Dust particle growth kinetics in a sputtering discharge using Ar or Kr

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A high density of dust particles is grown by sputtering a polymer layer in Ar or Kr plasmas produced in capacitively-coupled radio-frequency discharges. The growth kinetics is compared in these two gases and the characteristics of the instabilities (evolution, frequency, shape) induced by the presence of dust particles are analyzed.

The presence of dust particles was discovered in industrial plasma reactors in the late 1980s [1], and becomes a severe issue for the microelectronics industry. Since then, many studies were developed in the field of dusty plasmas: in the laboratory, dust particles can be generated by using reactive gases [2] or material sputtering [3]. In the present work, experiments are performed in the PKE-Nefedov reactor where dust particles are grown by sputtering a polymer layer previously deposited on the electrodes. Due to the high density of grown dust particles, many unstable behaviors are noticed like dust particle growth instabilities [4] and plasma spheroids in the vicinity of the electrodes [5, 6]. Two different gases are used (Kr and Ar) to compare the growth kinetics and the instabilities induced by the dust particle presence.

This analysis is performed by recording the amplitude of the discharge current (ac and dc components). In Fig. 1, it clearly appears that in both cases, dust particle growth instabilities begin a few tens of seconds after plasma ignition. However, the oscillation amplitude is twice as high for Kr as for Ar.

Different phases are evidenced in both cases, but discrepancies exist in the frequency evolution as shown by the calculated Fourier spectrograms (Fig. 2). To highlight more finely the different phases, the intensity of the spectrogram has been normalized separately on each series of 100 s. In Kr, the frequency increases very quickly and then a chaotic phase appears and lasts for a long time. During this phase, the dominant frequencies can still be detected. Close to the end of the instability, the oscillation becomes more regular and the frequency starts to increase.

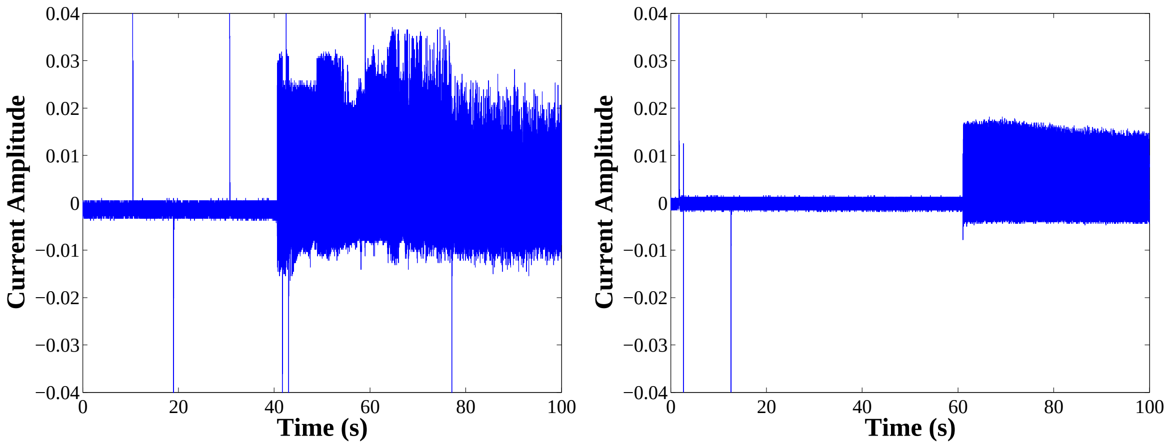

Fig. 1: Amplitude of the rf current (ac component) for (a) Krypton plasma, (b) Argon plasma.

Concerning the Ar plasma, the instability follows globally the same scheme: several regular phases followed by a chaotic regime and another more regular phase at the end. However the details of these regimes are different than in Kr. The fast increase is not observed before the chaotic regime and at the end a frequency decrease is observed instead of an increase as in Kr. It can also be noted that the typical frequencies are globally lower in Ar than in Kr. It is consistent with the observation that the dust particle cloud observed in Ar is less dense and composed of bigger dust particles.

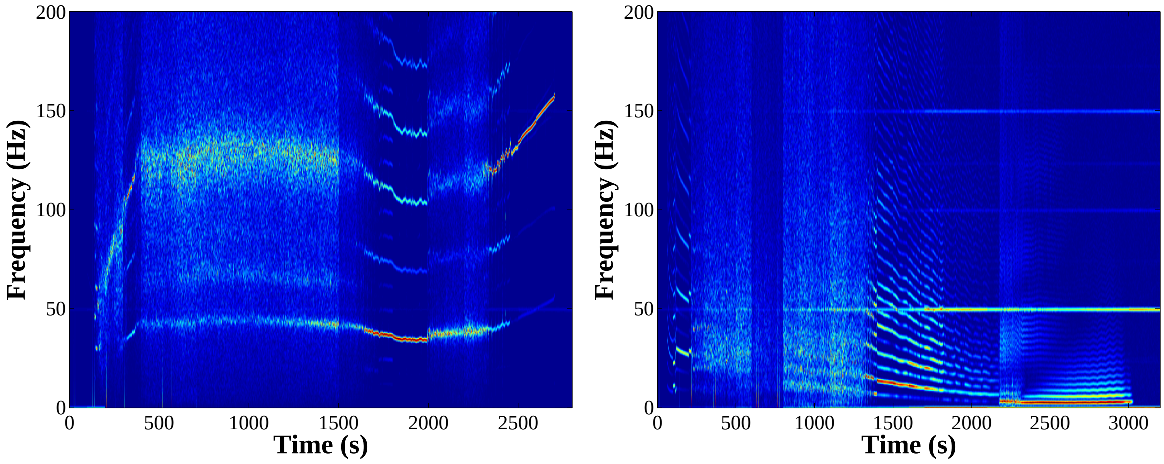

Fig. 2: Fourier spectrogram for the ac component for (a) Krypton and (b) Argon.

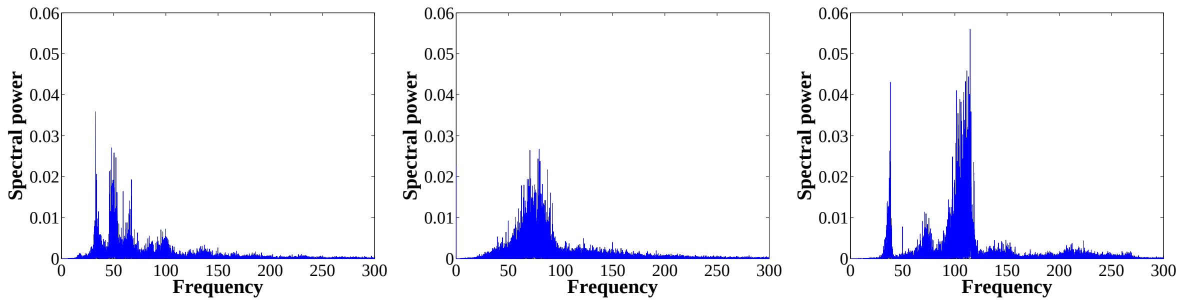

Fig. 3: Evolution of the frequencies during the different regular phases (Kr plasmas) between (a) 40 – 100 s, (b) 100 – 200 s, (c) 200 – 300 s

In Fig. 3, Fourier spectra for Kr plasmas have been calculated to evidence the frequency evolution during the successive regular regimes observed at the instability beginning.

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