Magneto-Electric Nanocomposites based Magnetic Field Sensors and Energy Harvesters

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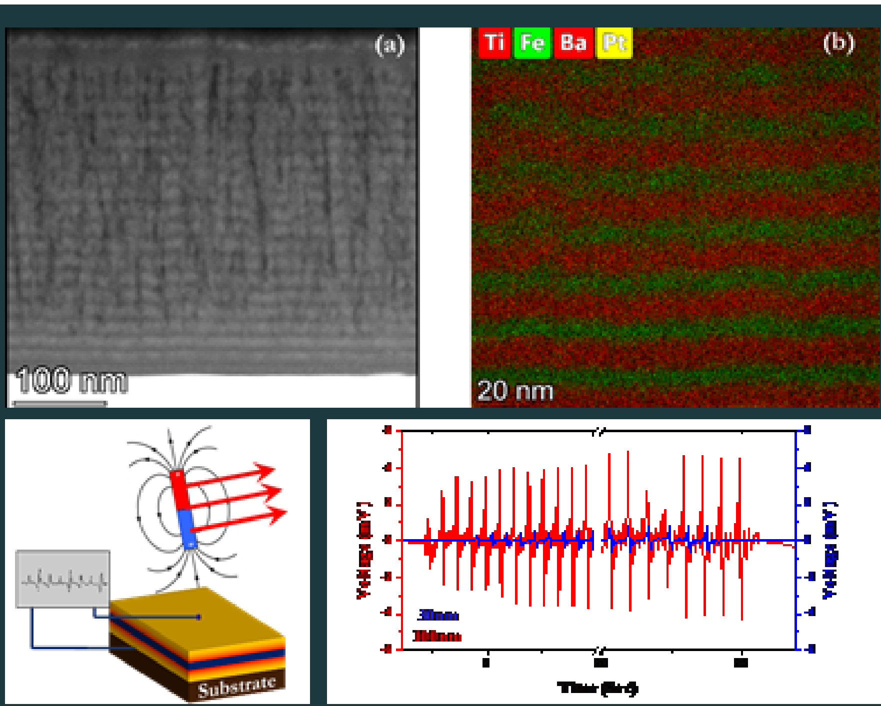
Magnetoelectric (ME) multiferroic composites couple the electric and magnetic order parameters of different materials and establish a relation between them via strain. Columnar growth of a ferroelectric ($Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ (BCZT)) and a ferromagnetic layer ($CoFe_2O_4$ (CFO)) was evident from magneto-electric (ME) coefficients (620-840 mV/cm.Oe). The ME coupling was found to be influenced by a variety of parameters such as morphology, interface quality, volume fraction, and interfacial strain.

The average interfacial strain in trilayer configuration is estimated as ~7% which gets relaxed at 25-35nm away from the interface. Under a magnetic field, the ME composite experiences an induced strain due to the magnetostriction phenomenon at the ferromagnetic layer. This induced strain is transferred to the ferroelectric layer due to the columnar grain-to-grain epitaxy-like feature which leads to voltage generation due to the piezoelectric phenomenon. Multilayers with periodicity with strained interface exhibited ~25 to 26 % increase in piezoelectric coefficient (d_{33}) in the presence of the magnetic field. Due to interfacial strain, a multilayer with a periodicity of 40-60nm showed a linear response of displacement curve for a wide range of applied voltage.

The vertically ordered columnar grains between BCZT and CFO interface with crystallographic relation between the sharp interfaces and lower defect densities are grown to enhance the strain coupling between the phases. The effective strain operating region is estimated to be ~30nm to 35nm where it exhibits 27% enhancement in inverse piezomagnetic effect and is found to relax beyond this region from the interface.

The effect of periodicity on piezoelectric properties is evaluated by cross-sectional piezo-response force microscopy.



Effect of Periodicity on Piezoelectric Properties

The multilayer ME composite with a periodicity between 40nm and 60nm exhibits the highest percentage of increment in d_{33} where there is an effective strain coupling across the interface of the two phases. The relaxation time for polarization switching of a multilayer with a periodicity of 40nm is found to be lesser compared to higher periodicities.

This confirms interfacial strain present in the multilayers with periodicities was found to directly influence the energy required for the polarisation to rotate.

The voltage generated by the multilayers of different periodicity shows a nonlinear response for ME composites with periodicity above 40nm. (DRDO - Indian Patent Application No: 202111048321).

Thus the nanocomposites offer a potential application of sensing magnetic fields and converting them into an electrical signal that can be either transmitted and/or stored for energy applications.

The effective strain transfer across layers makes them a potential candidate for actuators as well.

> **The effect of periodicity on piezoelectric properties is evaluated by cross-sectional piezo-response force microscopy**

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