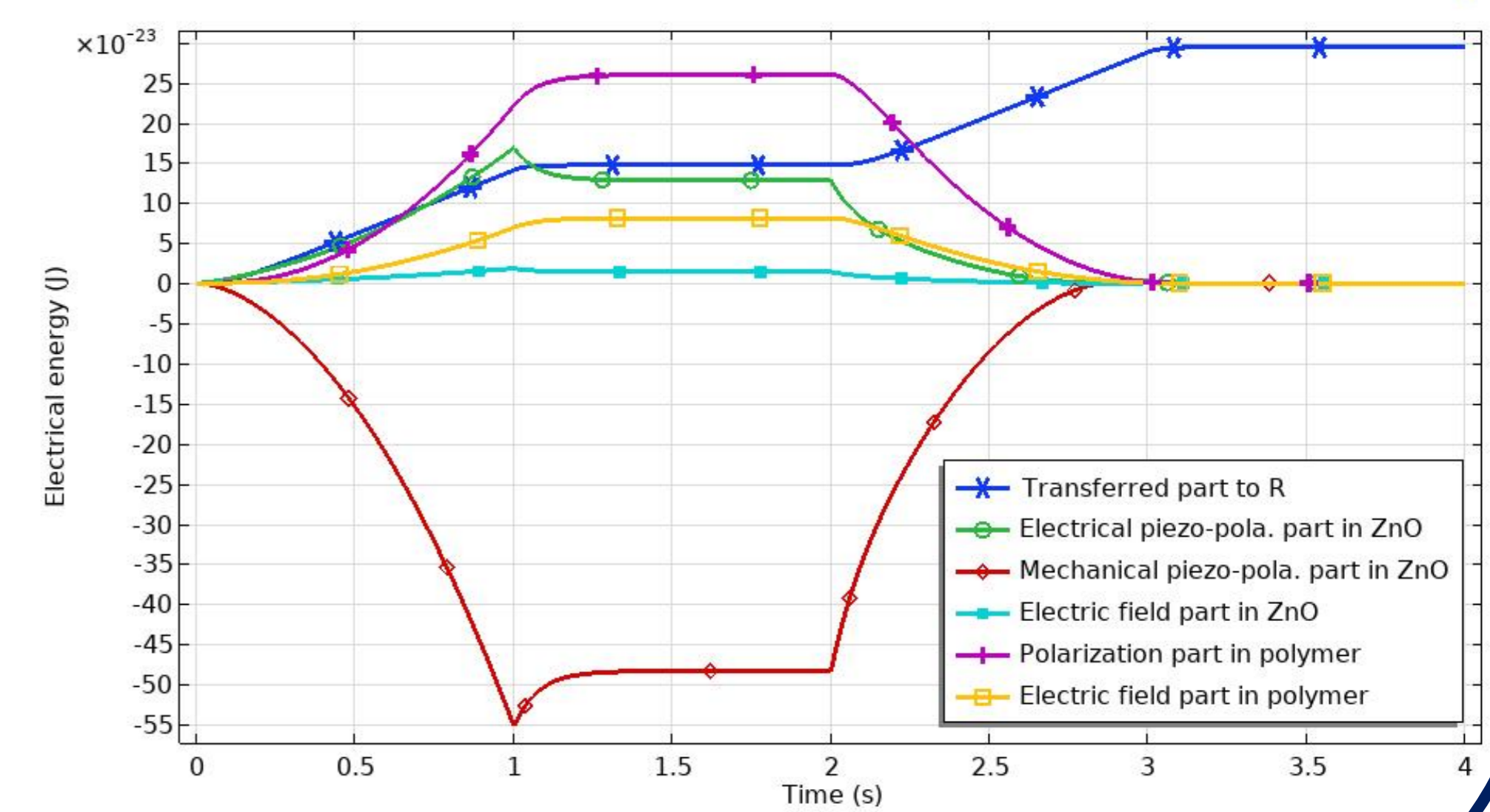
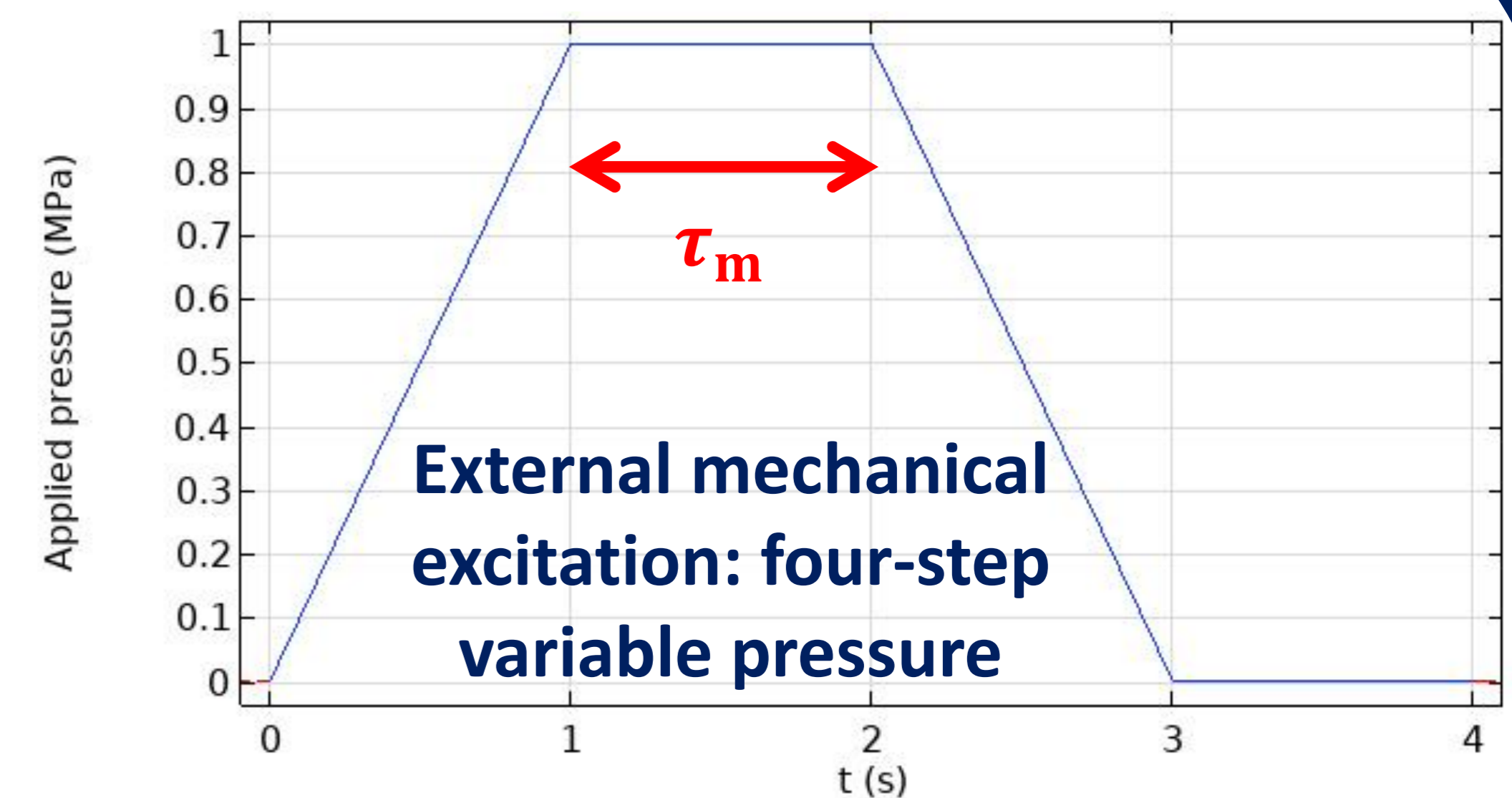
SEM images of ZnO NWs grown on a ZnO seed layer

