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# Design optimization and antireflection of silicon nanowire arrays fabricated by Au-assisted chemical etching

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ABSTRACT

In this work, we have synthesized a highly periodic silicon nanowire (SiNW) arrays with the spacing from 300 nm to 1000 nm by combining nanosphere lithography (NSL) and metal-assisted chemical etching (MACE). It has been demonstrated that it is effective to produce large-area, well-separated and controlled SiNW arrays. We also present a simple method to solve the problem of distorting spherical shape by angled-deposition method according to shadowing effect during NSL process. So we do not need to reduce the diameter of polystyrene (PS) spheres heavily and avoid making spherical shape distorted and rough. The large-area Au meshes can be further optimized using angled-deposition method and have a small nanohole diameter and relatively large nanohole spacings. And the center-center distance of PSs used as mask merely keeps invariable with 820 nm and 1300 nm pitch after reactive ion etching (RIE) process. The method help improve the distortion of spherical shape heavily during NSL process so that we can obtain SiNW arrays with controlled diameter, length and density using the non-close-packed PSs as the mask. Furthermore, the SiNW arrays obtained by MACE can improve antireflection properties of silicon substrate. The high surface area of SiNW arrays makes the reflectance below 10% or less over a wavelength range of 300–1000 nm. The antireflection structure (ARS) is great of importance in application of nanoscale optical devices.

## 1. Introduction

The research of silicon nanowires (SiNWs) has aroused tremendous interest recently in nano-material domain [1,2]. Many researchers have made theirs efforts to the fabrication and application of silicon nanowires [3–11]. For example, functional devices, including solar cells [12], chemical sensors [13] and field effect transistors [14]. Vapor-liquid-solid (VLS) method is usually employed to fabricate SiNW arrays [15]. However, this method always requires higher temperature, which increases the cost and complexity of experimental instrument. Furthermore, VLS method can hardly fabricate vertically aligned SiNW arrays with controlled diameter, density and large-scale placement. Notably, it is difficult to create large spacing SiNW arrays and the distance between nanowires have proved to be tough to adjust.

Recently, the large-area and controlled SiNWs can be etched underneath the thin layer of Au by combining the nanosphere lithography (NSL) and metal-assisted chemical etching (MACE) [16–28]. The method has been widely used to fabricate ordered SiNW arrays and other nanostructures due to its low cost. However, polystyrene (PS) nanospheres used as mask become distorted and rough during the NSL process. Junghoon Yeom et al. have shown that the spherical shape of the PSs etched by 90% during the NSL process is proved to be distorted heavily for maintaining the surface smoothness and hexagonal array placement. The reason is that such high reduction relative to their original diameter is nearly impossible and cause the MACE step to face enormous challenges [29]. What's more, Hamdana, et al. have obtained the area-selective nanofabrication SiNW arrays by combining resist microstructures and PS nanospheres as a template. However, on the one hand, the nanohole diameter (between 225 and 146 nm) and nanohole spacings are still small compared to the result we have obtained (ranging from 200 to 1000 nm). On the other hand, we present a simple method to solve the problem of distorting spherical shape which appears in many researches by angled-deposition method during NSL process [30].

Various nanostructures silicon-based have been used as nanoscale optical devices, for instance, solar cells [31], filed emission devices [32], and high-sensitivity sensors [33]. Antireflection (AR) technology has been widely employed to reduce the scattering loss of the surface of solar cells [34]. The ARS surfaces of silicon-based structure not only possess higher mechanical stability but also greatly suppress the losses

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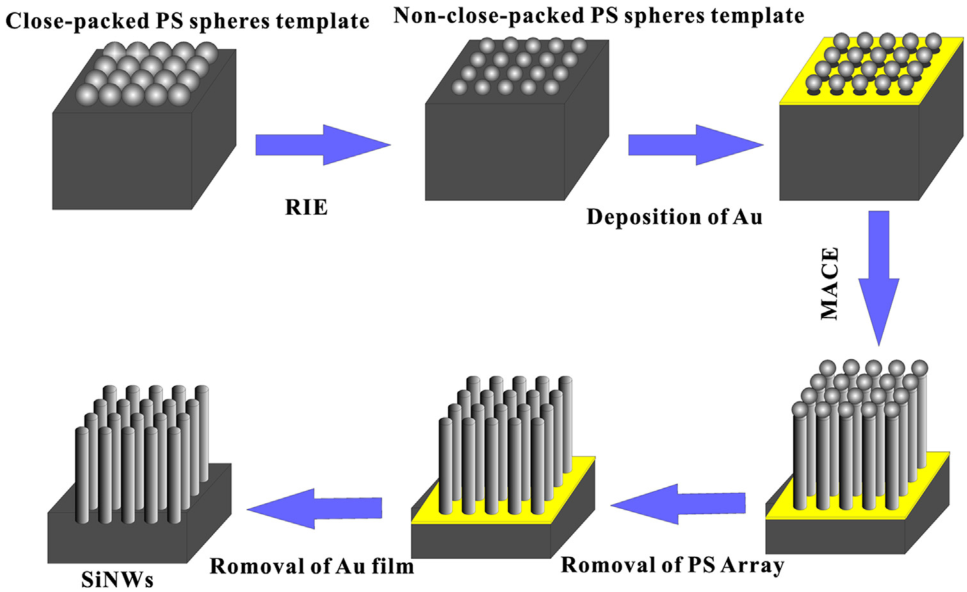


