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Optimizing the Field Emission Performance of SiNWs-Based Heterostructures: Controllable Synthesis, Core-Shell Structure, 3D ZnO/Si Nanotrees and Graphene/SiNWs

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Abstract : Due to the CMOS compatibility, silicon-based field emission (FE) devices as potential electron sources have attracted much attention. The geometrical arrangement and dimensional features of aligned silicon nanowires (SiNWs) have a determining influence on the FE properties. We discuss a multistep template replication process of Ag-assisted chemical etching combined with polystyrene (PS) spheres to fabricate highly periodic and well-aligned silicon nanowires, then their diameter, aspect ratio and density were further controlled via dry oxidation and post chemical treatment. The FE properties related to proximity and aspect ratio were systematically studied. A remarkable improvement of FE propertiy was observed with the average nanowires tip interspace increasing from 80 to 820 nm. On the basis of adjusting SiNWs dimensions and morphology, addition of a secondary material whose properties complement the SiNWs could yield a combined characteristic. Three different nanoheterostructures were fabricated to control the FE performance, they are: NiSi/Si core-shell structures, ZnO/Si nanotrees, and Graphene/SiNWs. We successfully fabricated the high-quality NiSi/Si heterostructured nanowires with excellent conformality. First, nickle nanoparticles were deposited onto SiNWs, then rapid thermal annealing process were utilized to form NiSi shell. In addition, we demonstrate a new and simple method for creating 3D nanotree-like ZnO/Si nanocomposites with a spatially branched hierarchical structure. Compared with the as-prepared SiNRs and ZnO NWs, the high-density ZnO NWs on SiNRs have exhibited predominant FE characteristics, and the FE enhancement factors were attributed to band bending effect and geometrical morphology. The FE efficiency from flat sheet structure of graphene is low. We discussed an effective approach towards full control over the diameter of uniform SiNWs to adjust the protrusions of large-scale graphene sheet deposited on SiNWs. The FE performance regarding the uniformity and dimensional control of graphene protrusions supported on SiNWs was systematically clarified. Therefore, the hybrid SiNWs/graphene structures with protrusions provide a promising class of field emission cathodes.

Keywords : field emission, silicon nanowires, heterostructures, controllable synthesis
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