

Seminar

Institute for Plasma Research

Title: Preformation Assessment of Epoxy Based Glass Fiber Composite to Metal Joints for Superconducting Fusion Magnet Applications under High Neutron Irradiation

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Date: 09th April 2026 (Thursday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

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(*Conference ID: 5992138016; Password: 232142*)

Abstract

In fusion reactors, insulation materials must exhibit exceptional resistance to neutron irradiation, as prolonged exposure can degrade both material and component properties, ultimately affecting reactor performance. Experimental studies show that, under high neutron fluence (ranging from 10^{14} to 10^{22} n/m²), mechanical properties such as tensile and interlinear shear strength can deteriorate by up to 30%. This study focuses on the development and evaluation of insulation materials suited for high-neutron environments, specifically for future domestic superconducting (SC) fusion magnets. The insulation material developed is a Glass Fiber Reinforced Plastic (GFRP) composite, made from boron-free S-glass fibers and liquid-modified bisphenol epoxy resin. Earlier investigations involved irradiating the insulation material samples up to a neutron fluence of 1.0×10^{21} n/m² and a gamma dose of 0.5 MGy at 32 MWt reactor power in the fast breeder test fission reactor at IGCAR, Kalpakkam. The mechanical and electrical testing of both unirradiated and irradiated samples was conducted at a government-approved laboratory. The results showed minimal degradation (less than 2%) in tensile strength, shear strength, and electrical breakdown strength. In-house developed epoxy-based dissimilar material (DM) joints, consisting of GFRP composite and stainless steel, were irradiated near the reactor core enclosure plate assembly to validate their performance in a neutron-rich environment. The estimated gamma dose rate at DM joint was 1.1×10^7 R/h at 1 MW irradiation with neutron flux of 3.5×10^{15} n/m²/s of fast neutron energy of >0.1 MeV. The cadmium sheet was wrapped on sample to absorb thermal neutrons and reduce neutron irradiation induced dose. These tests were conducted at the APSARA (U) reactor, BARC, Mumbai, under irradiation conditions that included a neutron fluence of 1.0×10^{21} n/m² and a gamma dose of 9.0 MGy at 800 kW of fast neutron energy (>0.1 MeV). The radiation tolerance thresholds for the GFRP material were established as a neutron fluence of 1.0×10^{22} n/m² and a gamma dose of 10 MGy. The helium leak-tightness of the irradiated DM joint was found to be within an acceptable value of 1.7×10^{-8} mbar-l/sec. The mechanical testing under tensile pull load condition revealed no significant degradation was found. The in-house developed epoxy resin system has been found to exhibit exceptional radiation stability under high neutron flux, potentially advancing the development of future fusion magnet technologies.

This paper outlines the in-house development of a neutron-resistant composite insulation material, covering irradiation experiments, post-irradiation observations, and performance test at 300 K and 77 K for unirradiated and irradiated cryogenic components.

Keywords: Irradiation with fast breeder radiation environment, superconducting magnet, insulation material, S-glass composite, mechanical and electrical performance
