Nanoscale Piezoelectric Materials: Structure, Properties, Applications

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Recent studies revealed several new classes of piezoelectrics including 2D materials (graphene) [1] and biomolecular crystals (self-assembled peptides, amino acids, nucleotides) [2,3,4] Piezoelectricity in these occurs because of symmetry breaking on the surface in the first case and presence of highly anisotropic hydrogen bonds in the second. Graphene in contact with oxides offers extremely high piezoelectric activity due to polarity of C-O bonds, while peptide nanotubes (PNTs) demonstrate excellent electromechanical properties due to self-assembly and intrinsic softness of directed hydrogen bonds. Remarkably stable structure, possibility of functionalization together with biocompatibility and easy synthesis and nanofabrication, make graphene, PNTs and other biomolecular crystals (e.g. amino acid glycine [4]) attractive alternatives to traditional lead-based piezoelectrics.

In this presentation, the mechanisms of piezoelectric effect in these structures will be delineated and methods for their studies will be introduced. Hybrid Piezoresponse Force Microscopy (Hybrid-PFM) will be presented allowing nanoscale electromechanical measurements during acquisition of force-distance curves [6]. Several demonstrators including piezoelectric membranes based on 2D materials (graphene), cantilevers based on PNTs, and piezoelectric scaffolds for cardiomyocite cells [7] will be presented. Recent results on piezoelectricity and pyroelectricity in PNTs show that they are very attractive for various piezoelectric applications in biomedicine, because of their intrinsic biocompatibility combined with mesoporous structure and ability to work in contact with living cells and biological liquids. Scaling of piezomaterials down to nanosize is expected to dramatically improve their performance, thus making nanoscale piezoelectrics more sensitive than the traditional ones.

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