Detection of hydrocarbon radicals during plasma etching

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Optical emission spectroscopy is used to study and monitor the plasma etching of hydrogenated amorphous carbon (*a*-C:H) thin films.

Introduction

Thin layers of carbon impurities are found on optical components in both fusion reactors and lithography devices, thereby reducing the reflectivity of the mirrors (1). Plasma etching has been proposed as a method to remove these impurity layers without damaging the optics. Optical emission spectroscopy is a suitable tool for *in situ* monitoring of the etch process.

Experimental conditions

At the Eindhoven University of Technology (TU/e) a cascaded arc is used to created a low energetic argon plasma jet (2). This jet expands into a low pressure vacuum system, whereby H_2 is admixed via the background. Charge transfer (CT), followed by dissociative recombination (DR) is responsible for the production of excited H* radicals.

$$Ar^+ + H_2 \rightarrow ArH^+ + H \quad \text{(CT)}$$
$$ArH^+ + e^- \rightarrow Ar + H^* \quad \text{(DR)}$$

A second, albeit slower, loss channel for the Ar^+ ions is three body recombination:

$$Ar^+ + e^- + e^- \rightarrow Ar^* + e^-.$$

Samples of *a*-C:H, deposited at the TU/e (3), are exposed to these H radicals and remaining argon ions. During exposure, light from the plasma is imaged by a lens (f: 5.7 ± 0.2 cm) onto a fiber and coupled to a four channel spectrometer (AvaSpec-2048-4-DT).

Results

The emission spectrum during plasma etching is shown in figure 1, whereby the lines above 690 nm are attributed to argon. The first two Balmer lines, i.e. H_α (656 nm) and H_β (486 nm), and the CH band emission are clearly visible as well.

Both the CH and C_2 emission are only visible during carbon etching. In particular, the time evolution of the band head of the CH(A-X) transition at 431 nm is used to monitor the presence of the *a*-C:H film. A sharp drop in emission is observed when it is totally eroded.

With a lifetime of 700 ns, these CH radicals are not directly etched from the surface, but rather produced within the plasma jet in a CT reaction between Ar^+ ions and heavier hydrocarbon etch products (4).

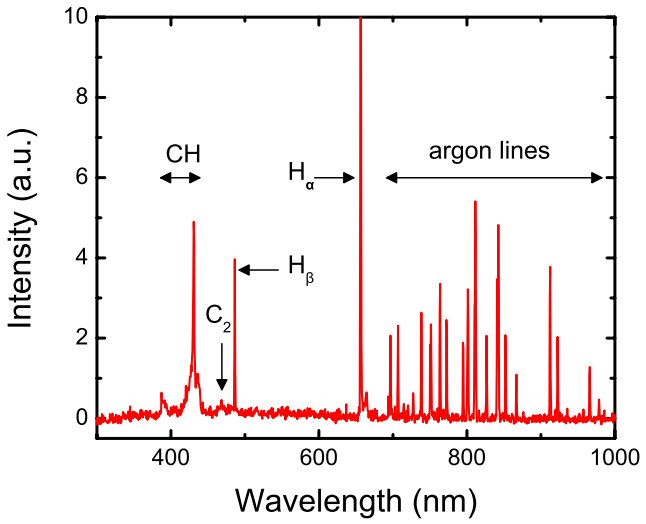

Figure 1: Spectrum during etching of an *a*-C:H sample, acquired with 1.3 nm resolution, 1 s integration time and averaged over 10 scans. H_α is in saturation.

Conclusions

Both CH and C_2 radicals, produced within the plasma jet, are detected during plasma etching of hydrogenated amorphous carbon. The CH emission is used to monitor the lifetime of such carbon layers.

References

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