Measurements of Carbon Stripper Foils Emissivity for Quantitative On-line Infrared Thermography

K. Kupka[1,2,#], M. Tomut[1,3], C. Hubert[1,2], R. Danjoux[4], B. Lommel[1], J. Steiner[1], and C. Trautmann[1,2]

[1] GSI, Darmstadt, Germany; [2]Technische Universität Darmstadt, Germany; [3]NIMP, Bucharest, Romania, [4]FLIR Systems, Inc., Croissy-Beaubourg, France.

Attempting to mitigate space charge limitation during the foreseen high-intensity operation of SIS at FAIR, the replacement of the gas stripper at 1.4 MeV/u and the foil stripper at 11.4 MeV/u (TK) by one carbon stripper foil at 1.4 MeV/u for directly delivering an intermediate charge state has been investigated.

Experiments with solid carbon stripper foils installed at the 1.4 MeV/u-stripper section revealed the capability of 20 µg/cm² amorphous carbon foils produced by the GSI Target Laboratory for delivering U^{39+} ions to SIS18. The foils exhibited an average lifetime of 11 h [1].

In order to predict and increase the life time of the stripper foils, systematic investigations of the processes leading to failure are needed. In this work, we strive to better understand which are the contributions of radiation damage, high temperature and stress waves induced by the pulsed beam to final failure. We report on emissivity measurements of amorphous carbon foils of different thicknesses. The data are needed for monitoring temperature evolution and gradients within the beam spot with an infrared (IR) camera during foil irradiation. Due to semi-transparency of the stripper foils, a method for measuring the emissivity in consideration with the background had to be developed.

Amorphous carbon stripper foils of different thicknesses (20, 30, 50, 97 µg/cm²) were installed in front of a box heating the foil and acting as a black body (Fig. 1 right). Additionally, a copper sheet of known emissivity was placed between the foil and the heat box. In order to subtract the background, the radiance was measured with the infrared camera on the copper sheet (location 1, Fig. 1 left) and on the heat box, not covered by any foil (location 2). The deviation of these two radiance values served as a background function. The same measurement was repeated for the area covered by the semitransparent carbon foil (location 3 and 4). The ratio of the difference function for the area covered by the foil, *Df*, and the background function, *Bf,* yielded the transmittance τ of the amorphous carbon foil ($\tau = Df / Bf$). Emissivity values for foils of different thicknesses were calculated by applying conservation of energy: $\varepsilon = 1 - \rho - \tau$, where ε is the emissivity, ρ the reflectance and τ the transmittance of the foil. The reflectance was assumed to be 4%. Resulting emissivity and transmittance values for different stripper foils are presented in Fig 1 (left). The emissivity increases exponentially with the thickness of the amorphous carbon foils. The calculated values were used as input parameters for the measurement of the temperature evolution during beam exposure of the foils (Fig. 2). The transmittance of a CaF_2 window similar to that of the infrared viewport of the irradiation chamber was measured. The resulting value of 87.2% was also used in the calculations.

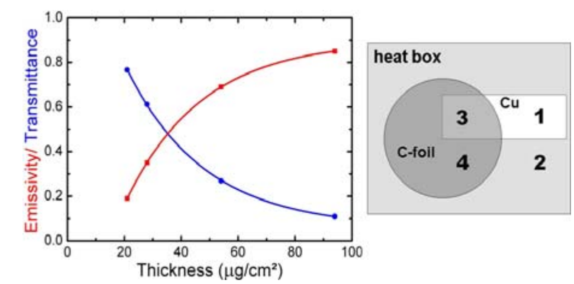

Figure 1: (left) Measured emissivity values for foils of different thicknesses, (right) radiance measurement setup.

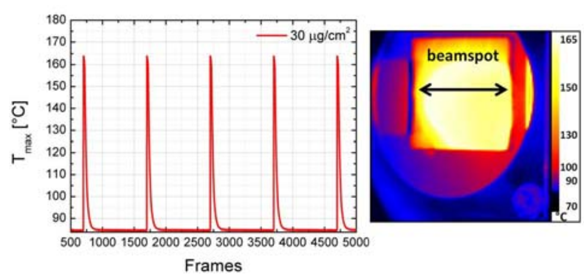

Figure 2: (left) Time and (right) temperature evolution in the beamspot during irradiation of the 30 µg/cm² foil with a 4.8 MeV/u ^{238}U beam.

Table 1 shows flux, energy density, and observed temperatures. A significant increase of peak temperature with increasing foil thickness is visible, reaching a maximum temperature of 353°C in the 97 µg/cm² foil.

Table 1: Irradiation parameters and measured temperatures for amorphous carbon foils of different thicknesses.

Thickness [µg/cm²]	Flux [ions/pulse cm²]	Power Density [kW/g pulse]	T(max) [°C]
20	7.30E+09	388.8	155
30	7.50E+09	399.4	163
50	7.00E+09	372.8	205
97	7.70E+09	410.1	353

The use of a multiple integration time mode upgrade of the IR camera is planned to increase accuracy of the IR measurements above 350°C.

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k.kupka@gsi.de

[1] W. Barth et al., LINAC2010, Tsukuba, Japan (2010)