Growth and dynamics of amorphous-C:H nanodust in a magnetized plasma

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Production of nano-particles by an in-situ plasmachemical process of flourocarbons, silan, methan or acetylene in an argon plasma radio frequency (rf) discharge is a well known technique [1, 2]. For acteylene (C_2H_2), the processing creates a dusty plasma with nearly monodispers, amorphous hydrocarbon (a-C:H) particles. The dwell time of the particles in the plasma bulk critically depends on the particle size. However, if the growth of the particles is stopped, e.g., by switching off the acetylene flow, the particles stay in the plasma for a long time and can be used for the investigation of the dynamics of (nano) dusty plasma.

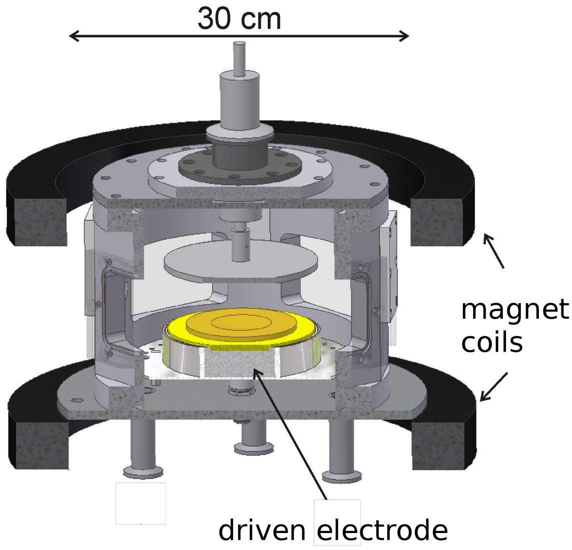

Figure 1: The plasma chamber is a parallel plate reactor. The lower electrode is driven with 13.56 MHz. A set of coils produces a homogenous magnetic field.

Nanodust cannot be observed by standard video microscopy, which is the main diagnostic workhorse of dusty plasma diagnostics for micrometer sized dust particles. This means that the investigation of the detailed dynamics of a single particle is not possible in the sub-micron range. Nevertheless, video microscopy can be used to investigate the global dynamics of nano dust clouds. To get informations about the size of the grown particles, Mie ellipsometry is a well established technique [3, 4]. The dust density can be estimated by laser extinction measurements [5].

Adding a magnetic field to a plasma containing nano-particles leads to new effects, e.g., global instablilities of the plasma [6] or additional *ExB* forces [7]. In this contribution we present investigations of a-C:H nano-particle production in weakly magnetized argon-acetylene radio frequency (13.56 MHz) plasma at low pressure. The experimental setup is shown in Fig. 1. A mixture of 10 sccm argon and 2 sccm acetylene is fed into the discharge chamber and the pres-

