HIGH RATE PECVD OF A-C:H COATINGS IN A HOLLOW CATHODE ARC PLASMA

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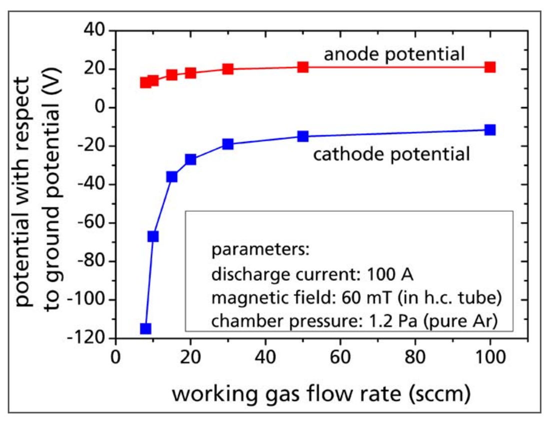
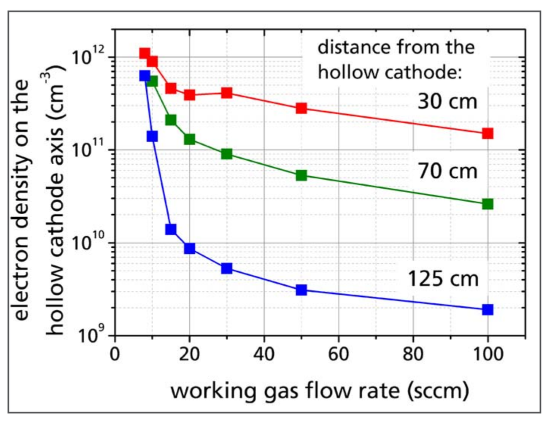
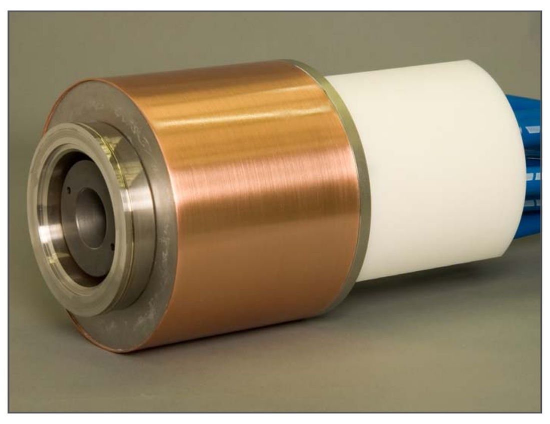
INTRODUCTION

ARC HOLLOW CATHODE »LAVOPLAS«

- large volume plasma source (plasma density of 10^{10} ... 10^{12} cm^{-3} in a volume of several 100 l)
- magnetic field allows for reduced working gas flow → strongly increased plasma density and range
- applications: plasma etching, plasma-assisted evaporation (e.g. Al) and reactive sputtering (e.g. CrN)