**Fig. 1.** A schematic of SiNWs fabrication process by NSL and MACE.

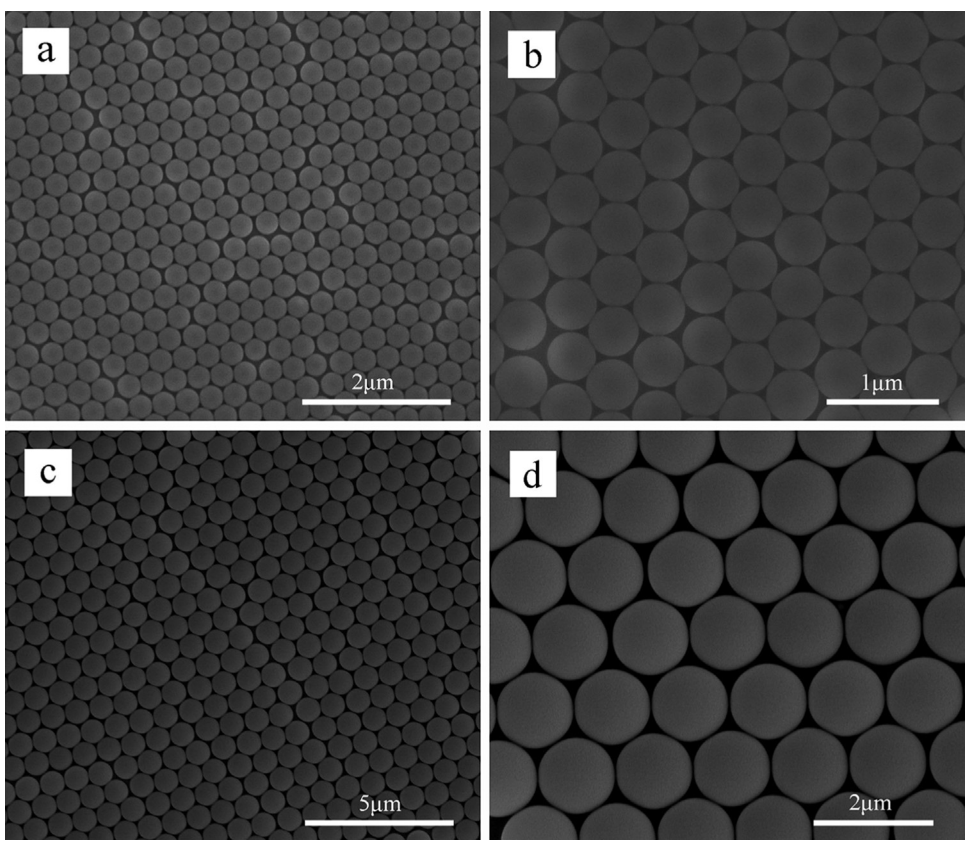


**Fig. 2.** SEM images of self-assembled PSs of different diameters 300 nm, 430 nm, 820 nm and 1300 nm.

of light over a long range of wavelength. SiNW arrays as antireflective structure (ARS) can provide a microstructured surface to effectively reduce reflection of light. However, the large-area fabrication of silicon-based structure with controlling parameters is still difficult in the future optical application.

Here we demonstrate a simple method to solve the problem of distorting spherical shape by angled-deposition according to shadowing effect. Thus, Au meshes with a small nanohole diameter and a relatively large nanohole spacings can be obtained and avoid reducing the PSs such high etching amount during NSL process. Furthermore, the ordered and adjustable SiNW arrays with controlled parameters are fabricated by combining MACE and NSL. What's more, the large-scale SiNW arrays have high-efficiency antireflection below 10% or less over a wavelength range of 300–1000 nm due to the high surface area and roughness.