Nanoimprint-Based Lift-off Process for a Large-Scale Epitaxial Growth of Nanowires

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Nanoimprint lithography (NIL) is an inexpensive technology with very high resolution and throughput, suitable for mass fabrication of both nanowire-based solar cells and large-area light emitting diode arrays. Substrate conformal imprint lithography (SCIL) has been used recently to form Au particle arrays on two-inch wafers for growth of III-V nanowires (NWs)[1].

Here we report on a method for large-area NWs growth using the Intermediate Polymer Stamp (IPS®) technique developed by Obducat[2]. The IPS stamp is flexible, which eliminates problems with stamp-substrate separation and reduces defects. It is also transparent for UV light, which allows exposure and cross-linking of an epoxy resist in a low temperature process. The IPS stamps were made as replicas from the 2.5" master Ni stamps and included rectangular array of 260 nm high pillars, with diameter of 240 nm. A 2" InP wafer (111) B with spin coated LOR and TU2 resists were used for the NIL experiments. The TU2 resist is imprinted using IPS stamp in a 6" Nano-imprinter (Obducat AB) and exposed by UV light. The TU2 resist residues are removed in a short O_2 plasma descum step just before dissolving of the LOR layer in MF319 developer. Cross-linked TU2 resist forms a polymer membrane completely insoluble in MF319 developer. This allows creation of the undercut suitable for lift off process. Further process steps include thermal evaporation of 30 nm Au layer, lift-off and epitaxial growth of the InP NWs in metalorganic vapor phase epitaxy machine (Aixtron 200). Schematic of the process flow is shown in Fig. 1, while SEM images of the IPS stamp, undercut profile, Au dots after lift-off and an array of the InP nanowires are illustrated in Fig. 2 (A, B, C and D).

We report the NIL process details to optimize size of the Au dots and their stability at the InP surface during the growth. It was found that annealing of the wafers prior to imprinting is necessary for immobilizing the Au on InP surface. The optimized process has been used for making solar cell devices. The overall quantum efficiency of the solar cells made using the InP NWs was measured to be 13.8%, which is the highest for NW-based solar cells[3].

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[1] A. Pierret, *et al,* Nanotechnology, **21**, 065305 (2010).
[2] IPS-STU process http://www.obducat.com.
[3] J. Wallentin, *et al*, Science, 10.1126/science (2013).

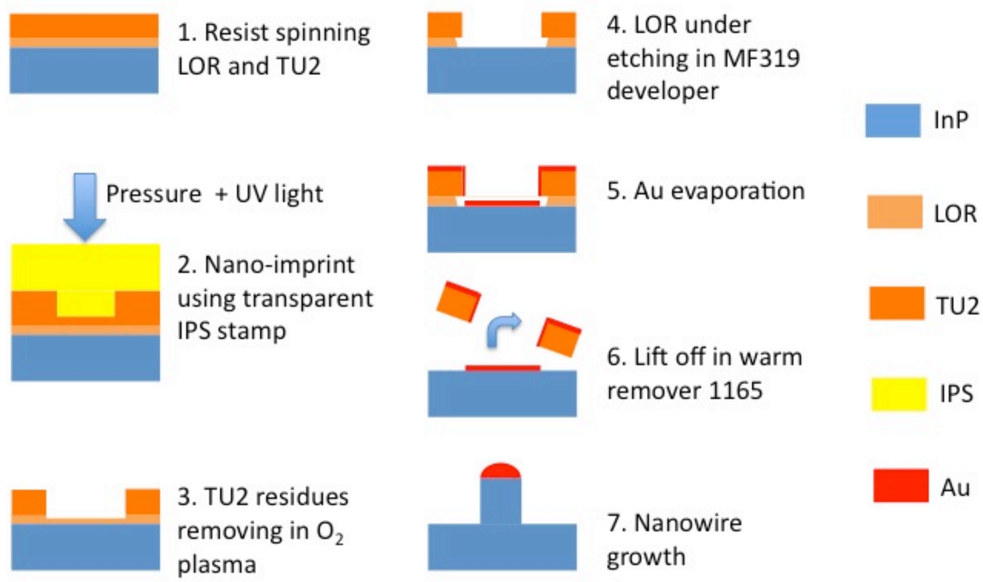

Figure 1: Schematic process flow of the nanoimprint-based process for fabrication of III-V nanowires.

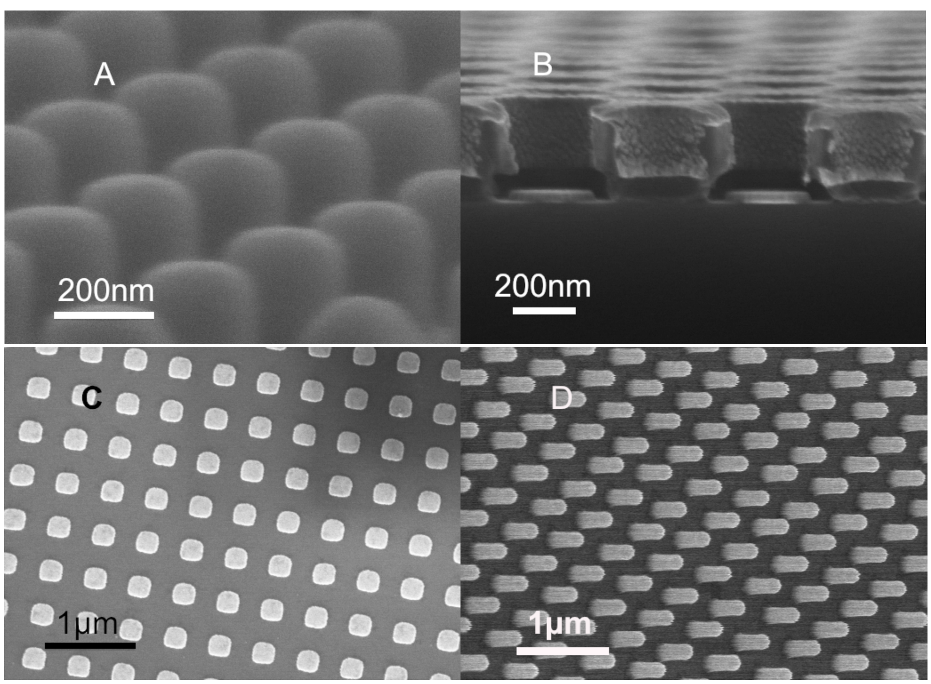

Figure 2: (A) features of the IPS-stamp, (B) cross-section of a double-layer resist system (LOR/TU2) after evaporation of Au, (C) top view of the array of Au dots after lift-off, (D) InP NWs with diameter of 200 nm and height 500 nm.