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# Thick composite piezoelectric films with graphene monolayers

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Three-phase, PZT($PbZr_{0.52}Ti_{o.48}O_3$)-Epoxy- Multi-walled Carbon-Nanotube (MWCNT) flexible films have been prepared via a combination solvent and spin coating technique. The composite materials were spin coated onto flexible stainless steel substrate, and either graphene or graphene - PMMA films were grown by a chemical vapor deposition process on the other side of the films. The thicknesses of the films were ~ 200 μm. The volume fraction of the MWCNTs was varied from 1% to 6%, while the PZT volume fraction was held constant at 30%. The strain coefficient and capacitance were measured as a function of the MWCNT volume fraction, and were subsequently used to determine the effective dielectric constant of the composite. Samples that incorporated graphene electrodes had higher effective dielectric constants than samples that incorporated graphene-PMMA electrodes and those with no top electrode. For example, the maximum values of effective dielectric constant for the composite films were ~4353, ~1945 and ~61, for graphene, graphene-PMMA and no electrode samples respectively. Similarly, composite films with graphene electrodes produced strain coefficients, e.g. d33 and d31 that were larger than their counterparts. Sample surface morphology and sample composition were observed using SEM and measured using Raman Spectroscopy respectively. Improved dielectric properties observed for samples with graphene coatings are due to graphene's high carrier mobility and ability to readily conform to the surface of the sample.

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