Modification of electrophysical parameters of $CuInP_2S_6$ crystals by betta, gamma and neutron irradiation

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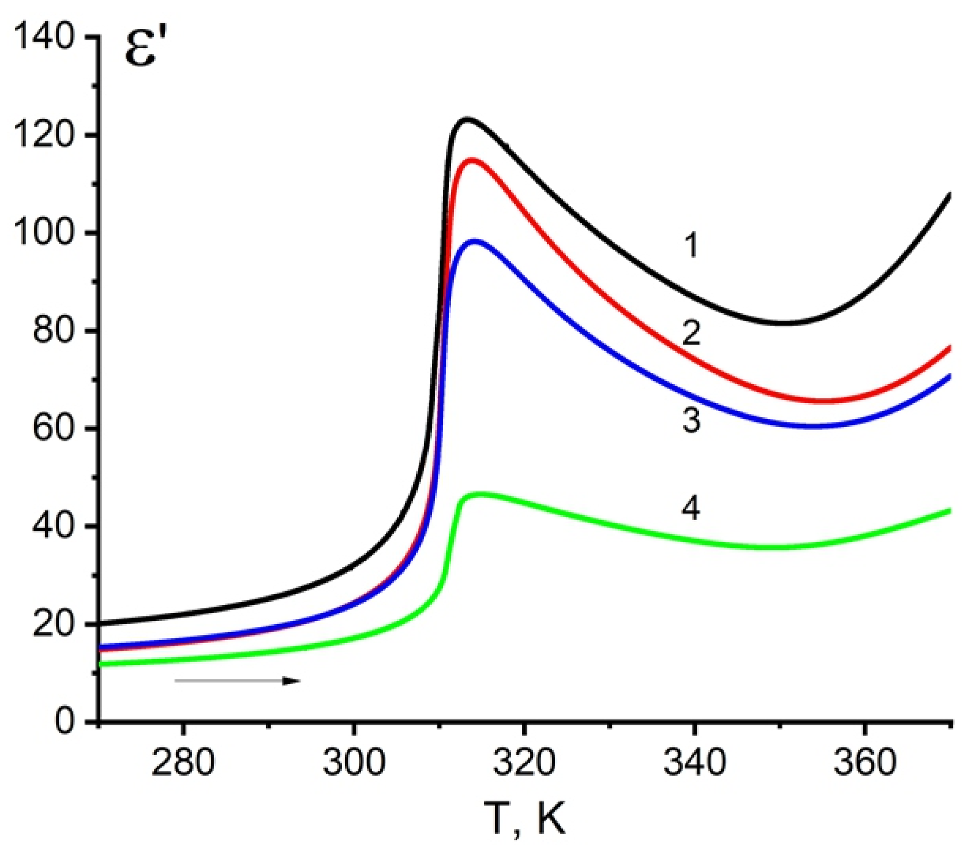
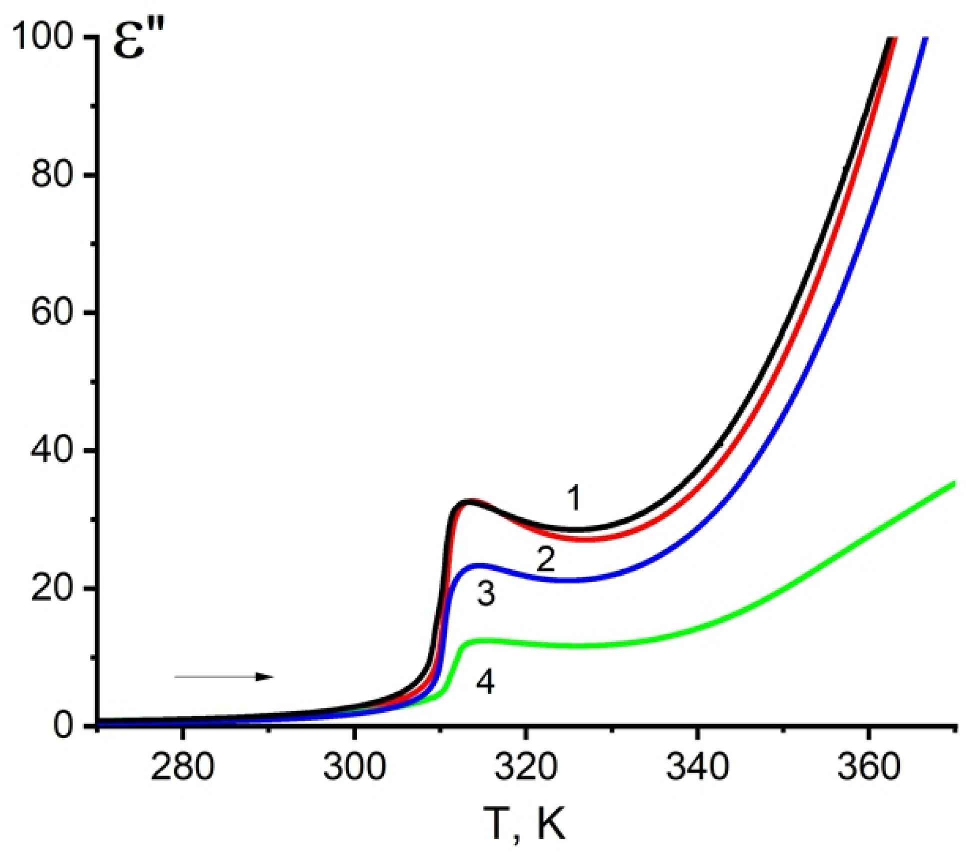
As with many electronic materials, $CuInP_2S_6$ crystals exhibit certain disadvantages, including a relatively low phase transition temperature ($T_c \approx 315$ K), ionic conductivity, and other limitations. The present study investigates the influence of radiation defects on the electrophysical parameters of $CuInP_2S_6$ crystals, a subject of particular importance for the further use of devices based on them in the aerospace industry. It is noteworthy that this technique (irradiation of samples) has a long-standing history in the semiconductor industry, particularly in modifying the mobility of charge carriers.

