Positioning and Isolation of Al-Catalyzed Si Nanowire Formation Using Al Catalyst Nanoarrays Patterned by Nanoimprint Lithography

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One-dimensional nanowires (NWs) have garnered significant attention for their potential in high-efficiency solar cells and high electron mobility transistors (HEMTs) due to their exceptional electrical, optical, and mechanical properties. In our previous reports [1-2], vapor-liquid-solid (VLS) growth using aluminum (Al) as a catalyst was proposed to synthesize single-crystalline silicon (Si) NWs, effectively addressing the issue of metal catalyst contamination. SiNW-based solar cells with efficiencies of up to 9% were successfully demonstrated. Additionally, the tuning of hole gas accumulation in the intrinsic germanium (i-Ge) shell region of unintentionally Al-doped p-Si/i-Ge core-shell nanowires (NWs), achieved through various core-multishell NW structure designs, has demonstrated promising progress toward vertical HEMT applications. However, for advanced device fabrications, the precise positioning and isolation of SiNW structures are essential for manufacturing. Therefore, in this study, we aim to tackle the challenge of achieving Al catalyst array nanopatterning with controllable size, position, and shape using nanoimprint lithography processes to facilitate the growth of SiNWs.

All samples were prepared using n-Si (111) substrates. A 50-nm-thick Al film was deposited via sputtering for both patterned and non-patterned catalyst samples. The formation of SiNWs was carried out with a growth time of 10 minutes, using a SiH_4 gas flow rate of 20 sccm at 700 °C [1-2]. For nanopattern creation, UV-imprint lithography was employed with a quartz mold featuring a 200-nm-diameter and a 500-nm-pitch circular pattern [3-4]. Then, lift-off processes were performed to reveal the Al catalyst nanoarrays after the Al film deposition, as illustrated in Fig. 1(a).

Figures 1(b) and 1(c) present a comparison between the as-sputtered Al catalyst and the Al catalyst nanoarrays. The as-sputtered Al catalyst exhibits scattered nanohillocked structures. In contrast, the nanoimprint process successfully

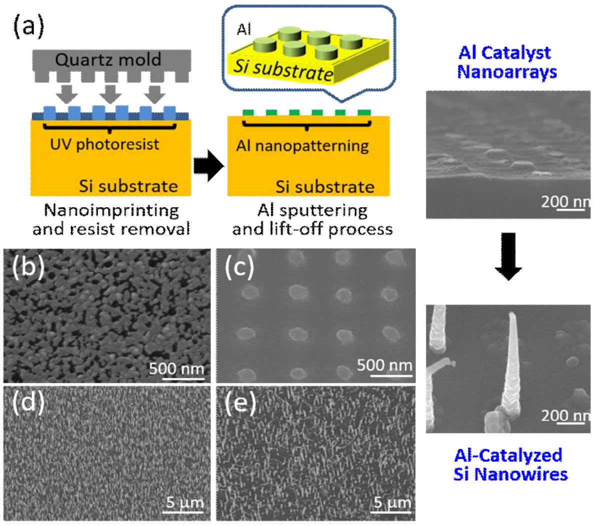

Fig. 1 (a) Schematics of Al catalyst nanopatterning by nanoimprint processes, and SEM images of (b) as-sputtered Al catalyst, (c) Al catalyst nanoarrays patterned through the nanoimprint process, (d) SiNWs formed by Al catalysts without patterning, and (e) SiNWs formed by Al catalyst nanoarrays.

facilitated the positioning and isolation of the Al catalyst, resulting in 50-nm-thick circular patterns that closely match the dimensions of the quartz mold design. The formation of SiNWs using these patterned Al catalysts demonstrated improved control over position and isolation, as shown in Figs. 1(d) and 1(e). Although location control was successful, the SiNW vertically misaligned orientation and their rough surface remain, indicating a need for further optimization of the catalyst or growth conditions. The adjustment of Al catalyst thickness and growth temperature is currently under investigation. Additional results, characterizations, and their Si/Ge core-shell structures for HEMT applications will be presented at the conference.

References:

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