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Dust Successive Generations in Ar/SiH_4 : Dust Cloud Dynamics

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Abstract. Silane-based plasmas are widely used to deposit nanostructured silicon thin films or to synthesize silicon nanoparticles. Dust particle formation in Ar/SiH_4 plasmas is a continuous phenomenon: as long as silane precursors are provided, new dust generations are formed. Successive generations can be monitored thanks to various electrical (V_{dc}/3H) and optical (OES, video imaging) diagnostics. Experiments presented in this paper have been performed in a capacitively-coupled radiofrequency discharge, at low pressure (12 Pa) in an Argon/Silane mixture (92:8).

Keywords: Dust particles, silicon, rf discharge, dust cloud, instabilities
PACS: Lw 52.27

EVIDENCE OF DUST SUCCESSIVE GENERATIONS

Thanks to correlation between the current third harmonic (3H), Laser Light Scattering (LLS) and Optical Emission Spectroscopy (OES), dust particle successive generations can be evidenced. They appear as a low frequency oscillation in the signals, with a period of typically one minute. Assuming a void region in the dust cloud, dust successive generations follow a three-step process. First, a void region opens in the dust cloud, where the ionization rate is enhanced and where a new dust particle generation grows. Newly formed dust particles push away bigger (highly charged) ones from the discharge center. Then, newly created dust particles grow in the void region and start to attach free electrons due to their increasing size. They keep on pushing bigger dust particles away, and tend to fill the whole void. After that, the new generation is still growing and now fills the void region. A new void region opens, and a new generation starts to grow inside. The phenomenon is cyclic and starts again as long as precursors are provided [1].

The first correlation between 3H, the LLS signal and the OES one lets think that a void region could appear in the dust cloud. Indeed, the increase in the ionization, before a new generation is detected by LLS, is typical of a void region. Thanks to video imaging, this region of higher ionization can be evidenced, confirming the results obtained by OES. Some spatially resolved depositions have been performed during the successive generations and analyzed using SEM. The combination of the various results is totally consistent with a void region, where new dust particle generations would grow [1].

SUCCESSIVE GENERATION INSTABILITIES

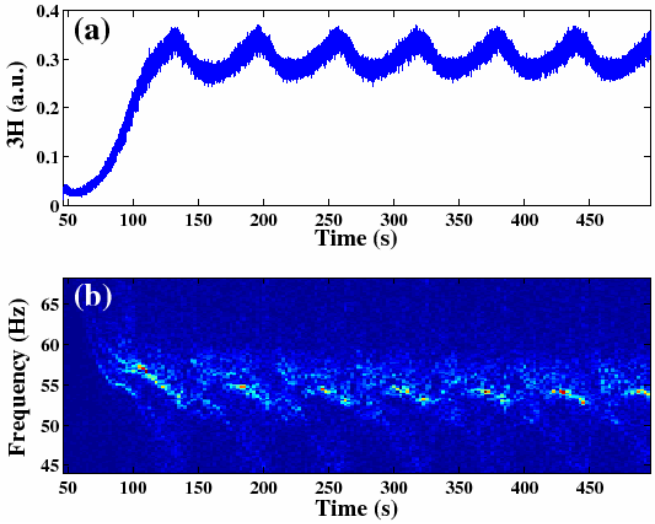

FIGURE 1. (a)Time-evolution of the third harmonic of the discharge current during dust particle successive generations in an argon-silane plasma (b) Spectrogram of 3H during the SGI.

The inner structure of the 3H signal during the oscillations brings to the light its unstable behavior (see fig. 1). Indeed, a self-excited instability is superimposed on the signal and lasts as long as the plasma is on. It begins generally a few seconds after the plasma ignition. Its setting-up appears as a progressive increase of its amplitude. The onset of the instability exhibits a very complex scheme with several frequency-branches in the spectrogram. Actually, the instability is mainly characterized by two very close frequencies that could explain the noticeable modulation of the electrical signal that we observe. This complex scheme is reproducible and does not depend on experimental parameters. When performing a time-resolved FFT of the 3H signal, we obtain a spectrogram as the one in fig. 1b, showing an alternation of highly-ordered and less-ordered phases. Typical frequencies are comprised between 40 and 60 Hz. Ordered phases correspond to dust formation for each new generation. Less ordered phases correspond to dust expelling from the plasma. The SGI are globally not very sensitive to experimental parameters compared to the aggregation instability previously studied in [2, 3]. Comparisons with other self-excited instabilities observed in the PKE-Nefedov reactor and related to the void region [4, 5] are currently underway.

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