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Active dopant and associated diffusion potential mapping in Silicon nanowires

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Silicon nanowires (SiNWs) are attractive for a variety of applications such as photoelectrochemical (PEC) devices for hydrogen fuel production which require precise compositional and morphological control for abrupt electrical interfaces. However, SiNWs grown by the vapour-solid-liquid method typically encounters problems such as nonselective deposition on sidewalls, catalyst-induced compositional gradients, inadvertent kinking and inhomogeneous doping. The bandgap of Si is 1.1 V, therefore multiple Si tunnel junctions are required for the operating voltage to exceed values required to split water (1.23 V).Tunnel junctions require degenerate-doping conditions such that the field in the depletion region is strong enough to induce tunnelling, with a sharp potential profile to increase its probability. Trap-assisted tunnelling in Si via gold impurity levels usually outnumbers band-to-band tunnelling at low field strength, therefore a very small concentration of gold impurities is believed to aid the tunnelling process. To this end electron holography (EH) combined with scanning TEM serve a critical role being able to non-invasively measure depletion region widths and their associated built-in voltages [1]. Although doping control has been demonstrated in VLS growth for SiNWs [2], growth of degenerate p-type Si, Boron (B) doped, has been challenging. Lower p-type doping is reached compared to n-type doping (Phosphorous) under the same conditions. We overcome these challenges synthesizing these structures by *in situ* chlorination of the NW surface with hydrochloric acid at temperatures ranging from 500 to 700 °C. We demonstrate degenerately doped p/n and n/p sections with abrupt potential profiles of 1.1 ± 1 V in SiNWs and depletion region widths as narrow as 10 ± 1 nm via EH. The results presented herein enable the growth of complex, degenerately-doped p-n junction nanostructures and are an essential step in the fabrication of PEC devices.

[1] A. Darbandi, J. C. McNeil,A. Akhtari-Zavareh, S. P. Watkings, K. L. Kavanagh, Nano Letters **16** (2016).
[2] D. J. Hill, T. S. Teitsworth, E. T. Ritchie, J. M. Atkin, J. F. Cahoon, ACS Nano **12** (2018).

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