Materials Science & Engineering Doctoral Defense

Origin of Microwave Loss in Dielectric Resonators

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Abstract

Complex perovskite materials, including Ba(Zn1/3Ta2/3)O3 (BZT), are commonly used to make resonators and filters in communication systems because of their low dielectric loss and high quality factors (Q). Transition metal additives are introduced (i.e. Ni2+, Co2+, Mn2+) to act as sintering agents and to tune their temperature coefficient to zero or near-zero. However, losses in these commercial dielectric materials at cryogenic temperatures increase markedly as a result of spin-excitation resulting from the presence of paramagnetic defects. Applying a large magnet field (e.g. 5 Tesla) quenches these losses and has allowed the study of other loss mechanisms present at low temperatures. Work was performed on Fe3+ doped LaAlO3. At high magnetic fields, the residual losses versus temperature plots exhibit Debye peaks at ~40 K, ~75 K and ~215 K temperature and can be tentatively associated with defect reactions O_i^x+V_O^x→O_i^'+V_O^•, Fe_Al^x+V_Al^"→Fe_Al^'+V_Al^' and Al_i^x+Al_i^(••)→〖2Al〗_i^•, respectively. Peaks in the loss tangent versus temperature graph of Zn-deficient BZT are indicative of a higher concentration of defects and appear to be a result of conduction losses.

Guided by the knowledge gained from this study, I performed a systematic study to develop high performance microwave materials for ultra-high performance at cryogenic temperatures. To this end, I produced and characterized perovskite materials which were either undoped or contained non-paramagnetic additives. Synthesis of BZT ceramic with over 98% theoretical density was obtained using B2O3 or BaZrO3 additives. At 4 K, the highest Q x f product of 283,000 GHz was recorded for 5% BaZrO3-BZT.

To make the EPR technique more accessible for high-school and university lab instruction, I designed, built and tested a portable, inexpensive open-air EPR spectrometer. In my design, the sample is placed near a dielectric resonator and does not need to be enclosed in a cavity, as is used in commercial EPR spectrometers. Permanent magnets are used to produce fields up to 1500 G, enabling EPR measurements up to 3 GHz.

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Zoom Link: https://asu.zoom.us/j/87196135949