CHARACTERIZATION OF PLASMA DEPOSITED CARBON-SILICON OXIDE THIN FILMS

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Abstract

Silicon oxicarbide thin films growth by plasma enhanced chemical vapor deposition (PECVD) is presented. The proposed technique is versatile, allows large-scale treatments and has the advantage to be easy to implement. The proprieties of films composition and morphology are investigated to understand to effect of the deposition parameters.

Experimental set-up

A low-pressure low-temperature plasma of Argon and Oxygen is employed to dissociate a volatile organosilicon compound, the hexamethyldisiloxane (HMDSO, Fulka $\geq$98%). An inductively coupled plasma is generated inside the deposition chamber by a cylindrically bent antenna (CCR Technologies Gmbh) connected to a RF 13.56 MHz power generator at 300 W.

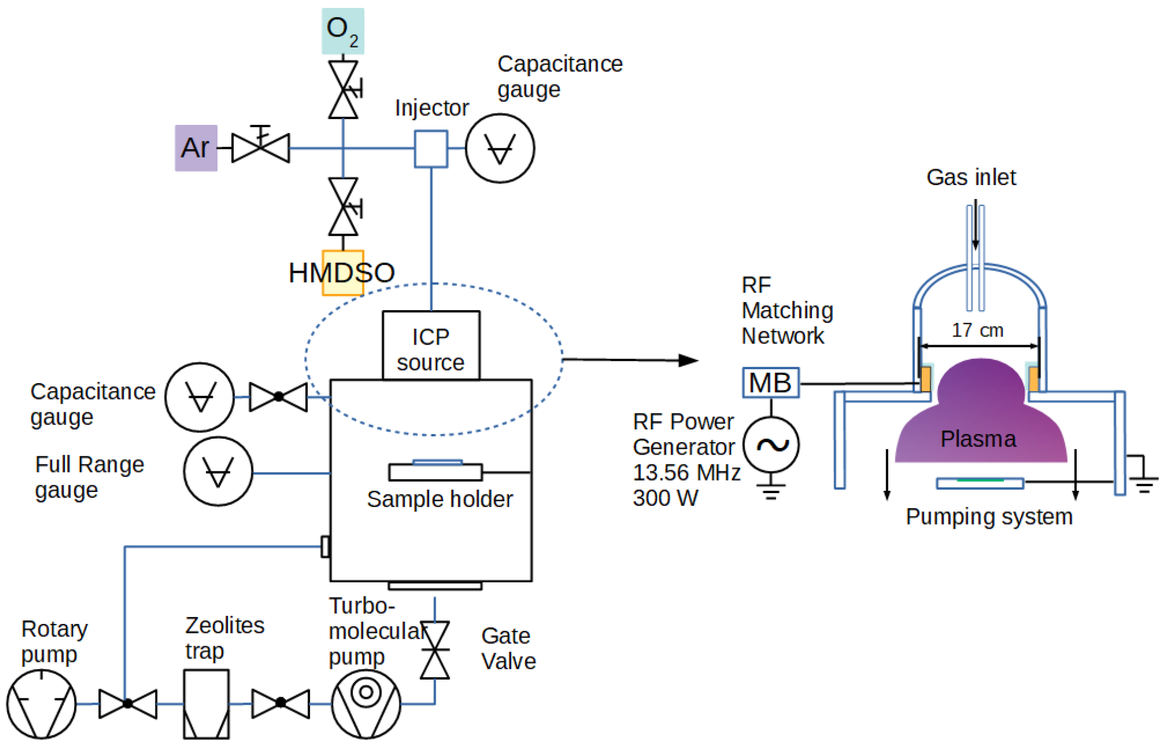

Figura 1: Schematic diagram of the deposition system and the ICP plasma source.

The vacuum vessel, the sample holder and the substrates are grounded.
A sheath is formed between the plasma and the sample holder and the sheath potential is 5-10 V lower than the plasma potential, while the electron temperature is 1-2 eV [1].

Methods

The influence of certain key parameters has been investigated. The plasma pressure in the deposition chamber is chosen between $3{\cdot}10^{-2}$–$3{\cdot}10^{-1}$ mbar. The starting mixtures for the deposition process differ in partial pressures of in-going gases, HMDSO has been varied from 10 to 40% of the total treatment pressure and the O_2:Ar ratio from 3:1 to 0:1. Deposition time is 10-30 min. The substrates are Si(001) wafers, aluminium foils and alumina slabs, placed directly within the diffuse plasma region.

