Roll Printing of Synthetic Nanowires for Novel Sensor and Electronic Applications

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Controlled and uniform assembly of "bottom-up" nanowire (NW) materials with high scalability presents one of the significant bottleneck challenges facing the integration of nanowires for electronic applications. Here, we present wafer-scale assembly of highly ordered, dense, and regular arrays of NWs with high uniformity and reproducibility through a simple contact printing process.[1,2] The assembled NW pitch is shown to be readily modulated through the surface chemical treatment of the receiver substrate, with the highest density approaching ~8 NW/μm, ~95% directional alignment and wafer-scale uniformity. Such fine control in the assembly is attained by applying a lubricant during the contact printing process which significantly minimizes the NW-NW mechanical interactions friction; therefore, enabling well controlled transfer of nanowires through surface chemical binding interactions. Furthermore, we demonstrate that our printing approach enables large-scale integration of NW arrays for various device structures on both rigid silicon and flexible plastic substrates, with a controlled semiconductor channel width ranging from a single NW (~10 nm) and up to ~250 μm, consisting of a parallel array of over 1,250 NWs and delivering over 1 mA of ON current. The potency and versatility of the method is further demonstrated by large-scale, heterogeneous integration of nanowires for image sensor circuitry by utilizing optically active nanowire sensors and high mobility nanowire transistors. The nanowire sensors and electronic devices are interfaced to enable an all-nanowire circuitry with on-chip integration, capable of detecting and amplifying an optical signal with high sensitivity and precision. Notably, the process is highly reproducible and scalable with a yield of ~80% functional circuits, therefore, enabling the fabrication of large arrays (i.e., 13x20) of nanowire photosensor circuitry with image sensing functionality. The ability to interface nanowire sensors with integrated electronics on large scales and with high uniformity presents an important advance toward the integration of nanomaterials for sensor applications.

[1] Z. Fan, J. C. Ho, Z. A. Jacobson, R. Yerushalmi, R. L. Alley, H. Razavi, A. Javey, "Wafer-Scale Assembly of Highly Ordered Semiconductor Nanowire Arrays by Contact Printing", Nano Letters, 8(1), 20-25, 2008.

[2] R. Yerushalmi, Z. A. Jacobson, J. C. Ho, Z. Fan, A. Javey, "Large scale, highly ordered assembly of nanowire parallel arrays by differential roll printing", Applied Physics Letters, 91, 203104, 2007.