Formation of dense submicronic clouds in low pressure Ar-SiH4 RF reactor: diagnostics and growth processes from monomers to large size particulates

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The formation of particulates in low pressure plasma reactors as used for surface processing is connected to homogeneous nucleation or surface clusters desorption phenomena. The first way of formation is evidenced in low pressure Argon-Silane or pure Silane RF plasmas through the results of a cooperative European research.
Specific conditions for particulates growth will be described here: 13.56 MHz parallel plate discharge (13 cm diameter, 3 cm height) in low pressure gas mixture (110 mTorrs Ar, few mTorrs SiH_4), low excitation power (3-10 W) and gas temperatures from 30 to 200 degrees Celsius.
The diagnostics developed in this study include laser multi-angle Mie scattering for particle size above 50 nm and excimer induced light emission for nm scale initial steps of growth. Preliminary results obtained by in-situ FTIR absorption spectroscopy add new insights both on the gas phase chemistry and particulates material. The evolution of the free electron concentration and of the discharge impedance are determined by using microwave diagnostics and V(t),I(t) recordings.
The data show that the formation of dense clouds of particles involves 4 successive steps: clustering of negative ions, formation of dense clouds of nm size crystallites, coalescence to few tens nm particulates and finally a final step of growth by deposition of a-Si:H on the electrically isolated particles trapped in the discharge. A drastic transition of plasma and discharge properties arise during the coalescence step of dust formation. The gas temperature appears as a highly sensitive parameter to reach the conditions of the coalescence step and the formation of particles. Modeling of growth kinetics is under way but a full self-consistent model taking into account the coupled evolution of particles and plasma parameters remains a rather difficult task.
Particulates processing by changing the plasma chemistry (N_2 or CH_4 post treatments) is readily possible. An in-situ analysis of material modification and new particle synthesis are described.