Role of Charged Nanoparticles in the Growth of Thin Films and Nanostructures in Plasma and Non-Plasma CVD

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Extensive studies have been made on non-classical crystallization, which refers to the crystal growth by the building unit of nanoparticles. In parallel with the non-classical crystallization in solution, the non-classical crystallization in the growth of thin films and nanostructures by CVD and some PVD has been studied extensively. Here, the charged nanoparticles (CNPs), which are spontaneously generated in the gas phase, become the building block of thin films and nanostructures. Charged nanoparticle-based crystallization appears to be very general, including the growth of diamond, Si, ZrO2, GaN, ZnO films as well as nanowires. The generation of CNPs in the gas phase was experimentally confirmed in many systems and their mass distribution was shown to play a decisive role in the microstructure evolution of films, nanowires, and nanotubes. The fact that CNPs can be a building block of crystals without leaving any void behind and of nanowires with smooth surface indicates that CNPs are quasi-solid, having a liquid-like property in diffusion. This means that the charge enhances the atomic diffusion, which is a newly discovered physical phenomenon. This means again that charge weakens the bond strength. Weakened bond strength would lower kinetic barriers and enhance kinetics of chemical and physical reactions. Charge-enhanced kinetics, which may be closely related with catalytic effects, can explain many phenomena, which have not been understood clearly. For example, in plasma CVD, the precursors are decomposed at temperatures much lower than those in thermal CVD. Besides, the crystalline phase can be deposited at temperatures much lower than those in thermal CVD. These phenomena can be approached newly from the weakening of bond strength of positively and negatively charged molecular ions generated in the plasma CVD process. Besides, the liquid-like property of CNPs would be enhanced if the charge-to-atom ratio in their number is increased. Since nanoparticles formed in the gas phase tend to be multiply charged in plasma CVD, the ratio would be much larger in plasma CVD than in thermal CVD. Therefore, CNPs generated in plasma CVD can have a crystalline phase at temperature much lower than those in thermal CVD. Based on this new understanding of charge-enhanced kinetics, lots of fundamental studies and applications can be done.

References

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