In the present study, we utilized $CuInP_2S_6$ crystals, grown from the melt using the Bridgman method. The chemical composition of the crystals was confirmed by the EDAX method, and their dimensions were measured to be 5x5x3 mm^3. After measuring the temperature dependence of their dielectric constant (as a reference measurement), the sample was divided into three 1 mm thick plates to ensure chemical composition uniformity. The same procedure was then repeated for each of the resulting plates. The samples were then exposed to β and γ particles at the Microtron accelerator (10^{15} cm^2). After irradiation, the temperature dependence of the dielectric permittivity was immediately measured again under the same conditions as in the initial reference studies.

It has been established that irradiation of $CuInP_2S_6$ samples with β and γ particles significantly affects the dielectric constant, both during phase transitions and at ambient temperature. Furthermore, the phase transition temperature and the shape of the ε(T) anomaly remain largely unaltered. It has been demonstrated that an enhancement in the irradiation dose leads to a suppression of the dielectric constant, with the replacement of β with γ particles resulting in a further reduction in ε. This phenomenon is attributed to an increase in the defectiveness of the crystal structure, and the observed difference in the efficiency of β and γ particles are attributed to the different penetration depths of these particles. The defect formation is likely to be charged, and the capture of charge carriers in the $CuInP_2S_6$ crystal is a probable consequence. This is manifested in the reduced electrical conductivity of the samples, which is reflected in the decrease in the high-temperature "tails" ε*(T) above 330 K, which are caused by the conductivity of the samples.

