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Electrical properties of GaAs/BGaAs nanowires

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We have investigated the incorporation of boron during the self-catalyzed molecular beam epitaxial growth of GaAs nanowires (NWs). Through high-resolution transmission electron microscopy (HRTEM) and energy dispersive x-ray microscopy (EDX) we determined that the nanowires grow with a rough surface morphology, where voids can be correlated to a high boron concentration (fig 1). Due to their large surface-to-volume ratio, NWs feel a strong influence of surface effects on their optical and electrical characteristics. In particular, Fermi level pinning affects the ability to form Ohmic contacts to GaAs nanowires, which has been related in several works to As-As dimers and As dangling bonds at the GaAs-native oxide interface [1]. Therefore such a large change in the surface morphology and chemistry could impact on the intrinsic properties of the NWs and the possibility to use them in applications such as sensing.

Nanowires were contacted with Au/Zn/Au (5/10/90nm) contacts, and it was found that Ohmic contacts could be formed to all nanowires grown under boron flux. This is in contrast to nominally undoped GaAs NWs, where no Ohmic contact could be formed under identical processing conditions (fig. 2) This suggests either high p-type doping of the BGaAs shell layer, as observed in planar growth of $B_xGa_{1-x}As$ [2], or an anomalous behavior of the surface oxide and therefore of As precipitation on the surface of the nanowire. We believe there is an interplay of these effects, which leads to a high sensitivity of BGaAs nanowires to measurement conditions, as evidenced in large back-gate hysteresis in transport measurements on these NWs under ambient conditions. This is despite the highly faceted surface of the NWs, which is hypothesized to decrease sensitivity to adsorbants in GaAs due to thickening of the native oxide [3].

Understanding the impact of the BGaAs nanowire surface on electrical characteristics, and the acceptor-like behavior of B, opens up new opportunities for the use of this material in forming contacts to NWs and in band engineering of NW heterostructures.

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[3] Ullah, A. R., Joyce, H. J., Tan, H. H., Jagadish, C., & Micolich, A. P. (2017). The influence of atmosphere on the performance of pure-phase WZ and ZB InAs nanowire transistors. *Nanotechnology*, *28*(45), 454001.

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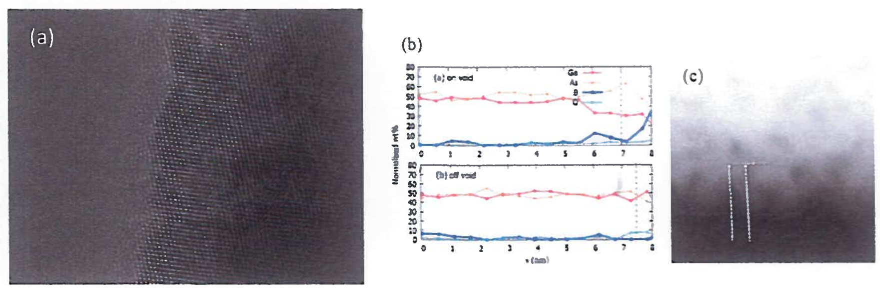

Fig. 1: (a) HRTEM measurement of a NW sidewall grown under boron flux. (b) EDX line scans across two points; on and adjacent to a 'void' on the NW sidewall. The position of the linescans are indicated in the HAADF image in (c).

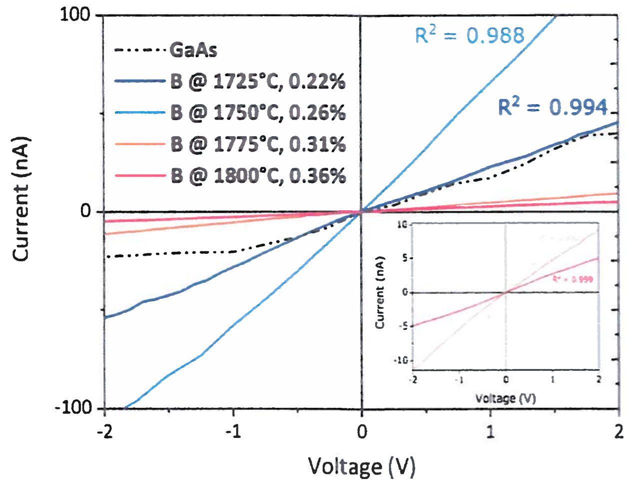

Fig. 2: Two-point IV measurements on NWs grown under varying boron fluxes, including a GaAs reference sample. BGaAs samples are labelled with R^2 fitting values to indicate the Ohmic nature of contacts. Measurements taken on NWs with higher boron content are enlarged in the inset.