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Piezoelectric nanofibers for smart material development

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Piezoelectric materials are frequently used for energy harvesting applications and for the realization of electronic sensors for mechanical vibration analysis or structural monitoring. Among these, polymeric piezoelectrics are often preferable to ceramic materials for many applications thanks to the possibility of realizing electroactive devices in the shape of thin films, even if their piezoelectric response is lower compared to that of ceramics. Poly(vinylidene fluoride) (PVdF) and its co-polymers are considered the most promising candidates. However, if these polymeric films have to be used in a composite system delaminations may occur. On the contrary, if these polymeric piezo devices are realized in the form of nanofibrous mat, the host material can penetrate between the fibers creating thus an intimate contact, which avoids delaminations to occur. A very simple way to produce nanofibers is electrospinning. To enhance piezoelectric behavior dipoles must be oriented by applying a strong electric field during or after material manufacturing is necessary. In electrospinning the stretching of the electrostatically charged jet and dipole orientation can be oriented during fiber formation However, if the electric field used in the electrospinning process is not high enough, dipole polarization could be partial or even absent, therefore a post-processing polarization is necessary to enhance the electromechanical response of the material. This paper deals with realization of multifunctional composite materials, integrating piezoelectric nanofibers and with the optimization of the piezoelectric behavior to be used in both sensing and energy harvesting applications.

Nanofibrous piezo mats obtained by means of electrospinning were realized with different geometries, e.g., stiff and core-shell, made by PVdF and PZT ceramic material. The mats are then polarized and integrated in different matrixes, e.g., silicon and epoxy based. Measurements of the electromechanical response of the composite materials thus manufactured are performed, to evaluate the capability to be used as sensors or energy harvesters.

A good integration of nanofibers inside the host material is evidenced by electron microscopy images, thus hindering delaminations which could occur using piezoelectric films. Moreover, a large electrical response to both impact and sinusoidal stimuli has been demonstrated. As expected, the amount of mechanical energy that can be converted using PZT nanofibers is one order of magnitude larger that that obtainable from PVdF nanofibers, due to their higher piezoelectric coefficient.

In conclusion, this paper illustrates that multifunctional materials with piezoelectric properties can be used self-sensing structural material and for energy harvesting applications: PVdF nanofibers, in particular with core-shell configuration show the best features for sensing applications while PZT nanofibers can be used more effectively for energy harvesting devices.