Charge-enhanced diffusion: insight from the deposition behavior of charged nanoparticles

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Many films and nanowires prepared by chemical vapor deposition (CVD), which have been believed to grow by individual atoms or molecules, were found to grow by charged nanoparticles (CNPs) formed in the gas phase [1,2]. Charged nanoparticle-based crystallization appears to be very general, including the growth of diamond, Si, ZrO₂, Si₃N₄, GaN films, ZnO, Si, GaN nanowires and carbon nanotubes by CVD. The generation of charged nanoparticles 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, 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. Charge-enhanced diffusion would depend on the number of atoms per charge. Thus, small nanoparticles can be liquid-like even if singly charged but large nanoparticles must be multiply charged to be liquid-like. Previously there were many reports on the nanoparticle-based crystallization but the critical role of charge was ignored. As a result, the phenomenon was not clearly understood. Many experimental evidences for CNP-based crystallization and charge-enhanced diffusion will be presented.