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Detection in the nanometer scale of particles generated in an Ar-SiH_4 radiofrequency low pressure discharge

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ABSTRACT The underlying phenomena leading to particle formation and trapping in plasma reactors are extensively studied as they are involved as a major pollution in many technological areas including etching and thin films deposition processes. Different aspects dealing with the particle formation in a low pressure radiofrequency (RF) discharge have been studied and are reported in this paper. The first aspect concerns the particle nucleation and growth. These particles are in general detected by light scattering. Nevertheless this method has clear limitations in terms of particles size. We developed a new powerful methode to detect particles in the nanometer scale. The results obtained give information on the first stage of the formation and growth process.

Particle formation in plasma reactors has been observed and studied in a wide variety of situations such as low pressure etching[1], sputtering[2], and plasma enhanced chemical vapor deposition (PECVD)[3]. It has been recognized that their occurrence and trapping in the plasma is a key problem for the ULSI technologies and also a limiting effect when trying to achieve high deposition rates with good thin films quality. In this contribution we focus our interest on both particle nucleation and growth and their effects on the plasma properties.

Particles appearing in plasma processing devices, or laboratory plasmas, are in general detected by light scattering (LLS). The (R^6/λ^4) law (Rayleigh scattering), in the small particle size domain, leads to a size limitation of scattering as diagnostic technique. For example using the blue (488 nm) line of the Ar^+ laser, the scattered intensity becomes observable at about 2s. At this time the particle mean size (diameter) is about 20 nm[4]. Clearly

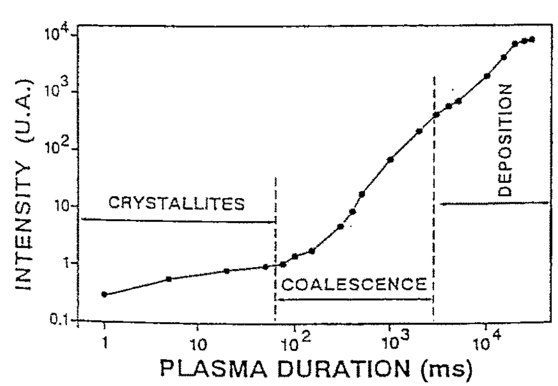

Fig. 1: Time *evolution of LIPEE emission intensity*

another method is required for the detection of much smaller (2 nm) particles. An in situ diagnostic, complementary to the light scattering, has been developed by E. Stoffels et al.[5] They showed that particles could be detected with high sensitivity by laser heating of particles and recording black-body emision. In this contribution we present a powerful method for particle detection in the nanometer scale based on UV excimer laser induced particle explosive evaporation (LIPEE)[6] and the results obtained concerning the initial phase of particle formation in a low pressure radiofrquency Ar-SiH_4 discharge. In the LIPEE experiment the white light emission induced (in the plasma reactor) by a pulsed XeCl excimer laser (power 200 MW/cm^2) appears to be a powerful way to detect very small size entities.

Figure 1 shows the evolution of the signal LIPEE corresponding to short plasma durations. Two well-defined phases are observable. The first one corresponds to the LIPEE emission induced by crystallites which are rapidly formed (within a few ms) when the discharge is switched on. The fast increase, observed here at about 150 ms, corresponds to the beginning of the coalescence step[4]. A study of the effect of the temperature on particle appearance and LIPEE signal confirms this interpretation. Figure 2 shows the time evolution of LIPEE emission intensity for different gas temperatures. The most important conclusion we can formulate is that the higher temperatures delay the appearance of the crystallites. When they appear they grow as explained above.

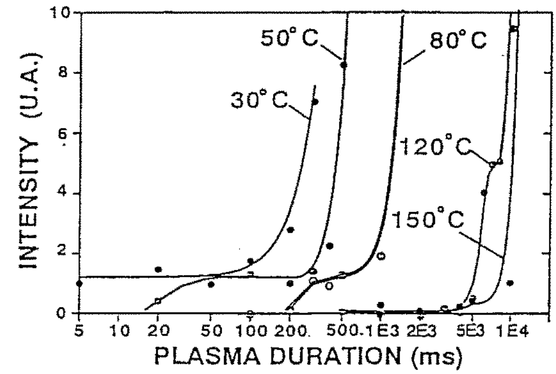

Fig.2: Time *evolution of LIPEE emission intensity for different temperatures*

The particle growth in silane plasmas is a rather well defined multistep process. The initial step corresponds to the formation of crystallites (2 nm). This first step has been clearly evidenced by the excimer laser induced fluorescence performed on the particles. Up to now the coalescence mechanisms are qualitatively but not quantitatively understood.

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