INFRARED-SPECTROMETRIC MONITORING OF THE GROWTH AND SURFACE TREATMENT OF NANOPARTICLES IN A LOW-PRESSURE PLASMA

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A capacitively coupled plasma is used for generating and confining carbon nanoparticles from acetylene (C_2H_2) for subsequent surface treatment with hydrogen and deuterium. The surface chemistry is then analyzed using fourier-transform infrared spectroscopy in a multi-pass setup for higher sensitivity.

Due to their unique physical, mechanical, electrical, and optical properties, nanoparticles have found a wide range of applications ranging from drug carriers in biomedicine over catalysts to batteries and solar cells in the last decades. In all of these, fine control over the particle's surface properties as well as the bulk crystallinity is required.

In this contribution, a capacitively couple plasma is used for generation, confinement, and treatment of carbon nanoparticles. Using a mixture of argon and acetylene (C_2H_2) at low plasma power, particles reach a size of about 500 nm after 90 seconds of growth. The charged particles are held in the electric field of the plasma sheath and can be confined easily for multiple hours. Afterwards, the particles are treated with hydrogen and deuterium to passivate their surface. Both the growth process and the particle treatment is monitored in-situ using Fourier-transform infrared spectroscopy (FTIR) over the course of 45 minutes. A multi-pass setup with 24 passes through the plasma chamber is used to maximize the absorption signal. This measurement allows insight into the chemical bonds on the particle surface as well as in the bulk material. Additionally, using the electrostatic particle extractor system (EPEX) created in our group [1], particle samples are extracted at multiple moments during the treatment for further SEM analysis with negligible disturbance of the plasma.

Fig. 1 shows the FTIR spectra of plasma-confined hydrocarbon nanoparticles during an etching experiment with D_2 gas admixture to the argon gas. Nanoparticle etching and the changes of the chemical groups can be observed. Additionally, the time evolution of the absorption lines is shown in Fig. 2. The same experiment has been repeated with H_2 and the differences as well as SEM images of the etched particles will be presented in the presentation.

In the future, surface modifications of silicon, metal, or metal-oxide nanoparticles generated in external plasma sources will be studied, which will allow further insight into the dynamics of surface oxidation, passivation, and thin-film deposition.

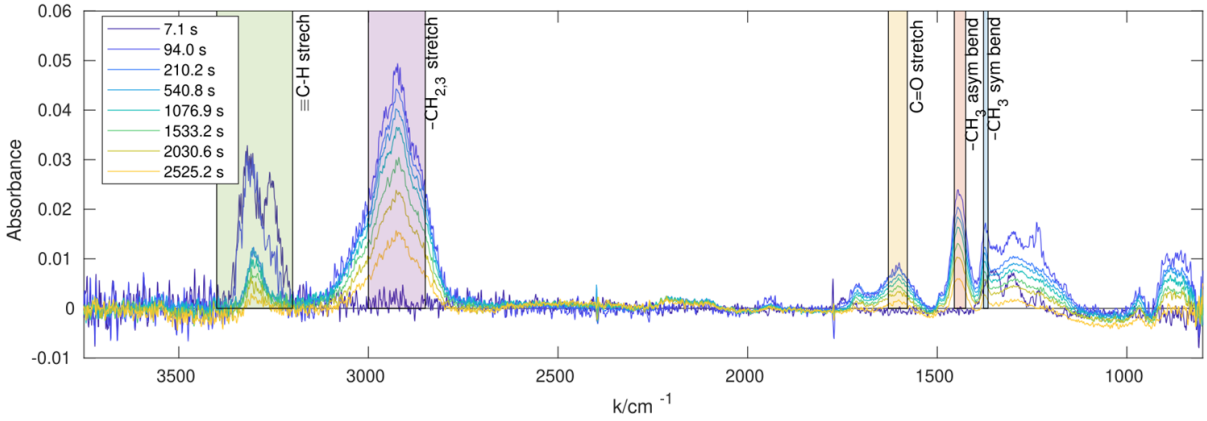

Fig. 1. Infrared absorption spectrum of a-C:H nanoparticles. The particles were generated by admixing acetylene for the first 90 seconds of the measurement. Starting at t = 210 s, deuterium was admixed to the plasma to initiate surface passivation. Regions of relevant absorption lines are labelled according to [2].

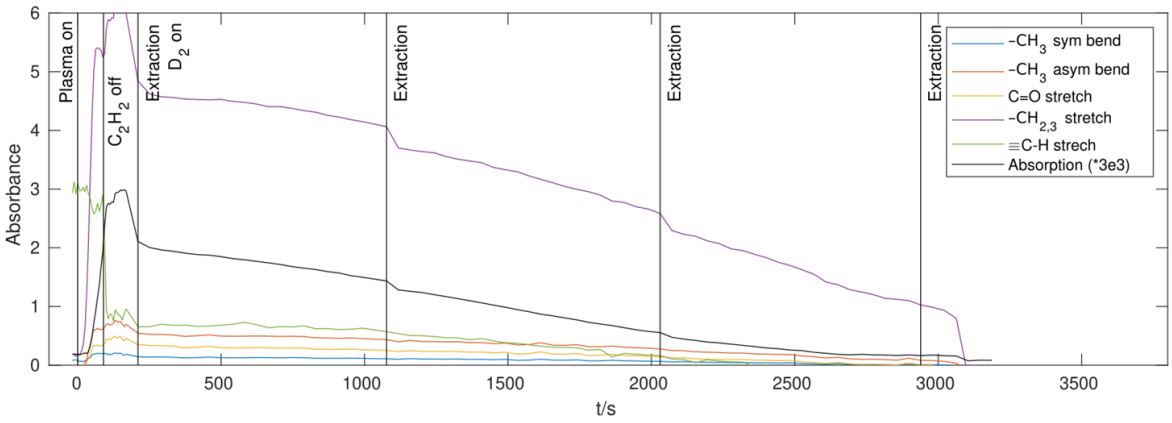

Fig. 2. Time evolution of the marked absorption lines from the spectra shown in Fig. 1. Additionally, the absorption coefficient from the Rayleigh fit is shown in black. The etching and subsequent size decrease of the particles can be seen in both the absorption coefficient and the general absorption intensities.

References

[1] M. Dworschak, O. Asnaz, and F. Greiner (2020). *Plasma Sources Sci. Technol.*, (submitted).
[2] E. Kovačević, I. Stefanović, et al. (2003). *Journal of Applied Physics*, 93(5), 2924–2930.