PbHf$_{1-x}$Sn$_x$O$_3$ kristalų dielektriniai tyrimai

Broadband dielectric measurements of PbHf$_{1-x}$Sn$_X$O$_3$ single crystal

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The lead-based perovskite oxides are chemically disordered compounds that have attracted considerable scientific interest due to their ferroelectric, antiferroelectric, and relaxor properties [1]. PbHf$_{0.92}$Sn$_{0.08}$O$_3$ exhibit phonon spectra near the center of Brillouin zone that is dominated by a soft transverse optic (TO) mode that reaches a minimum frequency on cooling and then hardens at lower temperatures [2]. Concurrent with the decrease in frequency, the frequency range of this mode broadens in energy until it becomes heavily damped, but only for wave vectors near the zone center.

PbHfO$_3$, a well-known antiferroelectric material, undergoes a first-order structural phase transition from a high-temperature paraelectric phase to a low-temperature antiferroelectric phase. Doping with different elements, such as tin (Sn), has shown promise in modifying the electrical properties and inducing the appearance of new intermediate phases.

In this study, we present a comprehensive investigation of the electrical properties of PbHf$_{0.92}$Sn$_{0.08}$O$_3$ using dielectric spectroscopy. The aim of this work is to characterize mode softening during the phase transition in microwave frequency range.

Dielectric spectra of PbHf$_{0.92}$Sn$_{0.08}$O$_3$ (later PHS) ceramics were measured in a broad frequency range from 20 Hz to 3 THz at temperatures 300 – 500 K.
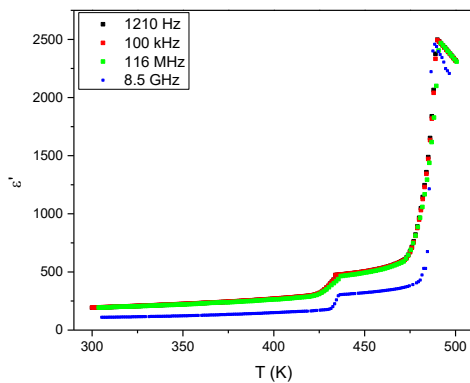

Fig. 1. Temperature dependencies of the real part of a complex dielectric permittivity of PHS ceramics at different frequencies.

The frequency dependences of complex dielectric permittivity (Fig. 2) reveal three separated processes. Based on this graph we see a rise of some peak near 1 GHz when temperature coming close to the Curie temperature. That peak due to its sharpness couldn't be explained by Debye or Cole-Cole type of dispersion.
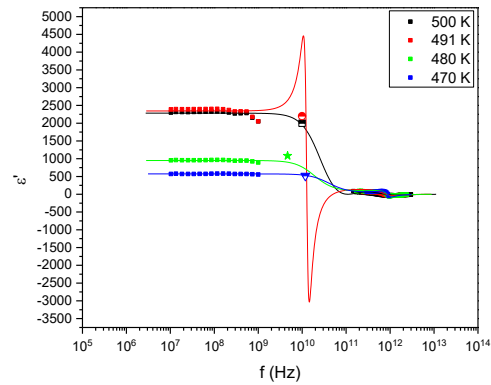

Fig. 2 Frequency dependencies of the real part of a dielectric permittivity data of PHS ceramics at high temperatures. Lines shows the best fits of experimental data points by formula (1).

So, to analyze that peak we could use the resonance dispersion formula as a superposition of 2 fitted peaks, one of them in GHz region and another in THz region.

$$\varepsilon(w) = \sum_{n=1}^{2} \frac{A_n}{w_{0_n}^2 + w_n^2 + iw_n g_n} \qquad (1)$$

The first part of the equation is used to describe the rise of imaginary part of dielectric constant, that we see in end of spectrum of our coaxial measurement (around 1 GHz) and beginning of waveguide measurements (from 0.15 THz). The second part of an equation describes a much smaller peak in THz region of measurement.

Keywords: PHS, lead-based ceramics, dielectric measurements, resonance frequency.

References

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