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Recent advances in tunable materials development

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Abstract – Voltage-tunable materials play a major role in advanced communication systems, as phase shifters, tunable filters, tunable capacitors, etc. Their implementation requires a distinctive dependence of the dielectric constant on the DC-bias field, i.e., high tunability, as well as low dielectric losses, a low dielectric constant and temperature-stable performance.

Materials with a large DC-bias dependence of dielectric constant have been the subject of many recent investigations for applications in microwave-tunable devices. This is mainly due to demands for miniaturization and the development of microelectronic technology. So far, mainly $(Ba_{1-x}Sr_x)TiO_3$-based materials have been studied for tunable devices, but their high losses and high temperature dependence of dielectric constant limit their use, leading us to investigate novel materials.

We focused our investigation on $Na_{0.5}Bi_{0.5}TiO_3$, which has the characteristics of a relaxor ferroelectric with a high dielectric constant at elevated temperatures (approximately 3000 at 320°C). The voltage-tunability of materials critically depends on their behavior in static and dynamic electric fields and is determined by the susceptibility of the dielectric constant to the DC-bias field ($n_r = (\varepsilon(0)- \varepsilon(E))/ \varepsilon(0)$). The behavior relates to the material's polar order, while most of the commercially available tunable materials are in a paraelectric phase, since in general they exhibit lower dielectric losses with respect to materials in the ferroelectric phase. However, promising tunable properties of ferroelectrics have been shown recently, especially above the relaxation frequency of the domain-wall motions. In contrast to paraelectric materials the tunability of polar phases has not yet been extensively studied. Therefore, we focused our study on the $Na_{0.5}Bi_{0.5}TiO_3$ relaxor ferroelectric, which is a polar compound and exhibits a broad dielectric maximum at 320°C, related to dielectric relaxation at the microwave frequencies. In addition, relaxor ferroelectrics are described by their polarization rotation, which is remarkably susceptible to the DC-bias field, and thus considerable tunability of the $Na_{0.5}Bi_{0.5}TiO_3$ is expected. The temperatures of the $Na_{0.5}Bi_{0.5}TiO_3$ phase transitions were optimized by various additions. Prior to an electrical characterization the mechanisms of solid-state synthesis and sub-solidus phase relations in the selected systems were determined. The dielectric, ferroelectric and tunable properties of the compounds from the homogeneity regions were measured at different temperatures, frequencies and electric fields. The differences in the tunable properties were related to the variation in the remanent and saturated polarizations, which further depend on the crystal chemistry and the stoichiometric properties across the homogeneity regions, which will be the main focus of our contribution.

References

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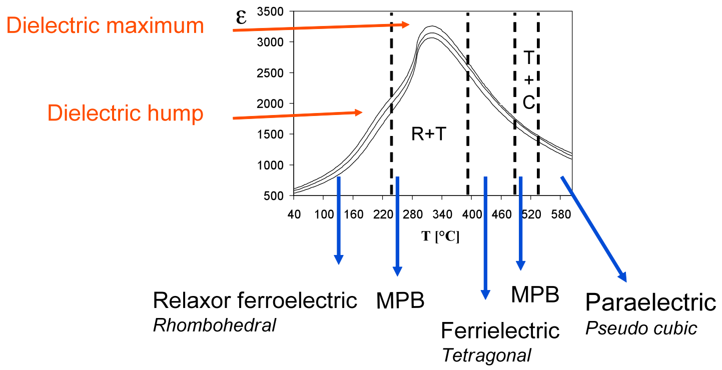

Figure 1: Temperature dependence of $Na_{0.5}Bi_{0.5}TiO_3$ dielectric properties showing the existence of morphotropic phase boundaries (MPB)