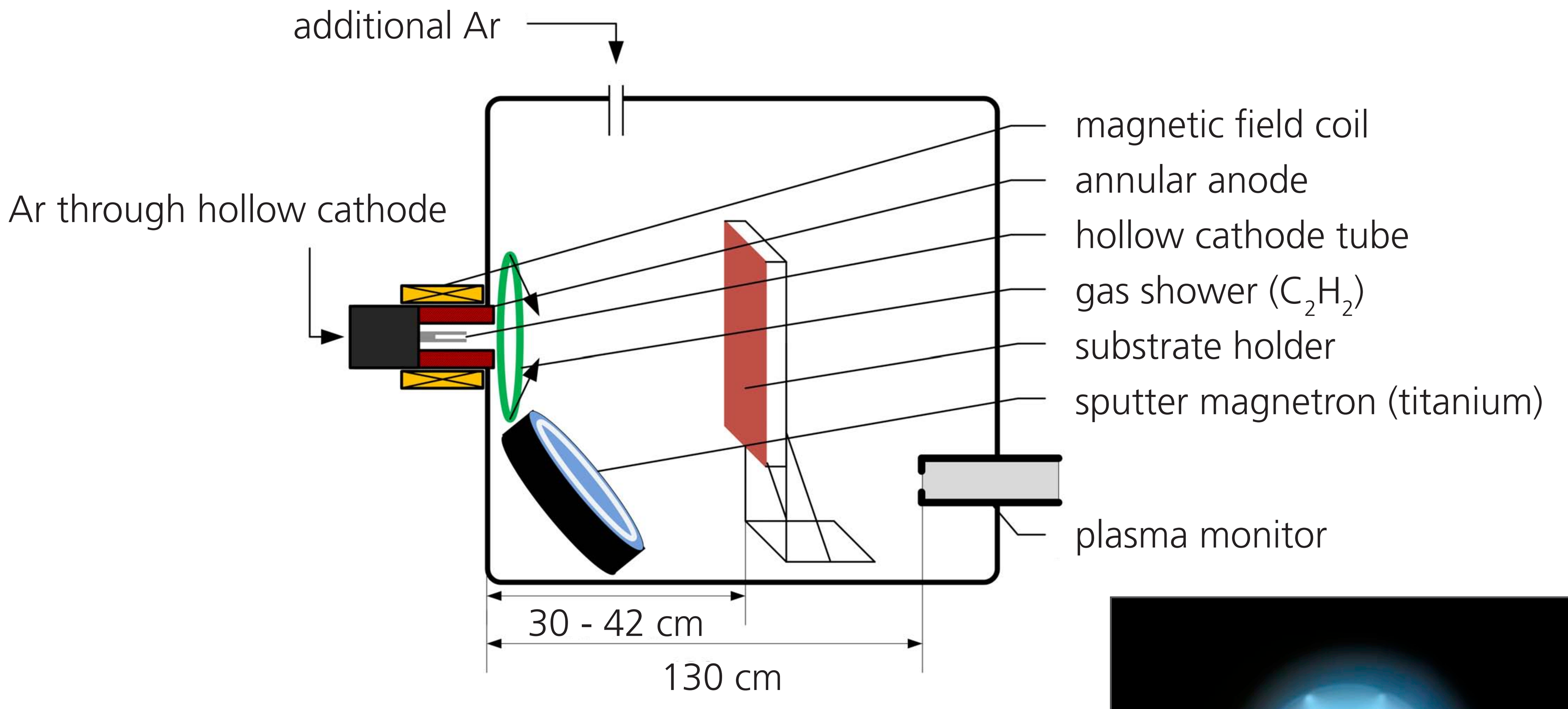
AMORPHOUS HYDROGENATED CARBON (A-C:H) FILMS

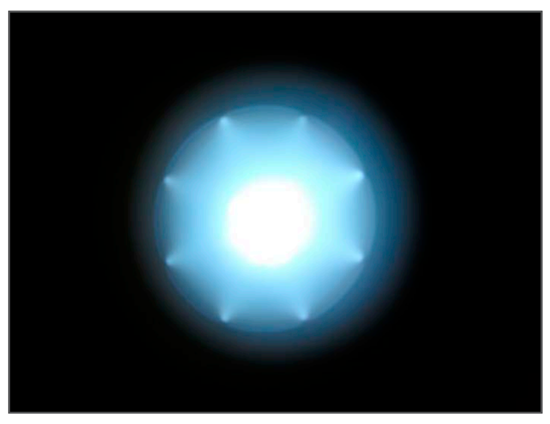
- 3 types of a-C:H: polymeric, graphitic, diamond-like carbon
- typical applications: tribological coating reducing wear or friction; biocompatible coating (implants)
- common deposition techniques: RF PECVD, (reactive) magnetron sputtering, arc evaporation

HOLLOW CATHODE ARC PECVD

- high rate PECVD: efficient activation of acetylene for a-C:H deposition with rates of up to 1 µm/min
- suitable for coating of large areas as well as 3D components

