Heavy ion induced radiation effects in novel molybdenum-carbide graphite composite materials

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Innovative molybdenum-carbide graphite (Mo-Gr) composites were specifically developed for high energy physics applications. These materials are showing a very promising combination of thermal, electrical, and mechanical properties for application in beam protection elements for high-power accelerators. To date very little is known about their structural and dimensional stability and about degradation of functional properties under irradiation. Within the EU, FP7, EuCARD-2 project [1], an intense campaign for testing radiation hardness using different particle beams and energies is taking place at GSI Helmholtzzentrum as well as at Brookhaven National Laboratory (USA) and Kurchatov Institute (Russia).

Mo-Gr composites are processed by Liquid Phase Sintering of molybdenum powder, graphite flakes and pitch-based carbon fibers at temperatures higher than 2000 ºC. First radiation hardness tests of this material with GeV heavy ions (^{238}U, ^{209}Bi, and ^{197}Au) were performed at the UNILAC accelerator at GSI. During irradiation, samples cut in transversal direction, with respect to the orientation of the carbon fibers, start to deform at fluences of 6×10^{12} ions/cm^2 (figure 1, top). Deformation was minimized by pre-annealing the samples at temperatures above 1000 ºC to release internal stresses introduced during Mo-Gr composite processing (figure 1, bottom).

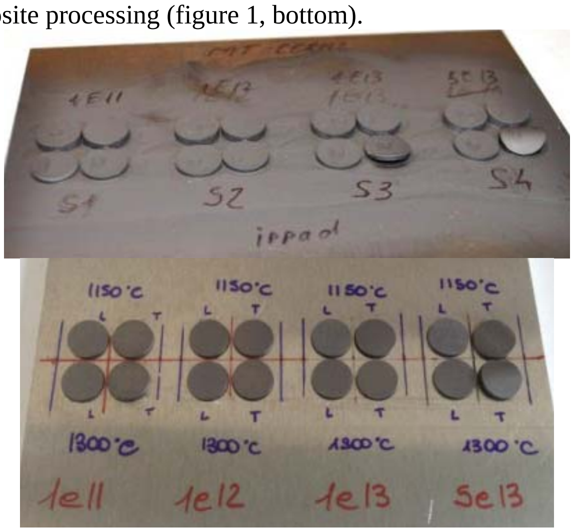

Figure 1: Series of Mo-GR samples cut in two different direction with respect to the orientation of the carbon fibers; (top) non-annealed samples after irradiation with U ions; (bottom) samples annealed at 1150 ºC and 1300 ºC irradiated with Au ions. Both series were exposed to fluences between 1×10^{11} and 3×10^{13} ions/cm^2.

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Online infrared (IR) thermography during irradiation was used to monitor ion-induced deformation. Sample deformation causes loss of contact to the sample holder and thus the cooling time of beam-pulse induced temperature spikes increases (figure 3).

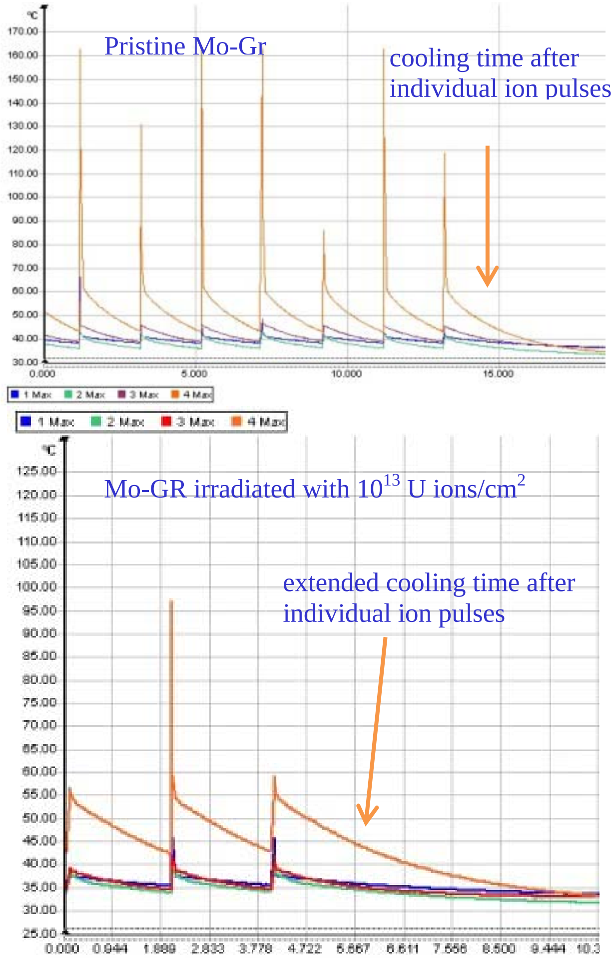

Figure 3: Infrared camera recorded time evolution of sample temperature at the initial state of the irradiation (top) and after exposure to a fluence of about 10^{13} ions/cm^2 (bottom). The irradiation was performed with 1-GeV U ions (frequency 0.6 Hz, 200 µs pulse duration)

Additional activities concentrate on the analysis of ion beam induced modification of the composites by means of Raman Spectroscopy, X-ray diffraction, scanning electron microscopy and nanoindentation.

[1] http://eucard2.web.cern.ch

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