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New Frontiers in Multifunctional Material Science and Processing

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Institute for Technology of Nuclear and Other Raw Mineral Materials
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Piezoelectric polymer/ceramic nanostructures for mechanical energy harvesting

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Vibration-based mechanical energy is one of the most accessible energy source in the surroundings. Harvesting this type of energy exhibits a great potential for remote/wireless sensing, charging batteries, and powering electronic devices. Piezoelectric and ferroelectric materials, including PZT, $BaTiO_3$, ZnO, polyvinylidene fluoride (PVDF), etc., can be used for converting ambient mechanical energy into electricity. Based on these materials, a variety of micro- or nanoelectromechanical systems can be developed for harvesting energies from random vibrations, mechanical waves, or body movements like walking, running, or typing. Recent investigations on nanocomposites of electroactive ceramics and ferroelectric polymers exploit this approach in order to produce new multifunctional materials for mechanical energy harvesting. Taking into account that mechanical activation is one of the methods for modification of physico-chemical properties of the filler, in this study we investigate the influence of mechanical activation of ZnO particles on structural properties of ZnO/polyvinylidene fluoride nanocomposites. The nanocomposite films were prepared by solution casting method and investigated by X-ray diffraction (XRD) method and Raman spectroscopy, while the microstructure morphology has been analyzed by scanning electron microscope (SEM). Presented results will enable optimization of PVDF processing techniques for the production of new mechanical energy harvesting devices.

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Pulsed Laser Deposition of $BaTiO_3$ on PVDF substrate

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Piezoelectric materials play an important role in development of advanced Micro-electro-mechanical systems (MEMS) and Nano-electro-mechanical systems (NEMS). Their applications span the aero-space industry, communications, defense systems, national security, health care, information technology and environmental monitoring. Materials used in MEMS/NEMS must

simultaneously satisfy numerous requirements for chemical, structural, mechanical and electrical properties. Although traditionally MEMS in particular have relied on silicon, the materials used in MEMS/NEMS are becoming more heterogeneous. Taking into account that materials nanostructuring can produce unique mechanical, electrical and piezoelectric properties, in this article the investigation of pulsed laser deposition of $BaTiO_3$ on PVDF substrate has been performed. The titanium-saphire laser operated at 800 nm with 40-fs pulse duration and 1 kHz repetition rate was focused onto a mechanically activated $BaTiO_3$ target. Deposition on PVDF substrate was done at an oxygen partial pressure of 10^{-7} Torr using a laser pulse frequency of 1 kHz at room temperature. The crystal structure and the microstructure of the films were examined using an X-ray diffractometer and scanning electron microscope, while the surface morphology was observed by atomic force microscopy.It was found that pulsed laser deposition of $BaTiO_3$ on PVDF substrate offers a new set of opportunities for development of advanced flexible piezo-films for the next generation of NEMS.

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Functionalization of graphene nanoplatelets via Bingel reaction for polymer nanocomposites

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In this study, we have performed functionalization of graphene nanoplatelets (GNPs) via Bingel reaction and investigated influence on the addition of covalently functionalized GPNs on the structural changes of the poly(methyl methacrylate). Preparation of poly(methyl methacrylate) nanocomposites with functionalized GNPs has been accomplished by drop casting method of dissolved PMMA mixed with modified graphene nanoplatelets dispersed in a *N*-methyl-1-pyrrolidone. Functionalizaton of graphene has been achieved under the conditions of Bingel reaction, which implies introduction of diethyl malonate on the graphene surfaces through the cyclopropane ring formation. Introduction of the cyclopropane ring on to the surface of graphene does not significantly affect the initial structural properties of graphene nanoplatelets, allowing better dispersible properties due to interaction of covalently attached diethyl malonate groups with the polymer chains. Fourier transform infrared spectroscopy (FTIR) and elemental analysis confirmed the effectiveness of the addition of diethyl malonate via Bingel reaction on the surface of GNPs. Scanning electron microscopy (SEM) has been used to provide information on the morphology of functionalized GNPs. Prepared nanocomposites have been characterized by Raman and FTIR spectroscopy. The changes regarding glass transition temperature have been monitored with differential scanning calorimetry (DSC).