EXPERIMENTAL SETUP

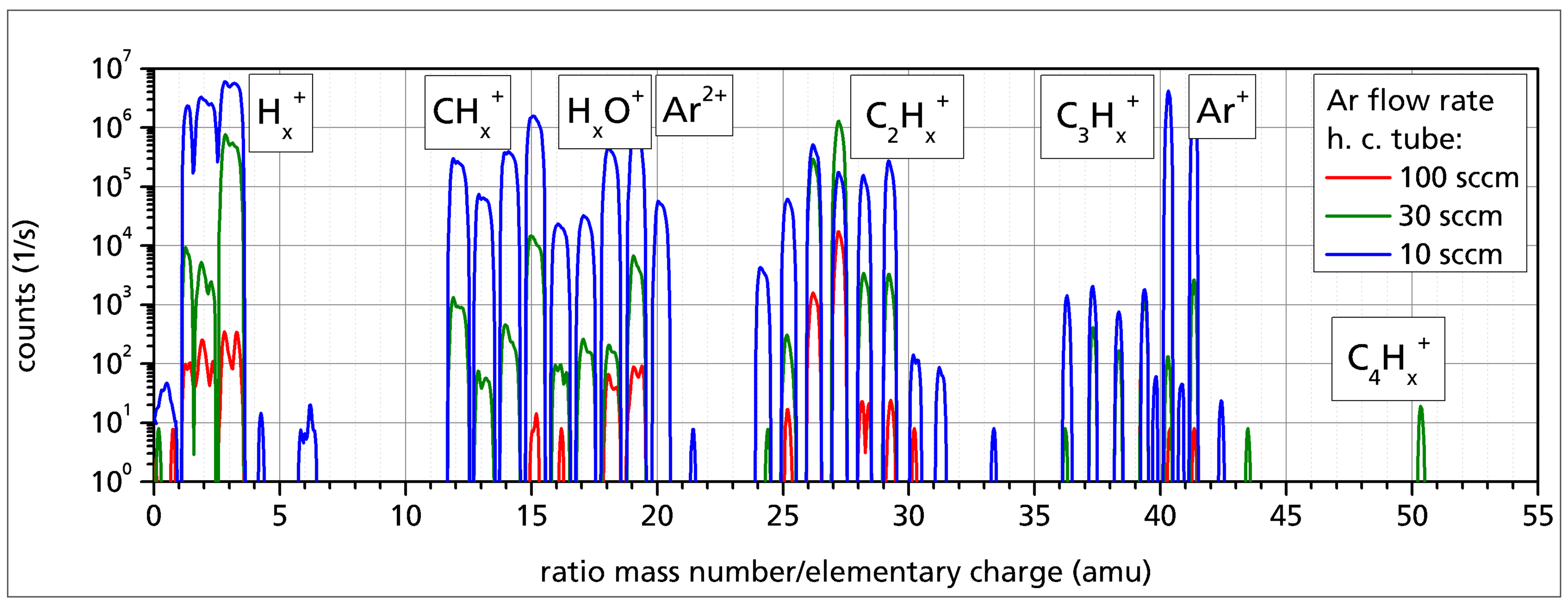




- water-cooled substrate holder
- plasma monitor: energy-resolved mass spectrometer PPM 422, Balzers Instruments
- sputter magnetron PPS 5 equipped with titanium target

