Dielectric properties of aged and modified by doping glassy selenium

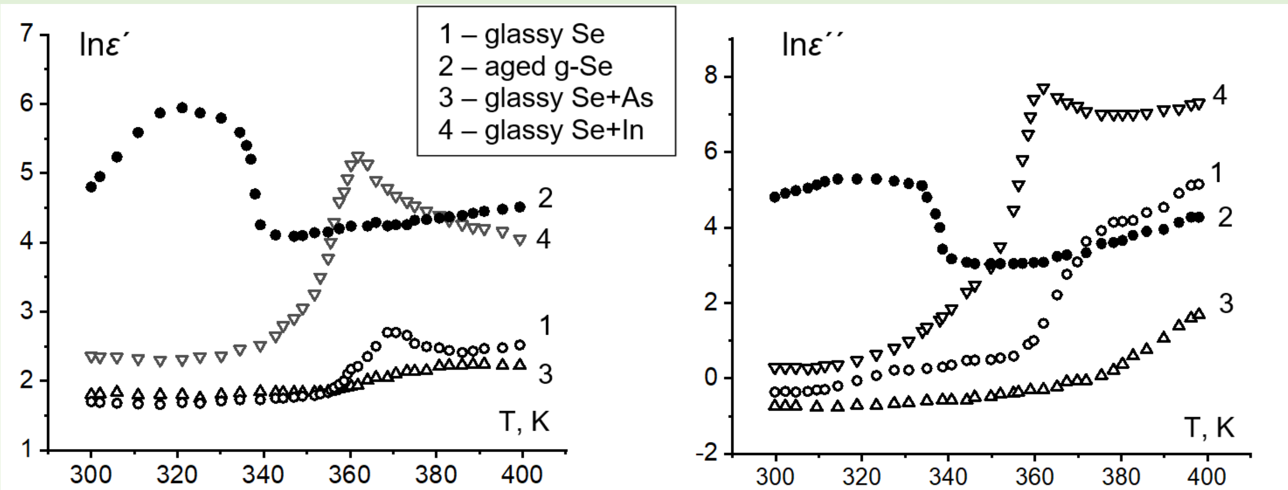
A. Horvat, A. Molnar, V. Minkovych

Department of Semiconductor Physics, Uzhhorod National University,
A. Voloshin str., 54, 88000 Uzhhorod, Ukraine
e-mail: ahorvat@ukr.net

Semiconductor chalcogenide alloys, which are primarily consist of selenium (Se), have a variety of commercial and technological applications, including infrared optical and electronic devices, sensors, optical fibers and phase-change materials [1, 2]. However, the amorphous selenium is characterised by low thermal stability, which limits its applications. This report presents an analysis of the behaviour of pure selenium glasses that have been aged under normal laboratory conditions for several decades, as well as glasses doped with small concentrations of impurities such as As, Sb, In, Ga Ge, etc., which alter the crystallisation ability.

The bulky glass samples were prepared using the well-known melt-quenching technique. The ampoules containing the molten alloys were cooled in ice water. The samples were then ground into a fine powder for further analysis. Various methods were employed to study the glass transition, crystallisation kinetics, glass-forming ability and thermal stability of the alloys under non-isothermal conditions, including X-ray diffraction, differential scanning calorimetry, electrophysical and dielectric investigations.

Figure 1, for example, shows the temperature dependences of the complex dielectric constant $\varepsilon^*=\varepsilon'+i\varepsilon''$ components of selenium-based glasses at a frequency of 1 kHz. To present the results more clearly, the temperature dependences of ε' and ε'' are shown on a logarithmic scale.



Temperature dependencies of complex dielectric constants $\varepsilon^*=\varepsilon'+i\varepsilon''$ components in selenium-based glasses.

A significant difference in the behaviour of the dielectric constants was observed in the crystallisation region for aged glasses (curve 2), namely that the anomalies associated with crystallisation have a much sharper form and are observed at much lower temperatures (by about 35 K) in comparison with as-obtained samples (curve 1). Curves 3 and 4 show the behaviour of selenium glass doped with arsenic and indium, respectively. As can be seen, a small addition (up to 5 mol%) of indium leads to a lower crystallization temperature and a more pronounced anomaly of dielectric parameters, while arsenic impurities stabilise the glassy state.

[1] H. Kumar, A.Lal Saroj. Recent Advances in Chalcogenide Glasses and their Applications. In Book Material Science: A Field of Diverse Industrial Application. 2023, p. 36 – 45. doi: 10.2174/9789815051247123010004
[2] J. D. Musgraves. Chalcogenide glasses: Engineering in the infrared spectrum. American Ceramic Society Bulletin.2024, v. 103, No. 4, p. 22 – 28.