Nb jonais legiruotų keramikų BiFeO3-BaTiO3 dielektriniai tyrimai

Broadband dielectric investigation of Nb-doped BiFeO3-BaTiO3 relaxor ceramics

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Electrically active ceramics are widely employed nowadays in electronics, robotics, energy storage, and other fields. [1] A large subset of these are ferroelectric materials that are actively used as piezoelectric sensors and actuators, tunable microwave elements, varactors, etc.

The pseudo-binary solid solution of bismuth ferrite ($BiFeO_3$, BF) with barium titanate ($BaTiO_3$, BT) is a potential substitute for PZT, particularly for high-temperature applications. Pure BF has a high ferroelectric-paraelectric phase transition temperature, however it is unsuitable for practical applications due to substantial leakage current and strong coercive field. In contrast, the BF-BT combination has lower electrical conductivity and dramatically better ferroelectric characteristics, particularly with moderate doping of Mn or Nb ions.

Here we present a broadband dielectric study of Nb-doped BF-BT ceramics. The main goal was to explore the low-temperature relaxor-like dispersion to complement the dielectric data published earlier [2].

Dielectric spectra of $0.7BiFe_{0.95}Nb_{0.05}O_3$-$0.3BaTiO_3$ ceramics were measured over a broad frequency range from 20 Hz to 36 GHz, and at temperatures from 200 to 500 K.

The temperature dependences of complex dielectric permittivity of BF-BT-0.5Nb ceramics are shown in Fig. 1. In the imaginary part of the dielectric permittivity this anomaly can be seen as a frequency-dependent maximum, which shifts toward higher temperatures on the increase of the frequency, superimposed on a bigger maximum which arises from the ferroelectric phase transition occurring around 740 K.

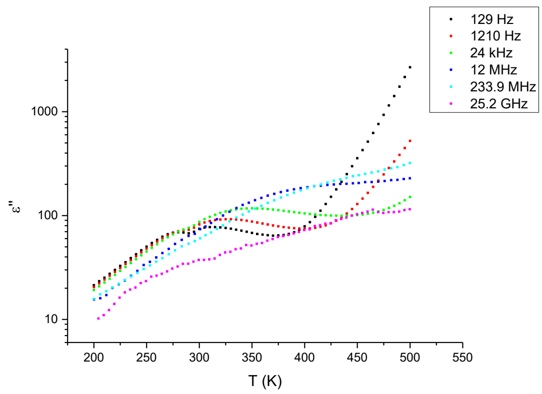

Fig. 1. Temperature dependencies of the imaginary part of a complex dielectric permittivity of 0.5Nb–$BiFeO_3$–$BaTiO_3$ ceramics at different frequencies.

At temperatures above 400 we see the qualitatively the same dispersion – both low-frequency and high-frequency dispersions remain active, their temperature evolution shows the same trend and we can use the same procedure for the fitting of their frequency dependencies. However, more careful analysis has indicated weak imperfections of the fit from 0.01 MHz to 1 MHz frequency range (in the vicinity of the minimum of the dielectric losses) and the best fits were obtained including a 3rd Cole-Cole process.

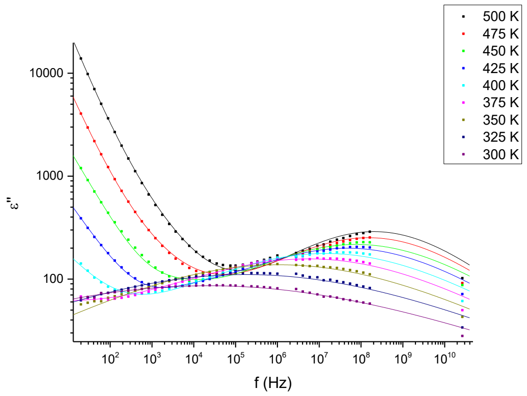

Fig. 2 Frequency dependencies of the imaginary part of a dielectric permittivity data of 0.5Nb-$BiFeO_3$–$BaTiO_3$ ceramics at different temperatures.

For analysis of the dielectric spectra, we used an empirical Cole-Cole equation to model the experimental permittivity data, to estimate the dielectric parameter values. Simultaneously, the Levenberg-Marquardt algorithm based non-linear least square method was used in the fitting procedure. OriginLab software implementing these algorithms was used to fit the experimental data with the following formula:

$$\varepsilon^*(\omega)=\sum_{i=1}^{n}\varepsilon_{\infty_i}+\frac{\Delta\varepsilon_i}{1+(i\omega\tau_i)^{1-\alpha_i}}, \quad (1)$$

Keywords: BF-BT, dielecric measurement, Cole-Cole equation.

References

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[2] Z. Yang et al., "Re-entrant Relaxor Ferroelectric Behaviour in Nb-Doped $BiFeO_3$-$BaTiO_3$ Ceramics", J. Mat. Chem. C (in press), 2023.