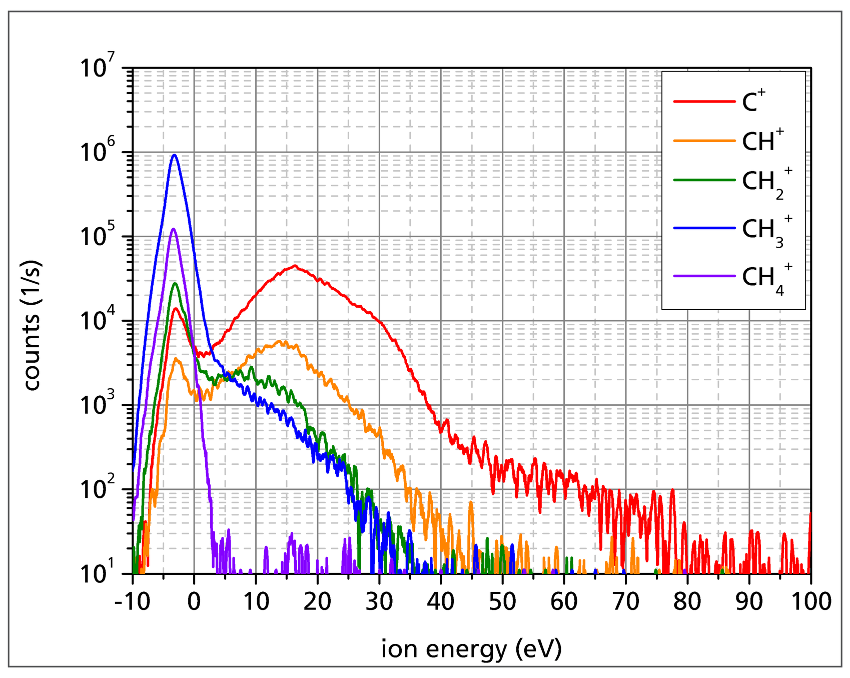
PLASMA CHARACTERIZATION: ENERGY-RESOLVED MASS SPECTROMETRY

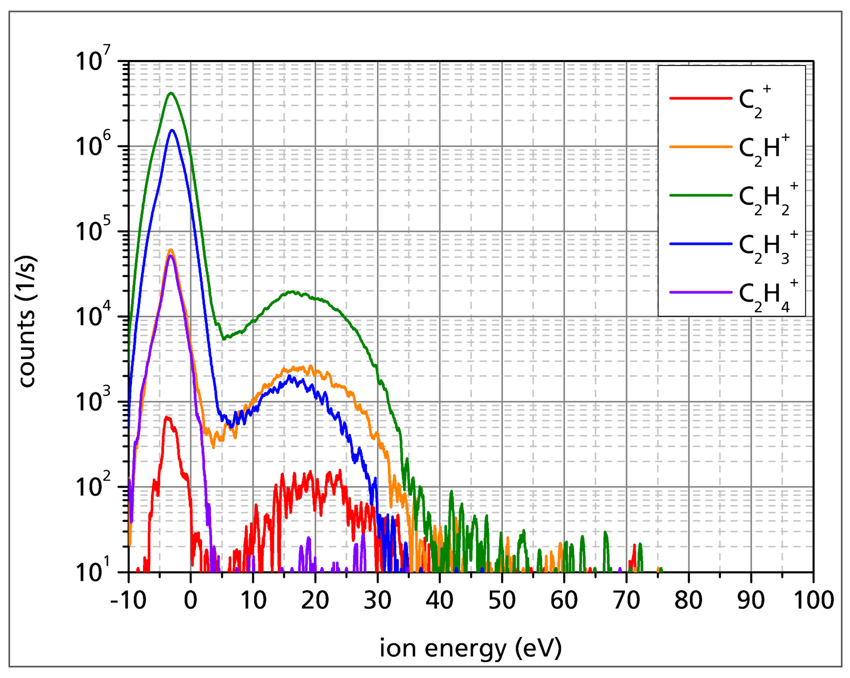
The reduction of the working gas flow rate (argon through the hollow cathode tube) leads to strongly increased acetylene (C_2H_2) dissociation. In the mass spectrum depicted below, signals recorded at three different values of working gas flow rate are shown. Signals of dissociation and polymerization as well as of hydrogenated residual gas and of working gas can be identified and the signal intensity increases with decreasing flow rate through the hollow cathode.



(discharge current 100 A, magnetic field 60 mT, constant argon/acetylene flow rates 100/200 sccm, 0.3 Pa)

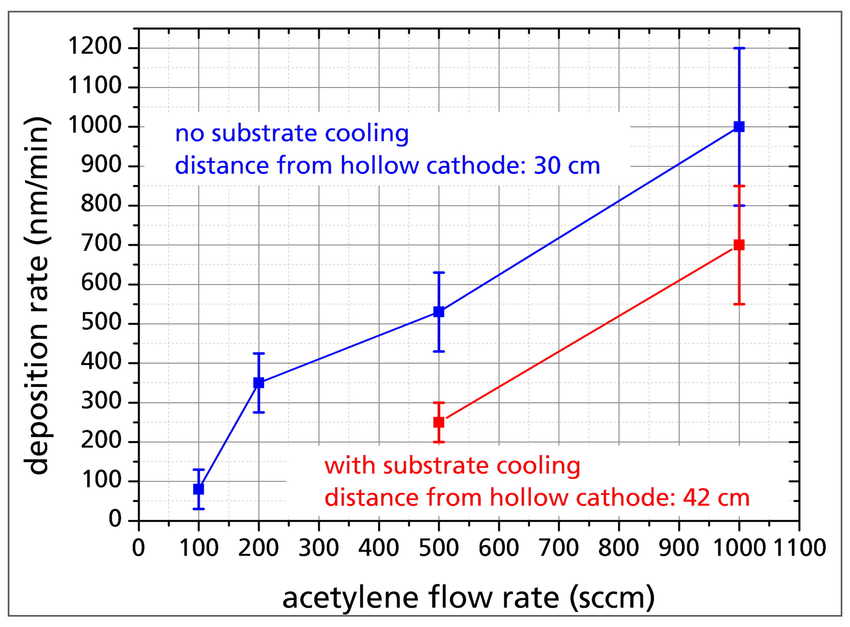
The ion energy distributions consist of a low energy peak (plasma potential: ions from the bulk plasma) and high energy tails (ions generated in the hollow cathode/anode vicinity at elevated potential). From the energy distribution shape of each single species (see depicted distribution functions), it can be derived that whereas dissociation is stimulated by high energy electrons near the hollow cathode orifice, polymerization predominantly takes place in the bulk plasma.

