Multi-scale analysis of sputtered amorphous carbon film under various deposition condition using transmission electron microscopy

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Carbon film with high selectivity in dry etching can be used as a mask material in a semiconductor process because it acts as a diffusion barrier by exploiting its amorphous structure. The properties are closely related with bonding nature, therefore, it is essential to understand the atomic configuration in carbon amorphous phase in order to improve the performance of the carbon film. Here, we performed radial distribution function (RDF) analysis using transmitted electron diffraction to correlate the bonding configurations and properties by comparing amorphous carbon films deposited at different working pressure and the samples annealed them.

We use sputtering system for depositing carbon films under 5 mT and 50 mT Ar pressure condition. The annealed samples were prepared at 750 K for 1 minuate. Both dry etching property measurements and fluorine penetration experiments suggest that the sputtered carbon under 5 mT pressure was expected to have a stronger bond and figure 1 shows the schematic of expected structure for sputtered carbon films under different pressure conditions. As shown in figure 2, These sputtered carbon films also exhibit different surface roughness depending on the pressure environment, and the film of 50 mT pressure environment has a rougher surface. To confirm the structural origin of these features, radial distribution function (RDF) analysis using electron diffraction patterns was carried out. For RDF analysis we used RDF tools, a DM script created by D. R. G. Mitchell [1] and we obtained selected area aperture diffraction (SAD) for overall film analysis and nano beam diffraction for local film analysis through JEOL 2100F.

We investigated the effect of the pressure environment and annealing on the bonding nature of thin films through the SAD, and studied the difference in bond length depending on the depth of the film through nano beam diffraction analysis. As shown in figure 2, RDF results indicated that under 5 mT working pressure condition, sp3 single bonds which are longer than sp2 double bonds are dominant in amorphous carbon film and annealing process reconfigures the interatomic bonds from sp3 single bonds to the sp2 double bonds. To further investigate the growth mechanism of the carbon film and the origin of the difference in atomic bonding caused by the pressure change, fluctuation electron microscopy (FEM) analysis using nano-area diffraction was performed. FEM is an analytical method by which we can identify the medium-range order of amorphous materials and can play a role in determining the effect of growth nuclei during film growth. In the FEM measurement, the density distribution of the ordered region in the amorphous carbon film is compared with k as a variable, and the size of the individual ordered region is determined with the prove size of nano beam as a variable.

Our multi-scale analysis reveals the atomic configuration and growth mechanism of sputtered amorphous carbon film under various pressure condition. This is expected to be an important research linking the physical properties of the amorphous carbon film with the structural characteristics of the atomic level.

[1] D. R. G. Mitchell and T. Petersen, Microscopy Research & Technique, KOI: 10.1002/jemt.21038

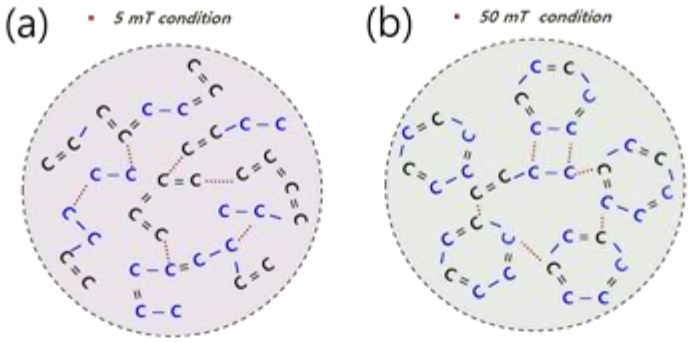

Figure 1: Structural diagram of sputtered amorphous carbon film. (a) Single bond dominant 5 mT condition carbon. (b) 50 mT condition sample with more sp2 double bond.

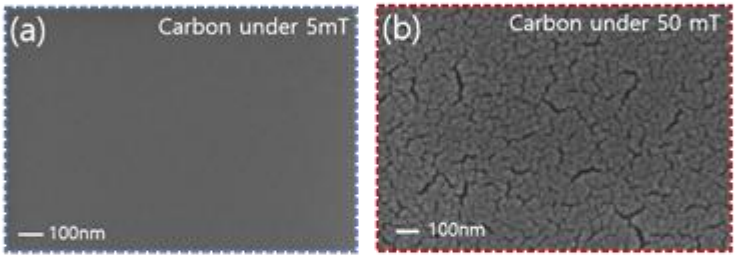

Figure 2: Scanning electron microscopy image of film surface of (a) 5 mT condition carbon film and (b) 50 mT condition carbon film with rougher surface.

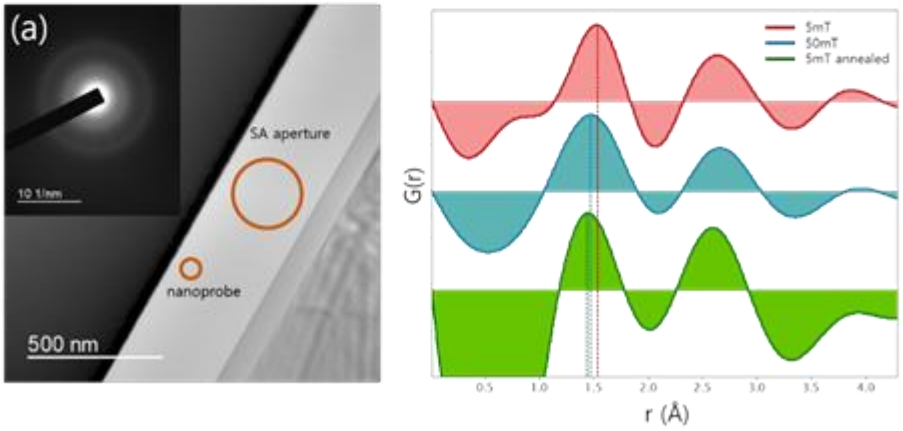

Figure 3: (a) Sample image and diffraction pattern according to probe. (b) RDF data of 5mT, 50mT, and annealed 5mT sample and comparison of their first nearest neighbor peak.