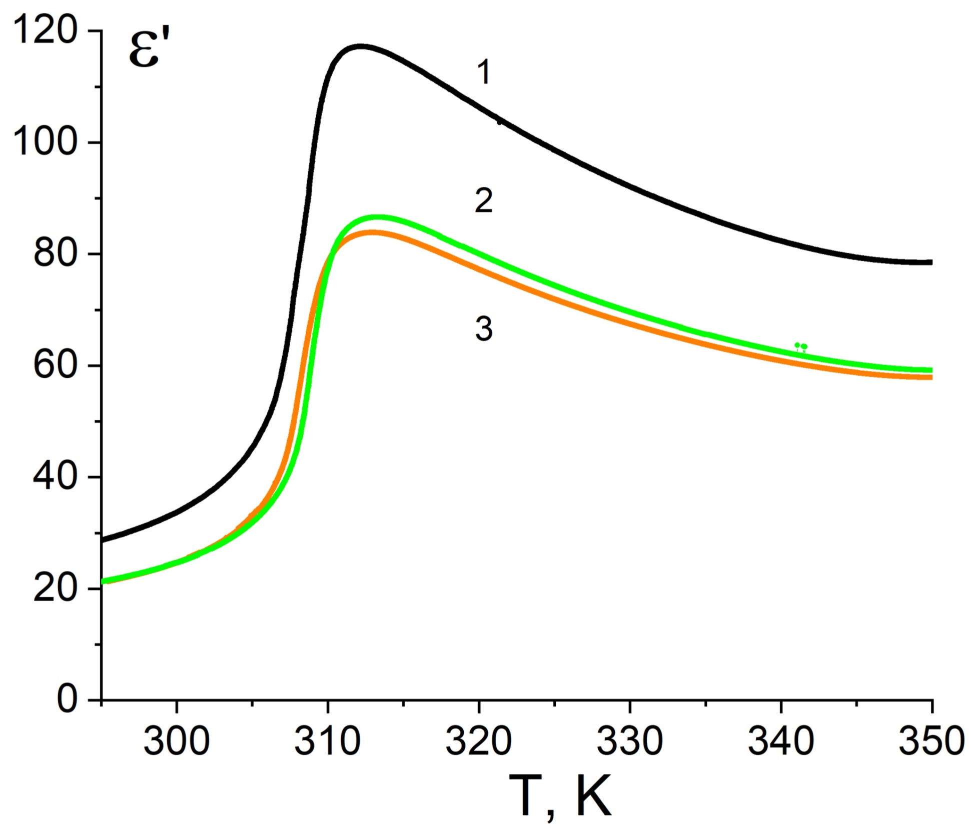
A photo of $CuInP_2S_6$ crystals obtained from the melt by the Bridgman method.

