Assembling Nanoparticle Catalysts with Nanospheres for Periodic Growth of Carbon Nanotube Arrays

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Periodic arrays of aligned nanowires have many potential applications, such as field emission, optoelectronic devices, biosensor arrays, and photonic devices. Using interference lithography [1] and nanosphere lithography [2,3], periodic arrays of carbon nanotube (CNT) and zinc oxide have been fabricated. The critical component in fabricating these structures is generating a periodic catalysts layer for the nanowires to grow. To achieve this layer formation step, these fabrication techniques employ multiple processes that include lithographic patterning and deposition of catalyst material.

In this work we outline a novel method to fabricate periodic catalyst layer using a one-step spincoating process. Monodispersed nanopheres are utilized to assemble a nanoparticle catalyst material into an ordered periodic pattern. The main advantage of this method is that it does not require a catalyst deposition step. Therefore, our approach presents itself as a practical potential nanomanufacturing process of lower complexity than existing approaches.

The purposed approach is illustrated in Figure 1. First, a solution containing monodispersed polystyrene (PS) nanospheres (d ~ 450 nm) and iron oxide nanoparticles (d ~ 10 nm) is synthesized, shown in Figure 1(a). The solution is then spincoated on a substrate. Upon drying the nanospheres self-assemble into a hexagonal array, while the smaller nanoparticles are arranged into a periodic cluster array, as shown in Figure 1(b). In a single anneal step, the PS nanospheres are burnt off; the remaining nanoparticles can be used as catalysts for CNT growth, shown in Figure 1(c) and 4(d). This process is essentially depositing and assembling the catalysts in an ordered array using a single spincoating step without using expensive equipment, greatly simplifying the fabrication process.

Preliminary experimental results are shown in Figure 2, where CNTs are grown in a honeycomb structure. Figure 2(a) depicts top-view micrographs of assembled PS nanospheres and iron oxide nanoparticles between the voids. Using a low temperature (~500° C) thermal anneal cycle the nanospheres can be burnt off, revealing nanoparticles assembled in a honeycomb cluster, shown in Figure 2(b). The nanoparticles clusters can then serve as the catalyst, and CNT can be grown using plasma-enhanced chemical vapor deposition, illustrated in Figure 2(c).

The purposed process is a simple and yet versatile process that exploits assembly of nanoparticles using monodispersed nanospheres to fabricate periodic CNT arrays. Initial results successfully demonstrated fabrication of CNT array in a honeycomb structure. We plan to explore various processing conditions, such as higher annealing temperature and using metallic nanoparticles as catalysts, to better control CNT growth.

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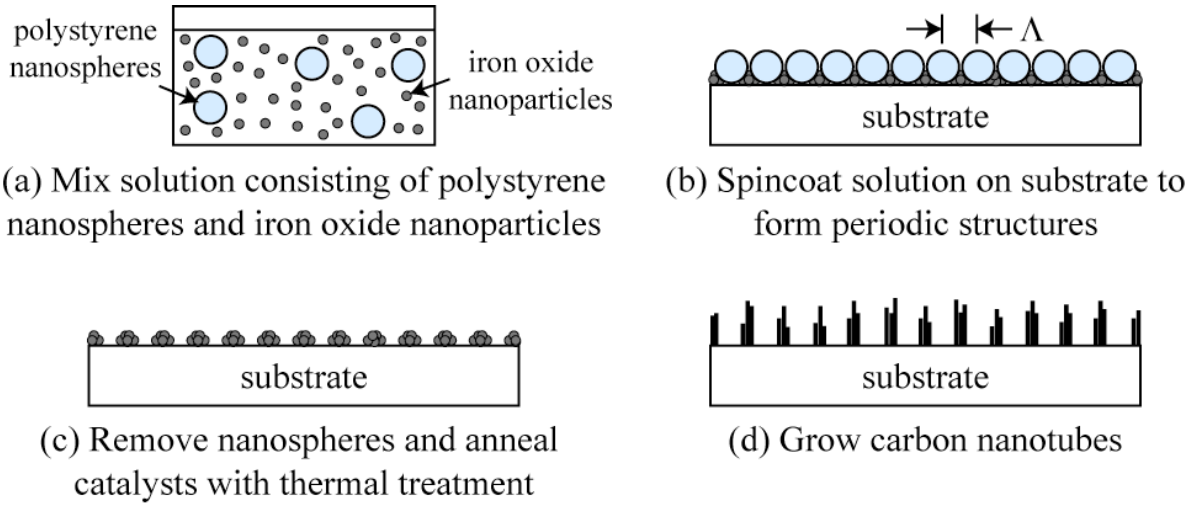

Figure 1 *Top-view micrographs of (a) templated assembly of nanoparticles by monodispersed polystyrene (PS) nanospheres, and (b) nanoparticles arrange in honeycomb geometry. Side-view micrograph of carbon nanotubes grown on a periodic honeycomb array.*

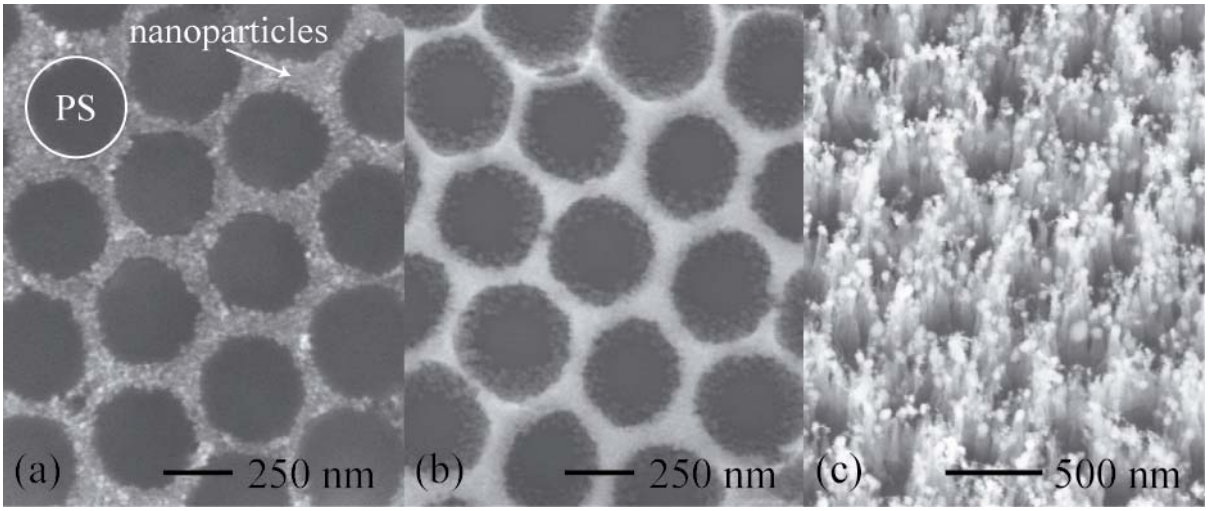

Figure 2 *Top-view micrographs of (a) templated assembly of nanoparticles by monodispersed polystyrene (PS) nanospheres, and (b) nanoparticles arrange in honeycomb geometry. Side-view micrograph of carbon nanotubes grown on a periodic honeycomb array.*

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