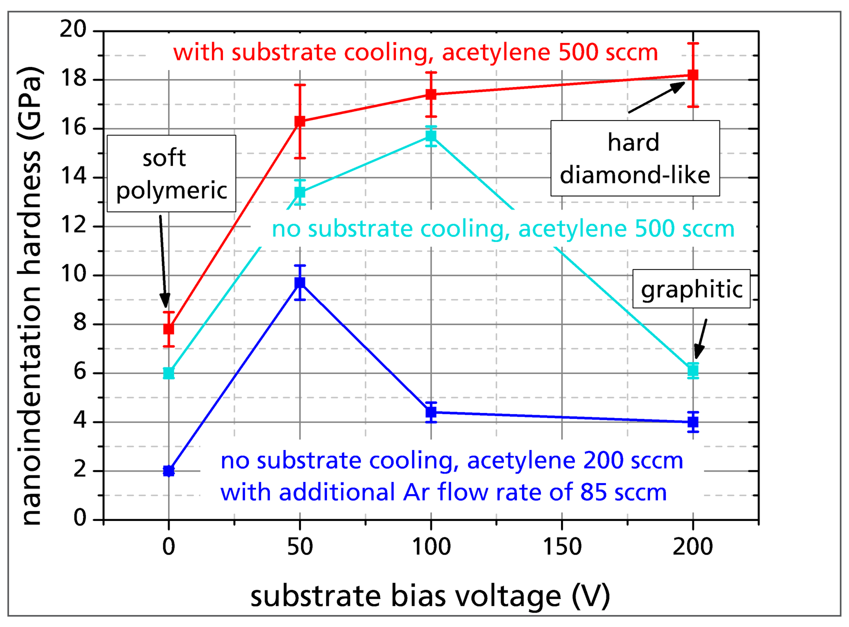




(discharge current 100 A, magnetic field 60 mT, argon/acetylene flow rates 15/200 sccm, 0.1 Pa)

