Quantitative outgassing analysis of polymers during heavy ion irradiation

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Degradation processes of polymers under heavy ion irradiation have been studied intensively over the past decades [1, 2]. A common approach is measuring outgassing of volatile fragments that are created during irradiation. So far outgassing measurements were conducted in a qualitative way, e.g., as pressure rise observed in a residual gas analyzer (RGA).

The aim of this experiment was to get access to quantitative outgassing. Therefore a calibration of the existing RGA setup concerning pressure measurement and pumping speed was needed. First the pumping speed S for various gas species was determined [3]. With the pressure rise Δp from outgassing fragments and the mean flux of the ion beam $\dot{N}$, one can derive the outgassing yield η (released fragments / incident ion) of volatile fragments:

$$\eta = \frac{\Delta p \cdot S}{\dot{N} \cdot k \cdot T} \qquad (1)$$

We have studied outgassing with respect to the origin of the desorbed gas; whether it is released from the surface or as volatile decomposition fragments out of the bulk of the polymer. For surface cleaning a keV sputter ion source (IQE 11/35 from Specs®) with xenon as sputter-gas was used at a distance of about 50 cm away from the samples.

Polycarbonate (Makrofol®) foils 100 and 30 μm thickness) and polyimide (Kapton®) foils 25 μm thickness) were irradiated at the M3 beamline of the UNILAC [4] at room temperature with xenon, gold and samarium ions of 4.8 MeV/u and a flux of (1 - 2) $\cdot$ 10^8 ions/cm^{2}s. The diameter of all samples was 1 cm, and a beamspot of about 8 mm x 8 mm was used for irradiation. Both sides of the polymer were cleaned for 45 min with xenon ions of 500 eV and a flux of 3e13 ions/cm^{2}s. For each sample species, a sample with and without sputter-cleaning was investigated.

The raw RGA data was calibrated with total pressure measurements of the dynamic pressure during irradiation. With the calibrated pressure rise Δp and the ion flux $\dot{N}$ the yield was calculated using equation 1. In figure 1 the outgassing yields for Makrofol® irradiated with gold ions are shown for various gas species. The plots marked with open symbols correspond to sputter-cleaned samples, full symbols to uncleaned foils. The estimated error for the fluence is 5%. Concerning the yield we estimate an error of 10% taking into account uncertainties of the total pressure measurement, pumping speed and flux. We observed that the yield of all sputter-cleaned samples is lower then the uncleaned counterpart; thus the surface condition has a strong effect on the outgassing of the polymer. However in both cases the yields are decreasing with increasing fluence. This could either be due to unsufficient surface cleaning or fluence dependent bulk decomposition induced by material changes. More in-situ investigations are planned. Our measurements clearly show that the surface state contributes to beam induced pressure increase.

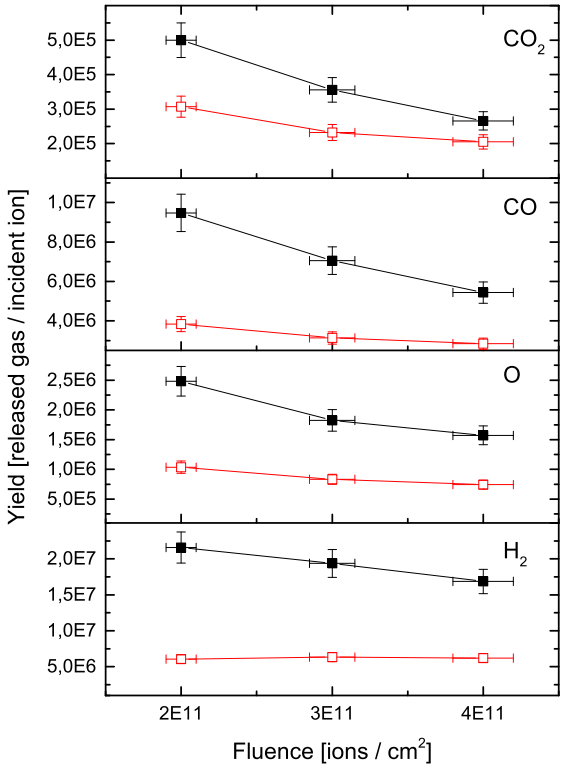

Figure 1: Outgassing-yield η of various gas species for a 100 μm thick Makrofol® foil during irradiation with gold ions. open symbols: sputter-cleaned before irradiation, full symbols: uncleaned. Lines are guides to the eye.

References

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