1 μm

Evolution of electrical energies during a quasi-static stress

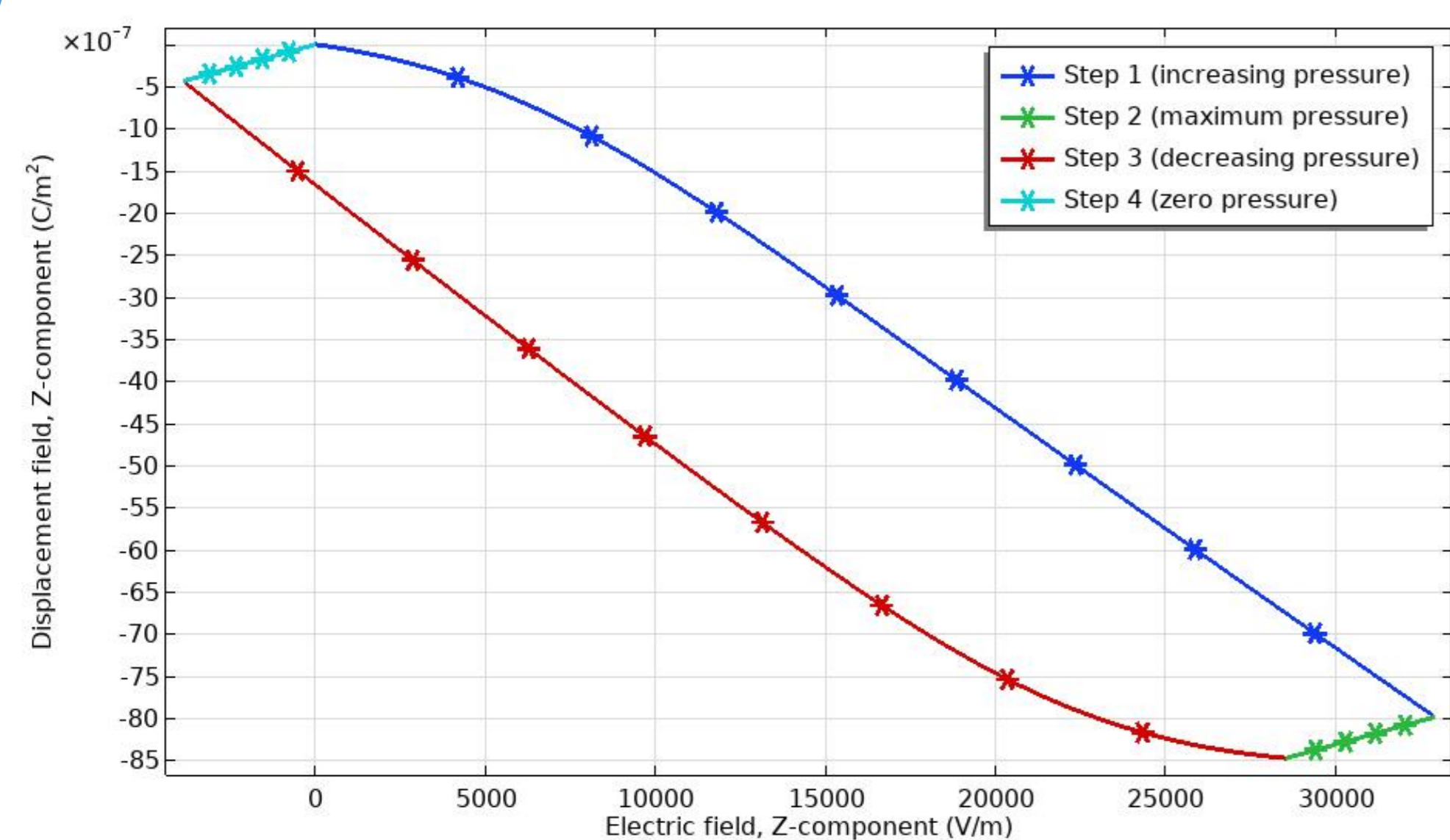


Electrical energy transfer to an external circuit with $\tau_e = RC_{unit\ cell}$



FEM Simulation: A unit cell with a single monocrystalline ZnO NW with piezoelectric and semiconducting coupled properties and a polymer capacitive layer above.

