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Multiferroic Microwave and Millimeter Wave Devices

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Layered composites of ferrites and ferroelectrics are magneto-electric (ME) multiferroics and are of interest for studies on the physics of ME interactions and for novel signal processing devices. There are two types of interactions. (i) *ME coupling in bound ferrite-piezoelectrics:* An electric field E applied to the composite produces a mechanical deformation in the piezoelectric phase that in turn is coupled to the ferrite, resulting in a shift in the ferromagnetic resonance field. The strength of the interactions is measured from the FMR shifts. (ii) *ME interactions in unbound ferrite-ferroelectrics*: This is a proximity effect in which hybrid spin-electromagnetic waves are formed. An electric field applied to the ferroelectric will result in a change in the permittivity and a shift in the hybrid modes. We performed studies on the nature of ME interactions at 1-110 GHz in bilayers of epitaxial yttrium iron garnet (YIG) films, single crystal spinel ferrites or hexagonal ferrites and single crystal lead magnesium niobate-lead titanate (PMN-PT) or polycrystalline lead zirconium titanate (PZT). A stripline structure or a cavity resonator was used. Electric fields effects were investigated on magnetostatic waves, uniform precession modes or hybrid modes in the ferrite. We found evidence for strong microwave ME coupling. The coupling strength has been found to be dependent on magnetic field orientation, the nature of piezoelectric coupling and volume for both phases [1]. The high frequency ME effect is of importance for dual electric and magnetic field tunable ferrite-ferroelectric devices. We will discuss the design and characterization of ME resonators, phase shifters, delay lines and filters [2]. The work is supported by grants from the Army Research Office and the office of Naval Research.

[1] "Multiferroic magnetoelectric composites: Historical perspective, status, and future direction," Ce-Wen Nan, M. I. Bichurin, S. Dong, D. Viehland, and G. Srinivasan, J. Appl. Phys. **103**, 031101 (2008).
[2] "Magnetoelectric interactions in a ferromagnetic-piezoelectric layered structures: Phenomena and devices," M. I. Bichurin, D. Viehland and G. Srinivasan, J. Elec. Ceramics **19**, 243 (2007).