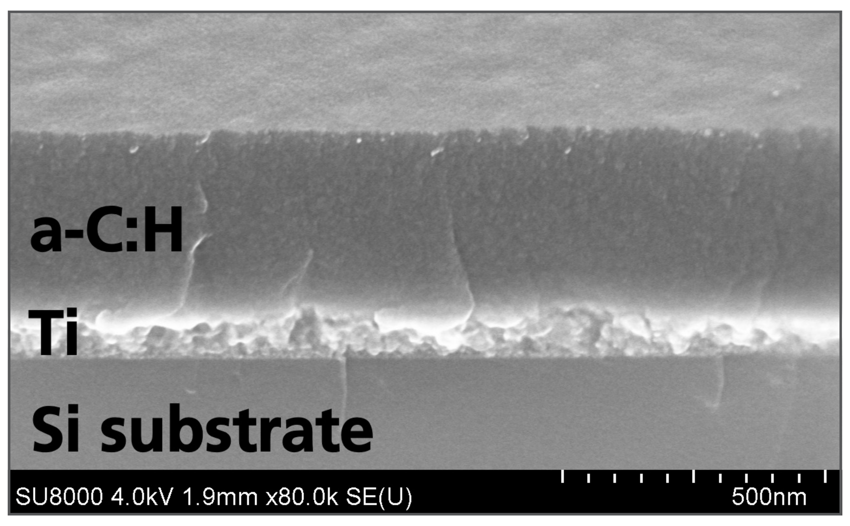
A-C:H FILM DEPOSITION AND ANALYSIS





A-C:H DEPOSITION ON GLASS, STAINLESS STEEL, AND N-DOPED SILICON WAFER

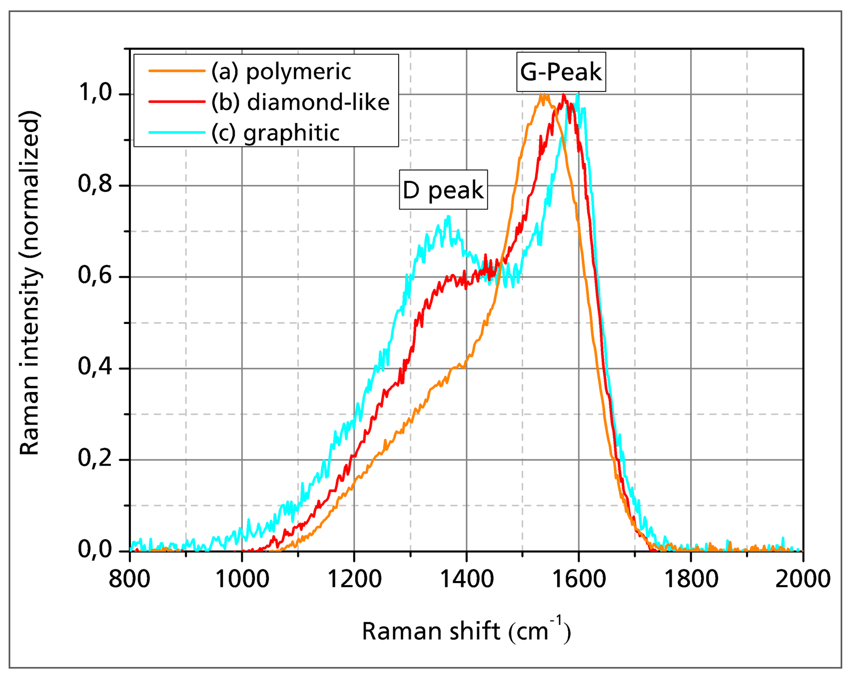
- hollow cathode-based plasma pre-treatment
- sputtering of 100 ... 200 nm titanium as sublayer
- arcPECVD of a-C:H (discharge current 100 A, magnetic field 60 mT, argon through hollow cathode tube 15 sccm)



The highest nanoindentation hardness has been reached in the case of substrate cooling and high substrate bias voltage (**diamond-like** a-C:H, substrate temperature up to 290°C). The content of hydrogen measured by elastic recoil detection analysis and Rutherford backscattering spectrometry (ERDA/RBS, with 1.7 MeV He^+ ions) as well as of the sp^3 sites obtained by Raman spectroscopy (see right figure) has been found to be medium. Scanning electron microscopy (small figure) reveals a dense microstructure and a smooth surface of the coatings.

Without substrate bias, soft **polymer-like films** have been produced with high hydrogen and sp^3 contents, respectively, as the hydrogen atoms are predominantly bonded by sp^3 sites to carbon atoms.

Without substrate cooling, high substrate temperatures of ca. 500°C were reached due to thermal load at high bias voltages resulting in **graphitic** film properties. The values of hardness, hydrogen and sp^3 content are low in this case.



film character	thickness (nm)	hardness (GPa)	H content (at.-%)	sp^3 content (%)
polymeric	250	7.8	42	40
diamond-like	250	18.2	31	25
graphitic	500	6.1	18	20

CONCLUSIONS

ArcPECVD has been found to be a versatile PECVD technique with very high deposition rates and simple technological assembly. Energy-resolved mass spectrometry reveals plenty of dissociation and polymerization products in the argon acetylene plasma; the energy distribution of the ions depends on the spatial distribution of their origin. A-C:H layers with a film hardness of up to 18.2 GPa have been deposited. First deposition experiments on small components treated as bulk good have been carried out successfully and will be published elsewhere. The presented results will be described in detail in a paper submitted to *Surface and Coatings Technology*.

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