Review of the proposal to prolong the project

"New Semiconductor Detectors for Basic and Applied Research "

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The project proposed for prolongation is aimed at studying and developing a new type of ionizing-radiation coordinate detectors based on a high-resistance ($\rho > 10^9$ $\Omega\times$cm) single-crystal gallium arsenide doped with chromium (GaAs:Cr). It is a detector-quality semiconductor material good to develop detectors of resistive type (without a rectifying contact) for detecting various types of ionizing radiation. A unique technology for production of this material was created in Russia by scientists from the Tomsk State University. Gallium arsenide is a “heavy” semiconductor material with a specific weight of 5.32 g/cm^3, which is more than twice as high as silicon density. Detectors based on GaAs have a high detection efficiency for gammas and X-rays at room temperature (the band gap is 1.42 eV wide), which makes this semiconductor material promising and important for using in coordinate X-ray and gamma detectors. A semiconductor material with competing parameters for X-ray and gamma detection is CdZnTe, which is very expensive (over US \$5/mm^3). The authors of the project under review have presented an account of the main research results obtained over the period of 2015–2017.

An important result is radiation hardness investigations of GaAs:Cr detectors using beams of electrons (20 MeV, Linac-200) and fast neutrons (IBR-2). It is shown that these detectors are capable of operating at doses up to 1.5 MGy when irradiated with 20-MeV electrons. It would be helpful to know the electron fluence corresponding to this dose. For semiconductor detectors, it is more comfortable and clearer to give the scale of their radiation load under hadron and electron irradiation in fluence values (cm^{-2}); a common practice is to use the rigidity coefficient of the above particles for deriving the equivalent fluence of fast neutrons with the energy of 1 MeV (judging by silicon damage), and this scale is adopted by the scientific community engaged in researching radiation damage of semiconductors. Also, normalization to a unit of the active volume of the detector is always necessary for correct comparison of radiation damage effects in detectors made from different types of semiconductors. I suggest that among the objectives to be pursued in further radiation research of GaAs:Cr detectors under the project should be determining the main parameters of their material, such as the dependence of the parameter $\mu\tau$ on the fluence and the current constant of the GaAs:Cr damage (for neutrons and electrons) by analogy with silicon. For any type of silicon single crystals there is linear dependence of the number of created radiation defects on the fast-neutron fluence, which is expressed by the formula of the detector current increment: $\Delta I = \alpha_I \times \Phi \times V$, where ΔI is the current increment (A), $\alpha_I=(5\pm0.5)\times10^{-17}$ (A/cm) is the current constant of silicon damage by 1-MeV fast neutrons reduced to the temperature of +20°C with self-annealing ignored, $\mathbf{\Phi}$ (cm^{-2}) is the silicon-damage-equivalent fluence of fast neutrons with the energy of 1 MeV, and $\mathbf{V}$=d×S (cm^3) is the sensitive volume of the detector.

The increased radiation hardness of GaAs:Cr-based detectors underlies plans and development activities (FCAL Collaboration) on special calorimeters to be used in the near-beam region at future electron–positron colliders (ILC, CLIC, etc.). Compact sandwich calorimeters with a tungsten absorber and an active medium based on GaAs:Cr detectors are proposed. For successive fulfillment of this task, it is necessary to demonstrate radiation hardness of both the detectors and their electronics, which is also an objective for the research.

Very interesting and important result have been obtained in the investigations of hybrid pixel detectors for various purposes. Very interesting detection methods are considered for pixel detectors based on the developed integrated circuits. The devices based on these detectors allow tracks to be measured with a high accuracy and various particles to be identified. This knowledge-intensive and informative direction in the detector research for high-energy and nuclear physics should certainly be developed to implement its results in experiments conducted at our institute. Devices based on pixel detectors are also widely used in applied research and medicine. The authors of the project have a large scientific and methodological background related to this theme; therefore, the goals of the project will certainly be achieved. On the other hand, the authors undertake to fulfil a great deal of technological tasks, including bump bonding assembly and chemical procedures. I also think that the purchasing of an expensive DLTS spectrometer and deep-level spectroscopy may lead away from achieving the ultimate goal related to detectors. The DLTS spectroscopy is a vast field of semiconductor physics, and it is therefore simpler to find experts in dedicated institutions like BSU (Minsk) or GIREDMET (Moscow) and establish scientific cooperation with them for studying radiation-induced defects by irradiating samples for DLTS with beams from JINR accelerators.

The project implementation expenditures are well justified. Skilled young experts and scientists participate in the project, which therefore must be fully supported as a first-priority JINR project with wishes of success and good luck to the authors engaged in this interesting work.

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