# Erosion of Polymer-like Hydrogenated Amorphous Carbon Films During ERD Analysis with Heavy Ion Beams

H. Huber, W. Assmann, R. Behrisch [a], M. Brodale, H. D. Mieskes, H. Nolte, V.M. Prozesky [b], and T. Reichelt

[a] Max Plank Institut für Plasmaphysik, EURATOM Association, D-85748 Garching

[b] Van de Graaff Group, National Accelerator Centre, PO Box 72, 7131 Faure, South Africa

C:H layers are of great technological interest due to their unusual properties and structures [1]. Depending on the deposition parameters one may form hard amorphous carbon-hydrogenated compounds (a-C:H) in which the H:C ratio is about 0.5 or polymer-like soft layers where the H:C ratio may be larger than 1.

The films analyzed have been about 3$\mu$m thick plasma deposited polymer-like a-C:H films on silicon substrate [2]. The ERD analysis was performed using a 200 MeV iodine beam.

The energy spectra of the recoils have been stored separately after each analyzing fluence of $5{\cdot}10^{11}\frac{ions}{cm^2}$. Fig. 1 shows the energy spectra of carbon, corresponding to a total fluence of $5{\cdot}10^{11}\frac{ions}{cm^2}$, $1.5{\cdot}10^{12}\frac{ions}{cm^2}$ and $3.0{\cdot}10^{12}\frac{ions}{cm^2}$.

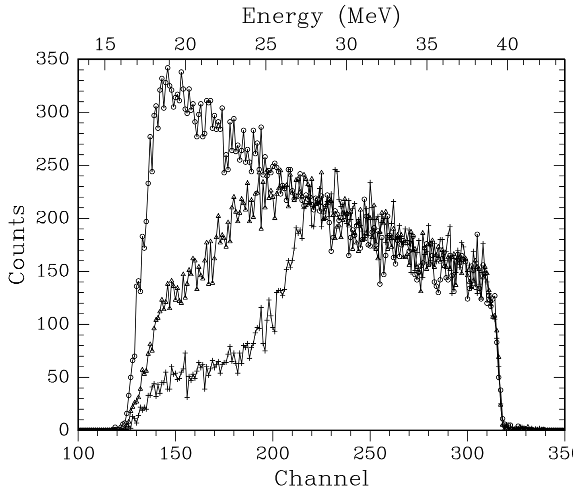


Fig. 1: Carbon energy spectra corresponding to a total fluence of $5{\cdot}10^{11}$ I-ions/cm$^2$, $1.5{\cdot}10^{12}$ I-ions/cm$^2$ and $3.0{\cdot}10^{12}$ I-ions/cm$^2$

From the integrals of these spectra the total amount of hydrogen and carbon versus accumulated fluence can be deduced. Fig. 2 shows the decrease of both, the amount of hydrogen and of carbon versus analyzing fluence in a semi- logarithmic plot. The measured points can be best fitted by an exponential decrease with [3]:

$$N_H(t) = N_{H,0} \cdot \exp^{-\sigma_H \cdot \Phi \cdot t};\ N_{H,0} = 1.92 \cdot 10^{19} cm^2$$
$$\sigma_H = 4.33 \cdot 10^{-13} cm^2$$
$$N_C(t) = N_{C,0} \cdot \exp^{-\sigma_C \cdot \Phi \cdot t};\ N_{C,0} = 1.64 \cdot 10^{19} cm^2$$
$$\sigma_C = 1.96 \cdot 10^{-13} cm^2$$

Here $\Phi$ is the ion flux in $\frac{ions}{cm^2 s}$, t is the measuring time in sec. $\sigma_H$ and $\sigma_C$ are release cross sections in $cm^2$. The decrease of hydrogen is larger than the decrease of carbon. This means that the hydrogen concentration of the remaining film can be described by:

$$c_H(t) = c_{H,0} \cdot \exp^{-\sigma \cdot \Phi \cdot t};\ c_{H,0} = \frac{N_{H,0}}{N_{H,0} + N_{C,0}} \approx 0.54$$
$$\sigma = \sigma_H - \sigma_C \approx 2.37 \cdot 10^{-13} cm^2$$

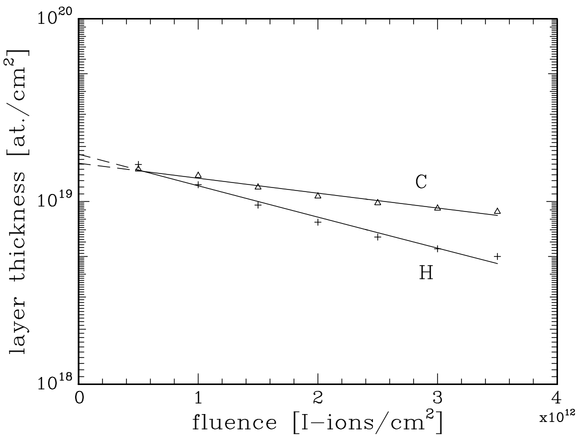


Fig. 2: Decrease of the amount of H and C in the a-C:H layer as a function of the analyzing fluence for ERDA measurements with 200 MeV I-ions

Extrapolating the fits to zero fluence yields a hydrogen to carbon ratio for the not irradiated sample of approximately 1.2. The initial sputtering yield $Y_H$ for hydrogen can be calculated to be $7.5 \cdot 10^6 \frac{H-atoms}{I-ion}$, whereas calculation of the initial erosion yield $Y_C$ of carbon gives $Y_C = 3.1 \cdot 10^6 \frac{C-atoms}{I-ion}$.

These enormous sputtering yields result for the maximum fluence of $3.5 \cdot 10^{12} \frac{I}{cm^2}$ in a macroscopic erosion of a 1.5$\mu$m thick layer from the investigated sample. The sputtering yield measured for carbon is much larger than would be expected from collision cascade theory [4]. In addition according to collision cascade theory the sputtering yield should not decrease with bombarding fluence. This indicates that the erosion of carbon is most likely due to building of anti-bonding states by electronic excitation and formation of volatile molecules such as $C_xH_y$ [5].

Additional measurements of a-C:H films with different surface coatings and higher analyzing fluences are planned to further study the erosion mechanism.

## References

[1] J. C. Angus, P. Koidl, and S. Domitz, Plasma Deposited Thin Films (CRC, Boca Raton, FL, 1986), Chap. 4

[2] A. von Keudel, A. Möller, J. Appl. Phys. **75(12)** (1994) 7718

[3] R. Behrisch, V. M. Prozesky, H. Huber, W. Assmann, Proc. of 12th Int. Conf. on Ion Beam Analysis, Tempe, AZ, USA, 1995

[4] R. Behrisch (ed.), Sputtering by particle bombardement I, Topics in Applied Physics, Vol 47, Springer, Berlin, Heidelberg, New York, 1981

[5] J. Roth, E. Vietzke and A.A. Haasz, Nucl. Fusion Supplement **1** (1994) 63