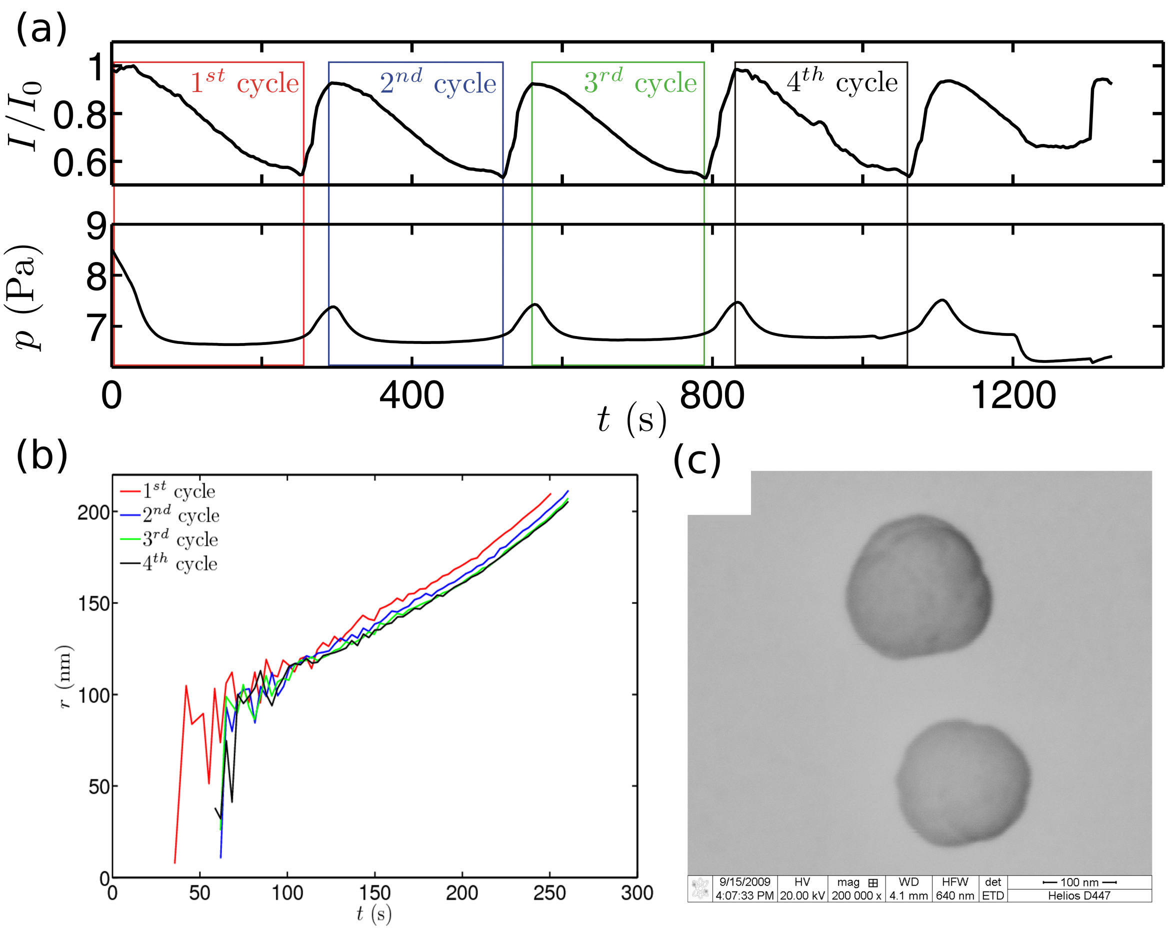

Figure 2: (a) Periodic sequence of particle production. Extinction signal and the external pressure are shown during five cycles of dust production. (b) Size evolution of the a-C:H-particles during four cycles as estimated from Mie ellipsometry. (c) SEM photo of a-C:H-particles.

sure is regulated by the flow of a turbomolecular pump resulting in a total neutral gas pressure of 10 Pa (when the plasma is off). When the rf is switched on, a-C:H particles start to grow in the Ar-C_2H_2 discharge, leading to a periodic process of particle production and particle exhaustion. This process can be observed on all plasma and discharge parameters. Fig. 2(a) shows a laser extinction signal and the total pressure for four periods. The relative extinction I/I_o decreases continuously due to the increased scattering of the laser light at the growing a-C:H-particles. At a minimum extinction signal, which corresponds to the maximum particle size, the extinction signal suddenly increases again. At this time, the entire particle inventory is removed from the discharge and a new production period starts. The total pressure shows a corresponding behavior. During the growth of the a-C:H-particles the total pressure shows the complete consumption of C_2H_2. Only during the short time, where the particles escape from the discharge, the C_2H_2 concentration is slightly increased. With conventional Mie ellipsometer (a 665nm laser and a rotating $\lambda/4$ polarimeter) we are able to measure the ellipsometric angles Ψ and Δ of the scattered laser light. Using Mie theory, one can estimate the complex refraction index and the size of the a-C:H nano-particles from the ellipsometric angles. To get reliable results, it is assumed that the refraction index is constant during the growth process. The estimated particle size evolution over four periods is shown in Fig. 2(b). A comparison with Scanning Electron Microscopy (SEM) gave excellent agreement with the particle size estimated from Mie analysis. The process produces nearly mono-disperse, spherical particles (see Fig. 2(c)).