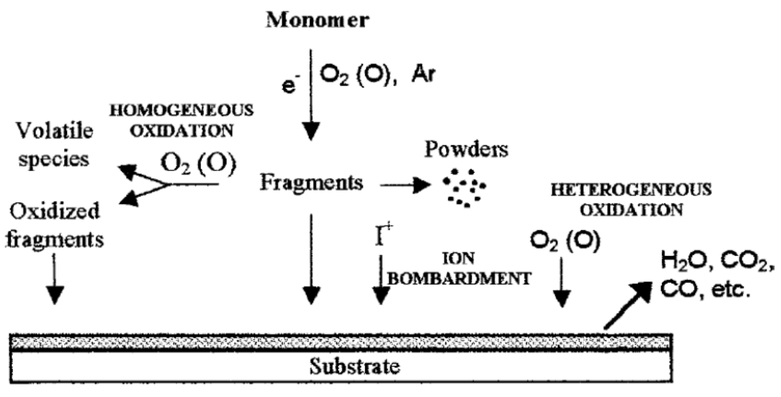

Figura 2: General deposition mechanism in low pressure organosilicon fed plasma. [2]

Post deposition thermal treatments are performed in order to allow desorption of interstitial species and induce crystallization of the amorphous layer. The films are annealed for 1h at 1050°C in controlled atmosphere, with a nitrogen flux of 8 L/min.

Results

The characterization of deposits is performed by means of Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR), Electron Paramagnetic Resonance (EPR), Raman spectroscopy and Scanning Electron Microscopy (SEM).

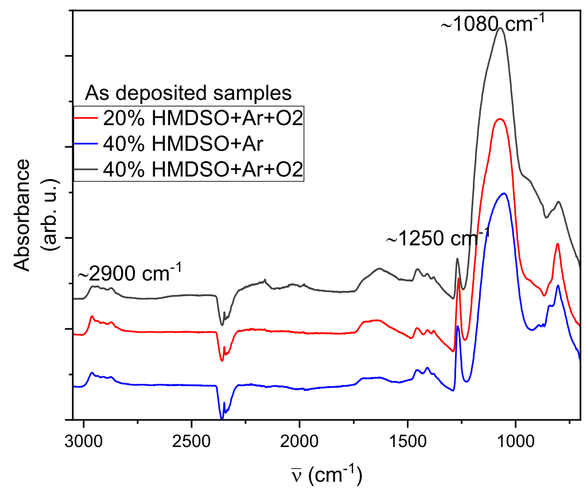

Figura 3: Normalized ATR-FTIR spectra in the 3050-700 cm^{-1} spectral region.

The SiOSi asymmetric stretching mode frequency shift is attributed to variations of bond angles, it follows that increasing the precursor concentration the films are closer to stochiometric or suboxide SiO_x. The $(CH_3)_3Si$- group is easily recognized by a sharp band at 1260 cm^{-1} and the stretching bands of sp^3 hydrogen coordinated carbon atoms in a linear aliphatic compound appear centred at 2900 cm^{-1}.
EPR experimental data are consistent with a $g = 2.0055 \pm 0.0002$, assigned to bulk silicon dangling bonds, called D center. The presence of amorphous silicon suggests the oxides deposits to have Si-rich domains.

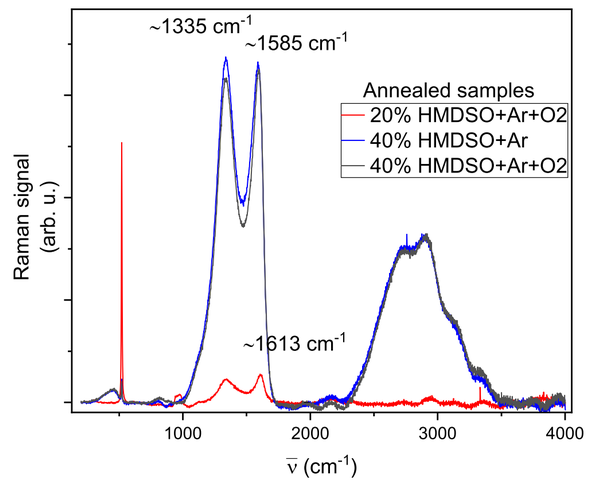

Figura 4: Raman spectra of the annealed samples irradiated at 514.5 nm.

Raman spectra reveal silica contents in the films, due to the broad and asymmetric band at 450 cm^{-1} assigned to SiOSi bending vibrations. The characteristic G peak at 1582 cm^{-1} corresponds to the LO phonon at Γ and the D and D' peaks at 1335 and 1585 cm^{-1} are associated to the sp^2 carbon bonds. Those features reveal a typical diamond-like-carbon structure and suggest that graphite crystallites are formed [3].

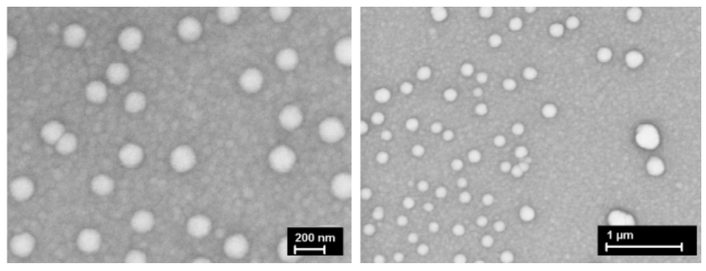

Figura 5: SEM planar views of the SiO_x film deposited at low pressure.

SEM images show that films are composed of quasi-spherical nanoparticles with size in the range of 20 nm, determining a nodular surface which is a typical result of ballistic aggregation.

References

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