PVDF nanostructuration, piezocomposites synthesis and modeling piezoelectric behaviors

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Flexibility has made the PVDF-based polymers (Polyvinylidene Fluoride) worldwide studied piezomaterials in the development of autonomous piezogenerators and in the field of energy harvesting. The race to achieve the best piezoperformances with PVDF is on.

To better understand how material modifications act on the figure of merit of the piezoelectricity is at the heart of the project. A physical modeling of the piezoelectric behaviors of polymers is under study. A recently developed experimental set-up defines the initial conditions of this model and enables to confront theoretical results with experimental measurements. When stressed by a quasi-sinusoidal strain, the direct quasi-sinusoidal piezoresponse of the membrane is real-time monitored for different frequencies of strains and different load resistances in the electrical circuit. Resulted quantitative analysis of experimental datasets allows verifying the model, derived from piezoelectric constitutive equations for large mechanical flexions of thin polymer films with $l \ll r$ (respectively the thickness of the membrane and the radius of the excited area).

First results on commercial PVDF have shown surprising characteristics such as a non-linear pressure/voltage behavior and the existence of a scaling law between the output voltage and the product of the load resistance by the mechanical solicitation frequency.

The herein developed model takes into account relevant intrinsic parameters such as the permittivity ε, Poisson's ratio v, Young's modulus E and the piezoelectric constant d. All of these properties can be experimentally tuned with the synthesis of PVDF-based piezocomposites in order to go deeper in the verification of the model. Mixing SHI irradiations and Materials Science engineering on thin piezoPVDF films (dozens of microns) enables to work on the nanostructuration of PVDF and on the elaboration of these composites. From the highly porous (fluencies of 10^8-10^9 cm^{-2}) PVDF matrices obtained after track-etching step, our strategy is to fill inorganic nanowires or MOF (Metal Organic Framework) inside PVDF nanoporosity in order to change the intrinsic parameters.

At the end, confrontation of experimental piezoresponses of various SHI-engineered piezocomposites with the electromechanical model will provide sufficient data sets to enrich and optimize a predictive model for flexible piezomaterials.