Electrical cycle



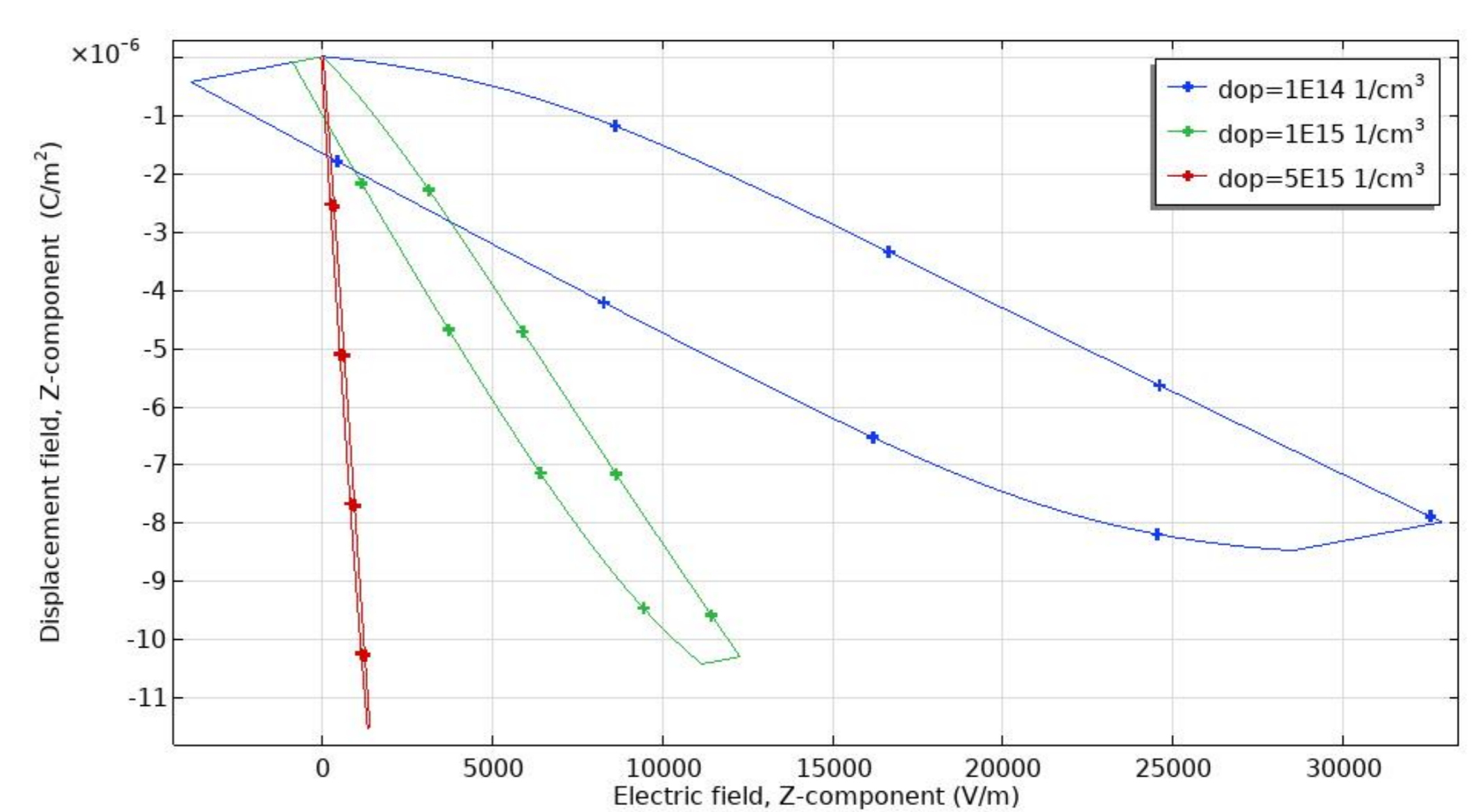
$$\omega_{el} = \oint D_3 dE_3$$

electrical energy density

The larger the cycle, the higher the electrical energy transferred to the external circuit