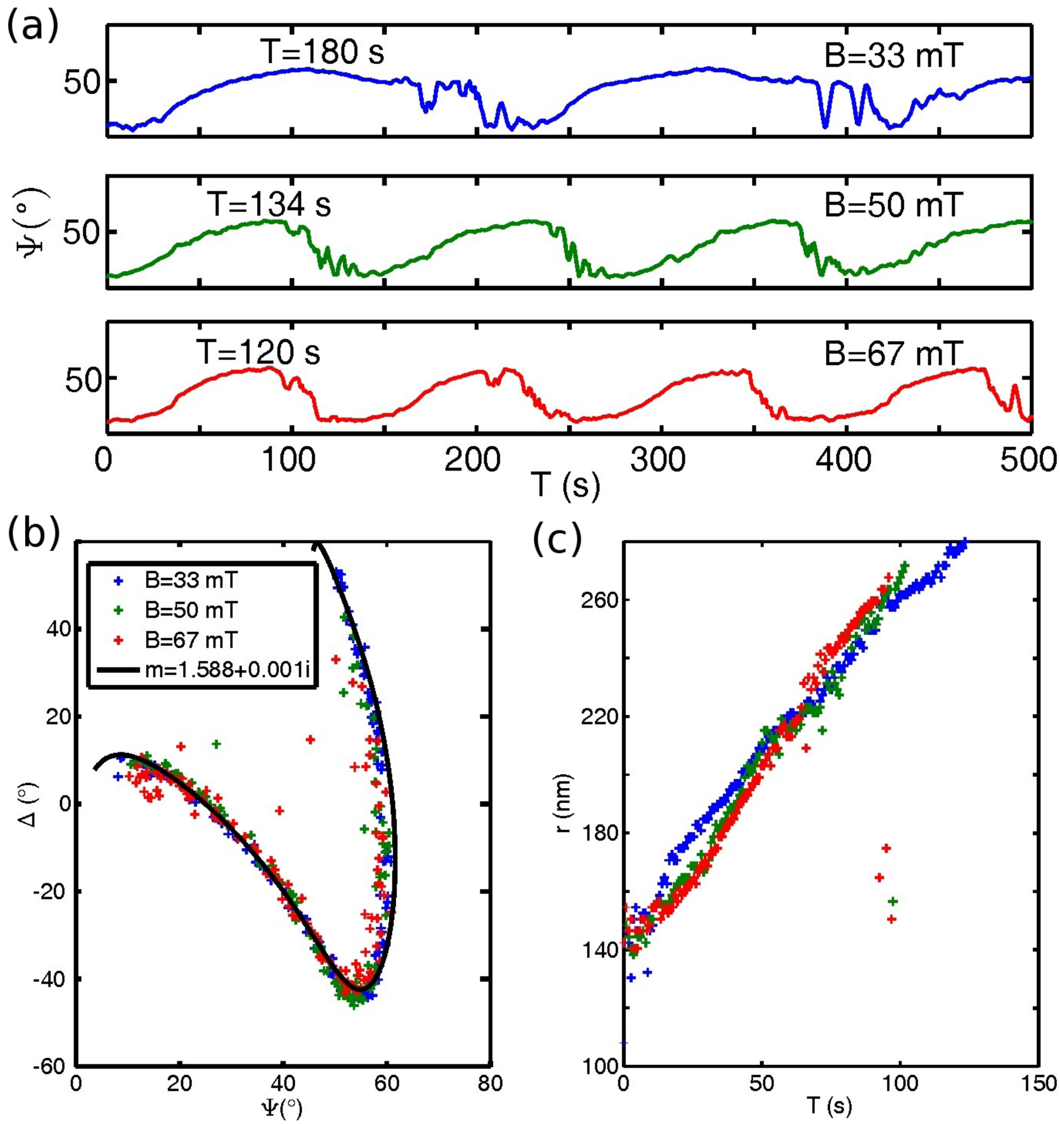

Figure 3: (a) Particle growth over time for different magnetic inductions. (b) Evolution of $\Delta(\Psi)$ for different magnetic inductions (c) Particle size estimated from Mie analysis.

The experiments with magnetic field are also performed at a pressure of 10 Pa. At a magnetic field of about 50mT, the Hall parameter of the electrons $H_e = \omega_{c,e}/\nu_{n,e}$ is $H_e > 1$ ($\omega_{c,e}$ electron

Larmor frequency and $\nu_{n,e}$ electron-neutral collision frequency). The Hall parameter of ions is $H_i < 1$, i e. only the electrons are magnetized. When the magnetic field is switched on, the general periodic behavior remains unchanged. However, if the magnetic induction is increased from 33 mT up to 67 mT, the period of the production process is shortened. This is shown in Fig. 3 (a) for the ellipsometric angle Ψ. There are two candidates that can lead to such a behavior: (i) particle growth is accelerated for higher magnetic fields or (ii) particle exhaustion of the bulk plasma starts earlier for higher magnetic fields. The graph of the ellipsometric angles $\Delta(\Psi)$ (Fig. 3(b)) shows that the growth curves are indistinguishable for all magnetic fields. Mie analysis can be done for all magnetic fields with the same complex refraction index and the particle growth evolves in the same way (Fig. 3(c)). Nevertheless, Fig. 3(c) shows the reason for the shorter particle production period at higher magnetic fields: For a higher magnetic field the growth process stops at smaller particle size.

To conclude, we have shown that weak magnetic fields do not influence the particle growth process in an Ar-C_2H_2 discharge directly. The growth dynamic of the a-C:H-particles is unchanged. The magnetic field alters the confinement condition of the particles in the plasma bulk. For higher magnetic field, the particle inventory is exhausted after a shorter growth period. The confinement of nano-particles in a plasma is based on the subtle balance of different forces on the dust particles. For sub-micron dust particles, these forces are mainly the electric field force and the ion drag force. Because a magnetic field is likely to reduce the plasma potential in the center of the discharge, it can be argued, that the shorter production period is due to a reduced confining electric field force.

Acknowledgments

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