Intense Heavy Ion Beam Induced Effects in Carbon-Based Stripper Foils

K. Kupka[1,2], M. Tomut[2,3], A. Dunlap[1], P. Simon[1], B. Lommel[2], C. Hubert[2], C. Trautmann[2,1]

[1]Technische Universität Darmstadt, Germany; [2]GSI, Darmstadt, Germany; [3]NIMP, Bucharest, Romania.

k.kupka@gsi.de

New challenges evolve with high beam intensities and a pulsed beam structure as foreseen at the planned Facility for Antiproton and Ion Research FAIR at GSI, Darmstadt. A solid stripper foil could provide an option for directly delivering an intermediate charge state to the heavy ion synchrotron, SIS 18, in order to mitigate space charge limitations during high-intensity operation. Regarding the exposure to these extreme conditions, a reliably working carbon stripper foil as well as the prediction and increase of its lifetime is of great interest. Due to its low density and excellent thermo-mechanical properties, carbon is so far the most promising material candidate to withstand highest beam intensities. We investigated various carbon-based stripper foils with respect to damage creation and performance limits under heavy ion irradiation.

Irradiation experiments were performed with a quasi-continuous 3.6 MeV/u ^{197}Au beam (50 Hz, 4 ms pulse length), and with a pulsed 4.8 MeV/u ^{238}U beam (1 Hz, 0.1-0.4 ms pulse length) applying fluences up to 6×10^{14} ions/cm². Amorphous carbon foils (provided by GSI target laboratory and ACF-Metals, respectively) and diamond-like carbon foils (provided by Vinder Jaggi, TRIUMF/ MICROMATTER) with different ratios of sp^2 and sp^3 bonds, as well as other carbon-materials like Carbon-Nano-Tube material (CNT) (provided by Hiroo Hasebe, RIKEN Nishina Center and Danubia NanoTech) and foils based on graphene platelets (provided by Applied Nanotech) were irradiated.

The carbon materials exhibit different behavior with a quasi-continuous and a pulsed beam structure as shown by Figure 1.

Figure 1: Carbon-based foils irradiated by different beams:
1): 97 µg/cm² amorphous carbon foil (provided by GSI target laboratory) irradiated with short-pulse 4.8 MeV/u ^{238}U beam, 5×10^{13} ions/cm²;
2): ~95 µg/cm² diamond-like carbon foil (20% B, provided by Vinder Jaggi, TRIUMF/ MICROMATTER) irradiated with 3.6 MeV/u ^{197}Au beam, 5×10^{13} ions/cm²;
3): ~95 µg/cm² diamond-like carbon foil (20% B, provided by Vinder Jaggi, TRIUMF/ MICROMATTER) irradiated with short-pulse 4.8 MeV/u ^{238}U beam, 5×10^{13} ions/cm²;
4): 200 µg/cm² graphene platelets-based carbon foil (provided by Applied Nanotech) irradiated with short-pulse 4.8 MeV/u ^{238}U beam, 5×10^{13} ions/cm²;
5): 140 µg/cm² CNT foil (provided by Hiroo Hasebe, RIKEN Nishina Center) irradiated with short-pulse 4.8 MeV/u ^{238}U beam, 2×10^{13} ions/cm².

Infrared thermography allowed us to record temperature evolution and temperature gradients in the beam spot during irradiation. Temperature dependence on fluence and ion flux was investigated.

Structural changes of the carbon foils were investigated by various methods: Raman spectroscopy indicates the formation of graphite nanocrystals by the increase of the ratio of D-peak and G-peak intensities I(D)/I(G) as stated by Ferrari [1]. X-ray photoelectron spectroscopy (XPS) and electron energy loss spectroscopy (EELS) quantify the amount of sp^2 and sp^3 bonding in pristine and irradiated foils.

Microstructural analysis by scanning electron microscopy (SEM) and scanning transmission electron microscopy (STEM) gives an insight into crack evolution in the beam spot and in the beam halo area depending on the fluence-value (?).

[1] A. C. Ferrari and J. Robertson, Phys. Rev. B 61, 14095–14107 (2000).