Dielectric permittivity of Nb₆VSB₃O₂₅

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Recent studies concerning the reactivity in the solid state among V₂O₅, Nb₂O₅ and α-Sb₂O₃ showed that those oxides interact in air, producing apart from Nb₂VSB₆O₁₀ [1] also new compound with formula Nb₆VSB₃O₂₅. It can find application as the component of gas sensors and element of catalysts in reactions of removing hydrogen by oxidizing of light hydrocarbons. In Nb₆VSB₃O₂₅, antimony, niobium and vanadium are mainly in +5 oxidation state. Preliminary studies by EPR, showed that the total content of V⁴⁺ + Nb⁴⁺ does not exceed 1.3%.

In the solid state new compound is stable in air up to ~1200 K and next melts with deposition of solid Nb₆VO₂₅. The electrical measurements performed on Nb₆VSB₃O₂₅-ceramics showed a sharp increase of the n-type electrical conduction at 330 K from the extrinsic region with the activation energy of E_A = 0.01 eV to the intrinsic one with the activation energy of E_A = 0.75 eV. At high temperatures, i.e. above 520 K, a rather well defined linear slope of diffusion thermopower was found which extrapolates to (0, 0). The I–V characteristics, measured at 300 and 400 K, showed a symmetric and non-linear behaviour as well as a broad minimum of the conductance G vs. the applied voltage V, which is being shifted into the higher voltages and simultaneously its value falls with a rise in temperature [2].

Real (ε’) and imaginary (ε’’) components of permittivity as well as loss tangent (tanδ) were measured in the temperature range 173-373 K using pellets, polished and sputtered with (~80 nm) Ag electrodes in a frequency range from 10² to 10⁶ Hz on a Novocontrol Alpha Impedance analyzer. For the dielectric measurements, the powder samples were compacted in a disc form (10 mm in diameter and 1–2 mm thick) using a pressure of 1.5 GPa and then they were sintered during 2 h at 1073 K.

Dielectric measurements showed that the real and imaginary components of permittivity strongly dependent on both the temperature above the room temperature (RT) and below 100 Hz. Below RT these dependences are weaker and ε’ decreases from 20 for f = 10² Hz to 10 for f = 10⁴ Hz while ε’’ decreases from 5 for f = 10² Hz to 0.2 for f = 10⁶ Hz. This means that the energy loss associated with the reorientation of electric dipoles is important only at higher temperatures. Generally, the loss tangent decreases with increasing frequency. In contrast, low-frequency loss tangent increases strongly with temperature. This suggests that in the compound under study additional energy losses are associated with the conduction of electric current, as determined by the Joule-Lenz law. One can conclude that the majority charge carriers must be partially recombined in the shallow trapping centres [3] lying under the bottom of the conduction band. A natural source of these traps can be the grain-boundaries with the depletion layers of the adjacent grains. Similar behaviour was observed for ZnO varistors [4] and for Nb₂VSB₆O₁₀-ceramics [5].