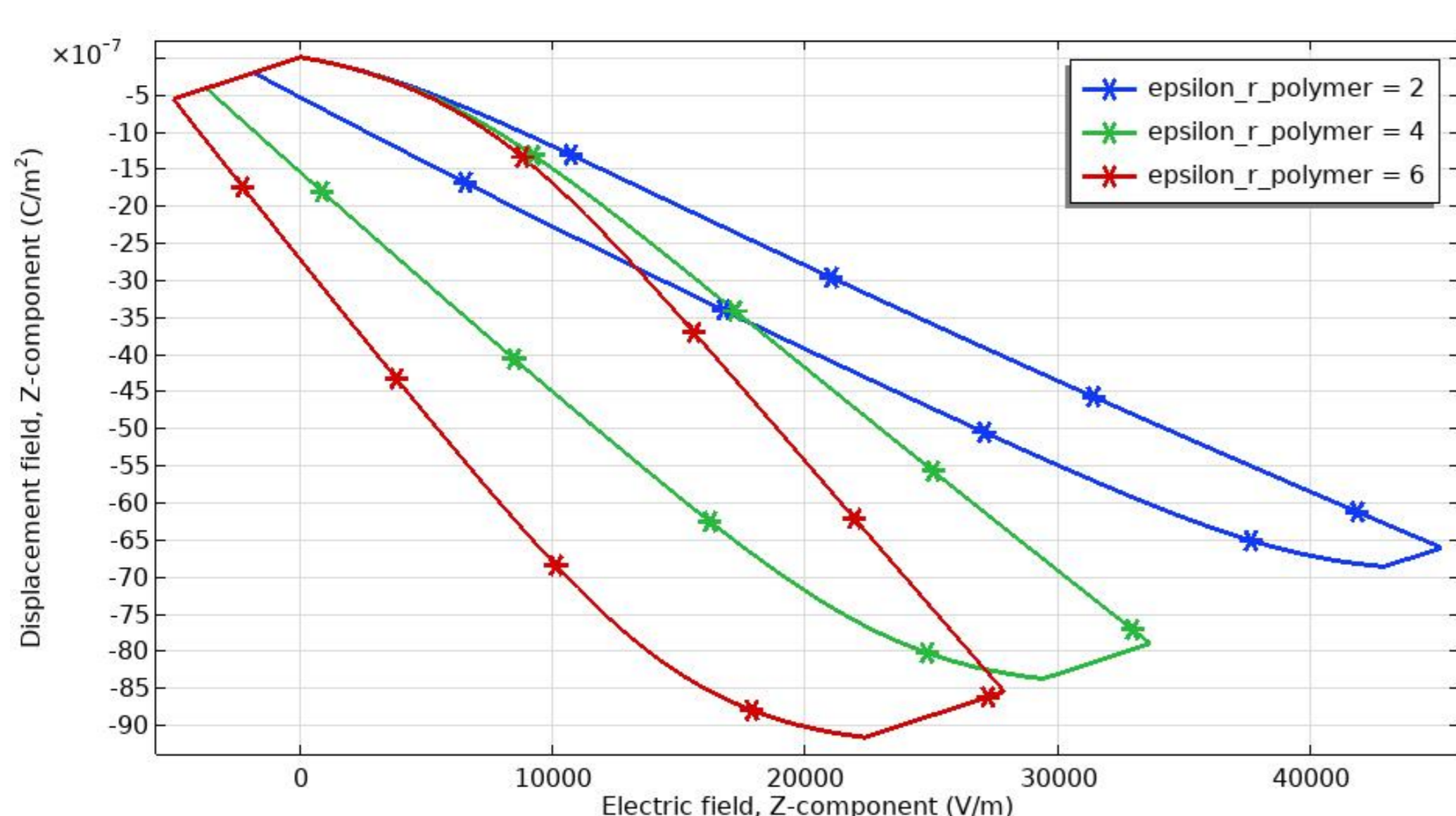
$D_3 = f(E_3)$ during the mechanical cycle

