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Investigation of changes of physical properties of Mo-Cu-Diamond material collimator irradiated with a 35 MeV proton beam

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Practically all materials from which various structural units and working parts of nuclear and thermonuclear facilities are made, both research and industrial, are exposed to radiation and radiation from various high-energy particles [6] during their work. Radiation, acting on materials, change their structure, and hence their strength, electrical and other properties. It is necessary to carry out tests for irradiation with various fast particles and to investigate changes in the microstructure and mechanical properties at different temperatures and doses of irradiation to understand the physical mechanisms of radiation resistance of ODS materials.
The results of irradiation of molybdenum-diamond collimator materials of different sizes on the cyclotron of NRC "Kurchatov institute"at different doses at room temperature for measurements of thermal conductivity coefficient, the thermal expansion coefficient (CTE, α), thermal conductivity (λ) and specific resistivity (ρ) of these irradiated materials are presented..
The materials of molybdenum-diamond collimators were irradiated with protons up to 35 MeV on the cyclotron of NRC KI at low temperature (below 100 ºC) and various doses: F1= 1017 p/cm2, F2 = 1018 p/cm2. Measurement temperature should not be higher than those one for irradiation to prevent radiation defects from annealing. The measurements we performed up to 120 °C after first irradiation and up to 200 °C for the second one.
The SRIM-2008 program was used to estimate the rate of formation of defects and proton ranges in the irradiated materials. Since both materials are non-uniform, their damageability was evaluated in two ways: by the average density of the material and for the material, which is alternating layers of metal and diamond in the direction perpendicular to the propagation of charged particles. The latter approach is due to the fact that high-energy protons in the process of propagation in materials weakly deviate from the initial direction, since they spend energy mainly on ionization.
Since the mileage of protons in the molybdenum composite is about 2 mm, the samples were irradiated from both sides alternately. The dose uniformity in the irradiation zone was controlled after irradiation by the gamma value of the induced activity. Based on the estimated value of the path (2–2.5 cm) in the irradiated materials for protons with an energy of 35 MeV, which indicates a large number of such layers, the fact of the initial penetration of protons into one or another layer was not taken into account.
For irradiation at each dose, NRC KI used three different samples of molybdenum-diamond (one point) to change the thermal conductivity (λ) of irradiated specimens of cylindrical molybdenum-diamond with a diameter of 10 mm and a thickness of 4 mm.
Researches of the samples after the 1st and 2nd irradiation with fast protons were carried out to measure the value of the coefficient of thermal expansion of the CTE (α). Three samples with length 16 mm and cross-section 4x4 mm2 were irradiated. Three samples with cross-section 4x4 mm and 16 mm length were chosen for measurements of thermal conductivity. The samples were irradiated with 30 MeV protons in the cyclotron of Φ1 = 1017. Irradiation was performed in a water flow at temperature 70-100 oC up to a dose 1017 p/cm2. Second irradiation was performed to a dose 10 times higher, 1018 p/cm2.
Magnitude of specific resistivity for Mo-Cu-Diamond samples was measured using "ampere-voltmeter"technique. In this method, voltage is applied to the sample ends via current contacts, while measured voltage is monitored from the side of the sample through potential contacts separated by 9.4 mm from each other. The measurements were carried out on 3 samples of molybdenum-diamond with a parallelepiped shape of dimensions: 60 mm x 5.5 mm x 4 mm at room temperature.
It was found that thermal conductivity (λ) of Mo-Cu-Diamond material is significantly lower than the same value for Cu-Diamond (approximately 1.5 times). Corresponding values at 200 oC equal to 40-45 mm 2/c and 55-95 mm 2/c.
It was established that the value of specific resistivity in non-irradiated samples significantly differs from 8.5·10-8 Ohm·m to 11.0·10-8 Ohm·m. The value of specific resistivity for Mo-Cu-Diamond samples has increased by 30-50 % after irradiation. Besides this, it should be noted that the value of specific resistivity for Cu-Diamond samples is significantly lower (an order of magnitude), than those one for Mo-Cu-Diamond samples.

Summary

It was found that thermal conductivity (λ) of Mo-Cu-Diamond material is significantly lower than the same value for Cu-Diamond (approximately 1.5 times).
It was established that the value of specific resistivity in non-irradiated samples is significantly different, the value of specific resistivity for Mo-Cu-Diamond samples has increased after irradiation. Besides this, it should be noted that the value of specific resistivity for Cu-Diamond samples is significantly lower (an order of magnitude), than those one for Mo-Cu-Diamond samples.

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