Investigation of Noise Characteristics of Phosphorous Chalcogenide Crystal in the Vicinity of Phase Transition

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Thiophosphates represent the wide and interesting group of ferroelectric crystals exhibiting semiconductive properties. In general, they crystalize in a layered two-dimensional (2D) structure with the $AIMIIP_2S_6$ (A=Cu, Ag; M=Cr, In) type. They are formed by layers built up by cores of sulfur atoms where metal cations and P-P pairs fill octahedral voids [1, 2]. Such 2D layered materials with strong in-plane chemical bonds and weak coupling between the layers appears as the most suitable candidate to create a new generation of flexible electronic devices because layered structures provide an opportunity to be cleaved into individual atomic-thick layers.

The spontaneous polarization arising in these crystals due to a dipole ordering at the phase transition is directed perpendicular to the layer planes. The copper indium thiophosphate ($CuInP_2S_6$) is the most prominent representative of these layered compounds. Up to now structrural and physical properties of $CuInP_2S_6$ crystals have been extensively studied and reviewed [1-4]. $CuInP_2S_6$ crystals undergo a first-order phase transition of the order-disorder type at 315 K. The phase transition is associated with dynamics in two cation sublattices: the relaxation of Cu+ cations in a multi-well potential and the displacement of In3+ cations away from the mid-plane of the layers [1]. Thus, the mechanism of the transition is likely to involve the hopping of the copper ions among two or more positions [1, 2]. The ionic conductivity of $CuInP_2S_6$ has been already investigated [3]. It was found that DC conductivity of $CuInP_2S_6$ follows the Arrhenius law with activation energy EA=0.73 eV [3].

Noise spectroscopy in the field of materials science adds new dimension to the experiment. Recently noise spectroscopy has been coupled to other measurement techniques. Noise has long been used to investigate metal films, semiconductors, oxides and composites [5, 6]. Nevertheless, a considerably small number of papers have been dedicated to the investigation of noise in ferroelectrics. The aim of this work is to study noise features in the phase transition region of the well-studied lamellar ferrielectric -semiconductor $CuInP_2S_6$ crystal.

The noise properties of $CuInP_2S_6$ crystal at phase transition have been investigated over the frequency range 10Hz-20kHz. Lorentzian-type spectra with thermally activated peak are observed in voltage fluctuation. Estimated activation energy of characteristic time constant is equal to 1,6 eV at phase transition region. Observed process is attributed to the generation-recombination at trap defect states. Ferroelectric hysteresis measurements approved existence of many trap defect states in the investigated crystal.

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