Exploring the Electrical Transport in Oxide Glasses through Model-Free Scaling Procedures of Conductivity and Permittivity Spectra

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Iron phosphate-based glasses (IPGs) belong to a family of electronically conducting amorphous materials known to their electronic conductivity. Due to the presence of transition metal (TM) ions, e.g. iron, in more than one valence state, the conduction mechanism is identified as small polaron hopping (SPH). These materials are of boundless scientific interest due to their potential application as electrode materials for batteries, electronic circuit elements, electrical switching devices and more.

This study explores the impact of adding modifier (MO) and glass-forming (GFO) oxides on polaron transport in binary IP glasses. To achieve this, we employ Solid-State Impedance Spectroscopy (SS-IS) to investigate the electrical transport properties and their correlation with the glass structure in B_2O_3–(HfO_2)–Fe_2O_3–P_2O_5 glass systems across a broad range of frequencies and temperatures.

Our findings reveal interesting characteristics underlying the polaronic transport. Compositional changes in glasses significantly alter the Fe^{2+}/Fe_{total} ratio, which directly affects the polaron number density and strongly controls the long-range transport and DC conductivity trends. Furthermore, we found that short-range polaron dynamics are also affected by structural changes. To thoroughly investigate these effects, we employed model-free scaling procedures, namely Summerfield and Sidebottom scaling of obtained experimental data. The relationship between structural changes and conductivity mechanisms is discussed in detail. Overall, our study provides valuable insights into the effects of existing glass network on polaron formation and dynamics, which has important implications for the development of new electronic materials.