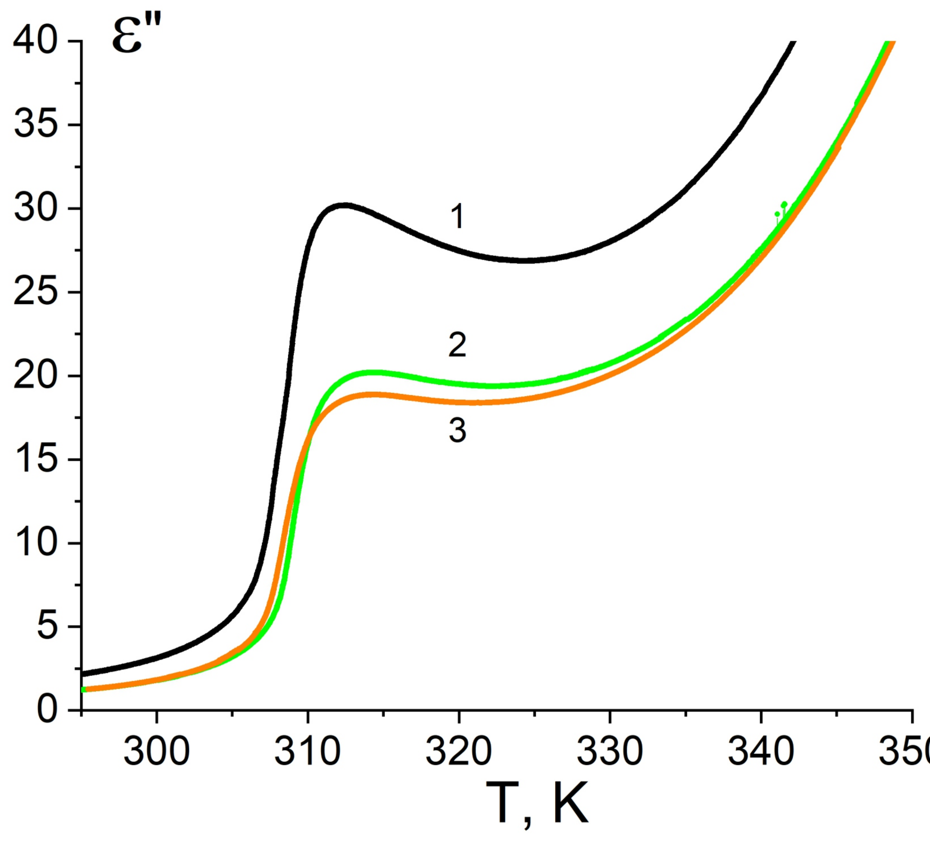




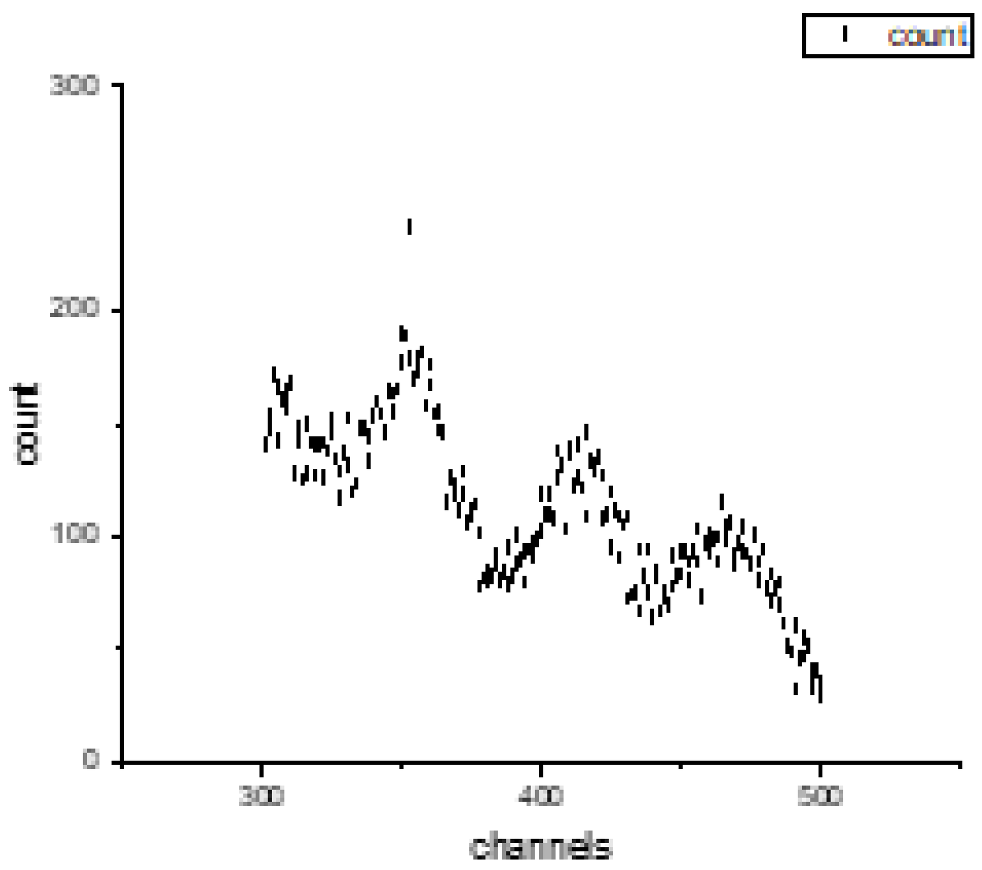
Temperature dependence of the real and imaginary parts of the dielectric constant ε* of $CuInP_2S_6$ crystals (at a frequency of 10 kHz) before irradiation - 1, after irradiation with β particles (10^{15} cm^2) - 2, ($2*10^{15}$ cm^2) - 3, and after irradiation with γ quanta (10^{15} cm^2) - 4.

Neutron irradiation was performed by the IBN-8 plutonium-beryllium neutron source. Neutron irradiation leads to more significant changes resulting in both phase transition blurring, a decrease in the phase transition temperature and the maximum value of the dielectric constant. This is most likely due to the transmutation of some elements in the $CuInP_2S_6$ crystals.





Temperature dependence of the real and imaginary parts of the dielectric constant ε* of $CuInP_2S_6$ crystals (at a frequency of 10 kHz) before irradiation - 1, irradiated with neutrons for two hours - 2 and for seven hours - 3.



Fragment of the gamma spectrum of the neutron-activated $CuInP_2S_6$ crystal.