Influence of ZnO doping level



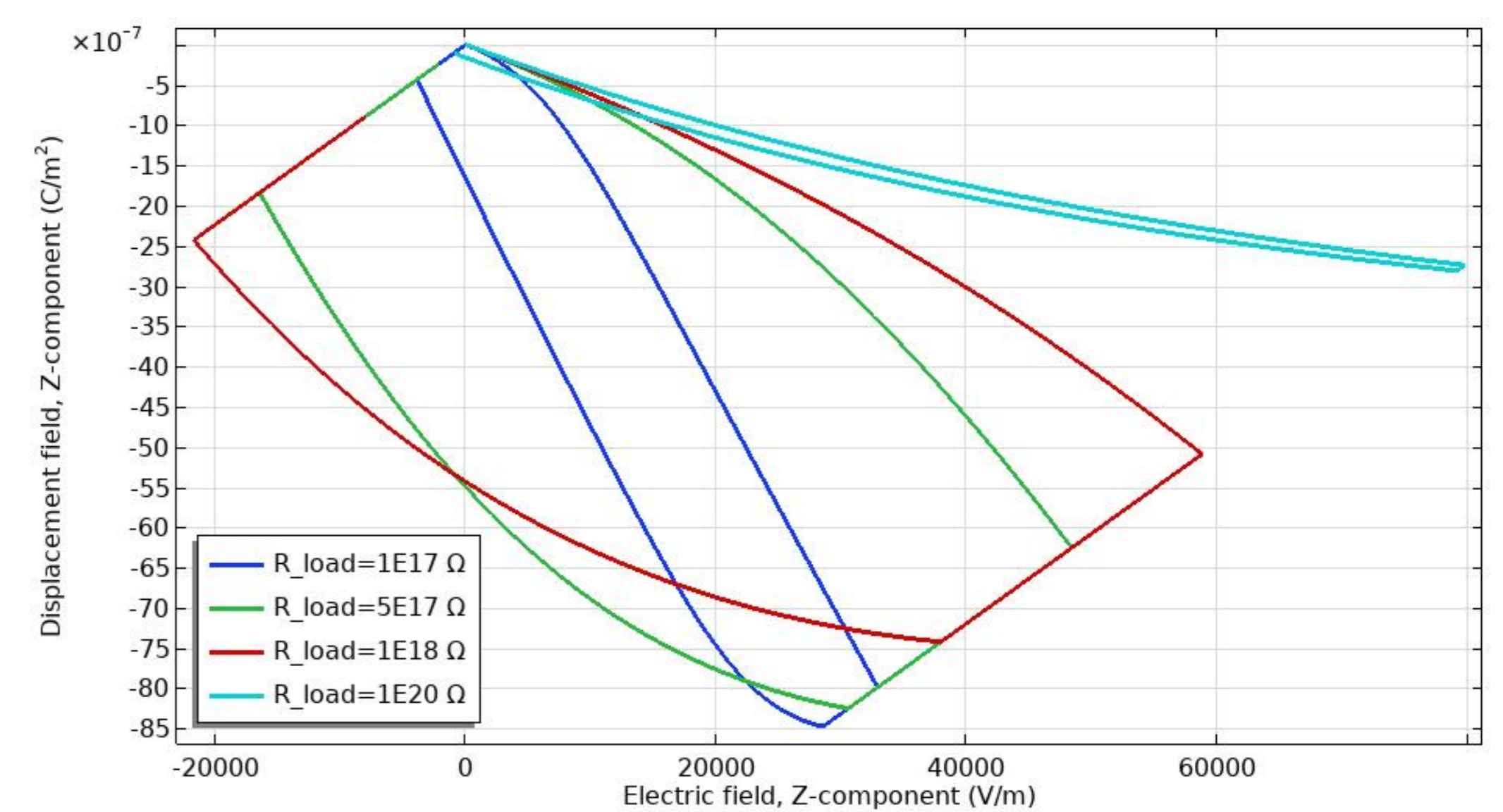
The higher the doping level, the thinner the cycle

Influence of the polymer dielectric permittivity



The higher the polymer dielectric permittivity, the larger the cycle

Influence of the external load



There is a match between mechanical τ_m and electrical τ_e characteristic times

Conclusion and perspectives: This transient analysis shows the influencing parameters that have a real impact on the amount of converted and transferred energy to an external resistor. This work opens perspectives to take into account even more realistic mechanical cycles in specific applications, by considering losses in the different materials, ZnO surface traps [2] and other external loads.

References

- [1] T. Slimani Tlemcani, C. Justeau, K. Nadaud, D. Alquier, & G. Poulin-Vittrant, « Fabrication of Piezoelectric ZnO Nanowires Energy Harvester on Flexible Substrate Coated with Various Seed Layer Structures », Nanomaterials, vol. 11, no 6, Art. no 6, Jun 2021
- [2] A. J. Lopez Garcia, M. Mouis, V. Consonni, & G. Ardila, « Dimensional Roadmap for Maximizing the Piezoelectrical Response of ZnO Nanowire-Based Transducers: Impact of Growth Method », Nanomaterials, vol. 11, no 4, Art. no 4, Apr. 2021