Local elastic properties of layered ferroelectric TGS crystals

A.L. Tolstikhina[1], R.V. Gainutdinov[1], A. K. Lashkova[1], D. A. Zolotov[1], B.S. Roschin[1], V. E. Asadchikov[1], V.N. Shut[2], S.E. Mozzharov[2], I.F. Kashevich[3*]

[1] Institute of Crystallography. A.V. Shubnikov Federal Research Center "Crystallography and Photonics" RAS, Moscow, Russia

[2] Vitebsk State Technological University, Vitebsk, Belarus

[3]Vitebsk State University named after P.M. Masherova, Vitebsk, Belarus

* corresponding authore-mail :kashevich@tut.by

The paper presents the method and results of studying the mechanical properties of ferroelectric crystals of triglycine sulfate (TGS) with a periodic layer-by-layer distribution of a non-isomorphic impurity of chromium ions and an isomorphic impurity of L-α-alanine. In this case, the following tasks were solved: to determine the width of the stripes and transitional boundaries using X-ray methods and probe microscopy, to select measurement points in the middle of the bands by controlling the domain structure and differential capacitance distribution, to measure the force curves using the AFS (atomic-force spectroscop) method and to calculate the Young's modulus.

The crystals of TGS-TGS+Cr and TGS-LATGS were obtained by periodically growing crystals in solutions of various compositions - nominally pure and containing an impurities of chromium ions and L-α-alanine . The method and device for growing such crystals are given in the work [1].

Combining the methods of correlation scanning force microscopy, X-ray fluorescence analysis with the control of the amount of impurities, and X-ray topography made it possible to separate the growth stripes of different compositions in TGS crystals with high reliability. It was shown that in crystals doped with chromium, the XRFA, XRT, SCFM, and PFM methods are effective for revealing band boundaries. While in the case of L-α-alanine impurity, only strain-sensitiveX RT and PFM methods give reliable results.

For the first time, mechanical characteristics (Young's modulus) were measured by atomic force spectroscopy in pure and doped stripes of crystals with a profile distribution of chromium and L-α-alanine impurities. It was found that the Young's modulus in stripes with impurities is lower than in pure ones, namely, in stripes with chromium impurities, the difference was 20–25%, while with L-α-alanine impurities it was 12–14%. In "pure" TGS stripes, Young's modulus is two times higher for TGS–TGS + LATGS crystals than for TGS–TGS + Cr crystals.

This may be due to the fact that a crystal with a polar impurity of L-α-alanine experiences strong mechanical stresses; however, additional studies are required to confirm this hypothesis. Thus, the profile introduction of an impurity affects not only the domain structure, optical and electrical characteristics of crystals, but also their mechanical properties. During the work, methods for complex nanodiagnostics of the structure and local physical properties of ferroelectric hydrogen-containing TGS single crystals with a profile distribution of nonpolar and polar impurities were developed. The proposed approach to measuring Young's modulus in the growth bands of ferroelectric crystals can be applied in studies of gradient structures on active pyro- and ferroelectrics, crystalline materials for nonlinear optical devices, and physical materials science.

[1]. V. N. Shut, et al. Crystallogr. Rep. 55 (3), (2010) P. 458.