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Radiation-resistant materials and sensors for magnetic diagnostics

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Here we present the results of the international collaboration of researchers for creation and testing of the radiation-resistant sensors and the magnetic measurement instrumentations based on them in the IBR-2 nuclear research reactor for the monitoring of the magnetic field under high neutron fluence environment, typical for the NICA collider, LHC at CERN, as well as for the ITER, JET, DEMO fusion reactors.
Semiconductor as well as metal materials were selected and tested in neutrons for the magnetic field sensors of the Hall type.
As it is shown, the most effective semiconductor compounds on the basis of theory predictions and experimental investigations complex are that of the III and V groups: indium antimonide (InSb) and indium arsenide (InAs). These indium-containing materials are characterized by high charge carrier mobility. A physical model of the processes that occur in these materials under the full spectrum of the reactor neutrons has been offered.
A method proposed for the parameter stabilization of the indium-containing III-V materials consist in the balancing of two competing mechanisms. It was shown that such balance could be achieved by ensuring the optimal initial charge carrier concentration. This is achieved by the doping of sensor materials with taking into account the energy spectrum of the neutron flux.
The optimal initial level of the charge carrier concentration for the InAs is n=3e18 cm^-3, it is provided via doping by tin in the process of growing. The optimal charge carrier concentration for the InSb is n=6.4e17 cm^-3. It is provided by the complex doping, which includes the main donor impurity Sn, the additional impurities Al and Cr (for creation of gettering centers of radiation induced defects), as well as rare-earth impurity Er (for binding of uncontrolled background impurities).
The radiation stability of the Hall sensors based on such semiconductor materials amounts: 99.95% at F=1e15 cm^-2 and 95% at F=1e17 cm^-2.
For even higher fluence of F≥1e19 cm-2, typical for the future DEMO reactor, radiation-resistant sensors were made based on the nano-thickness gold films (~50 nm). The main parameter –sensors sensitivity –remains unchanged up to F=2e19 cm-2
The sensors were tested in the channel #3 of IBR-2 reactor (JINR, Dubna) as well as in the channel #V13 of WWR-M reactor (PNPI, Gatchina).
Experimental investigations were carried out using online method and the remote access to the experimental data. For this purpose the special hardware-software complex was developed: sensor samples were placed in the reactor channel; control electronics were placed at a distance of 10 m from the reactor active area; the computer with the software was placed in the personnel area at a distance of 50 m from the active area.
The results obtained from the testing of the radiation-resistant semiconductor sensors were presented at FEC-2014 conference and published in Nuclear Fusion journal (2015, V.55, N8, 083006). The results of the testing of the metal sensors were presented at the FEC-2016 conference in October 2016, published in the conference proceedings (Book of abstracts, P.473).

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