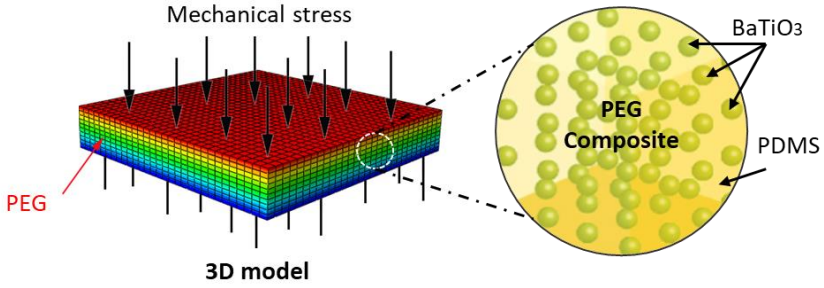
Research Project/Master
WS2024/25

3D simulation approach using COMSOL for optimizing particle concentration in composite generators

Project type: ▒ Hardware ✓ **Software** ▒ Hardware/Software ✓ **Simulation** ✓ **Modelling**

Project description:

Nanogenerators have recently emerged as promising devices for energy harvesting applications. They can convert various forms of energy such as mechanical, thermal, and electromagnetic into electrical energy. However, the performance of nanogenerators is limited by their design, materials, and manufacturing processes. Piezoelectric nanogenerator (PEGs) devices, which convert low-frequency mechanical energy sources to electrical fields such as human motion are useful for powering portable devices and sensors. The project under consideration focuses on biocompatible mechanical energy harvesters based on the piezoelectric nanoparticles of Barium titanate ($BaTiO_3$) and polydimethylsiloxane (PDMS) polymer. The project involves the development of a 3D numerical model using COMSOL Multiphysics software, allowing for a detailed simulation of the electro-mechanical behavior of the PDMS- $BaTiO_3$ composite. Through a comprehensive literature review, the study establishes a solid foundation, and finite element simulation coupled with design optimization using the COMSOL Optimization Module seeks to refine the composite's design parameters for improved piezoelectric performance. Experimental validation of the optimized composite will validate the simulation results, providing valuable insights into the relationship between $BaTiO_3$ particle concentration and the dielectric properties critical for the effective functioning of Piezoelectric Nanogenerators.



Methodology:

Tasks:

The project will involve the following steps:

- **Literature Review:** Conduct an extensive review of existing research on PDMS-based composites, nanogenerators, and relevant material properties to establish a foundation for the study.
- **Finite Element Simulation:** A 3D numerical model should be created using COMSOL Multiphysics software to simulate the electromechanical behavior of the PDMS-$BaTiO_3$ composite. The impact of varying $BaTiO_3$ concentrations on piezoelectric properties should also be considered.
- **Design Optimization:** Employ the COMSOL Optimization Module to iteratively refine the composite's design by adjusting $BaTiO_3$ concentration, particle shape, and other relevant parameters. Set the optimization objective as improved mechanical properties for effective energy conversion.
- **Experimental Validation:** Validate simulation results through experimental testing. Fabricate samples with optimized $BaTiO_3$ concentrations, measure their electro-mechanical properties, and compare the results with the simulation data.
- **Documentation of the project.**

Competences:

Electromechanical theory knowledge / 3D simulation methodology / Piezoelectricity and ferroelectricity
COMSOL Multiphysics software
Creative thinking and Problem-Solving Skills

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