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Growth, n-type doping, and electrical characterization of InAs nanowires

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Abstract

We report on growth, in-situ doping and electrical characterization of InAs nanowires on Si. The study is motivated by the interest to explore the potential of this alternative fabrication method and resulting devices.
InAs nanowires were grown within openings defined by electron beam lithography in oxide masks and using MOCVD. The growth conditions were optimized by varying temperature, indium molar flow, V/III ratio, and mask dimensions to result in close to 100% yield of vertical wires. Several micrometer long wires that are suitable for electrical characterization by four-point configuration could be achieved by patterning the wires in large arrays.
In-situ doping of the catalyst-free InAs growth was studied by introducing H_2S, Si_2H_6, CBr_4 and DETe in the reactor. The addition of dopants during growth can affect both the axial, <111>, and radial, <1-10>, growth rates as well as morphology and nucleation. We observe that when using CBr_4 the nucleation of nanowires is drastically reduced at molar ratios larger than 10^{-3}. The addition of the slightest amount of DETe (10^{-6}) completely inhibits <111> growth. In contrast, doping of InAs nanowires with sulfur or silicon shows no change in growth rates, morphology or nucleation as compared to undoped wires. Only when the silicon molar ratio exceeds $2 \cdot 10^{-3}$ the growth selectivity is compromised and eventually ceases. A summary of the resistivity measurements as function of dopant concentration during growth is displayed in Figure 1a. Sulfur as well as silicon are well incorporated as donors as revealed by the fast decrease of the resistivity, while adding carbon results in an increase of the resistivity indicating incorporation as shallow acceptor. Interestingly we observed a dependence of the sulfur incorporation on the molar In flow. We attribute the difference between these two curves to a change in distribution coefficient of H_2S. In the inset of Figure 1a the axial growth rate, v_{111}, is displayed as a function of TMIn flow, showing two distinct regions corresponding to the conditions used for the two sulfur data sets in Figure 1a.
The doping concentrations of the nanowires were extracted from the measured resistivity values by using three experimental reference measurements that are independent of the carrier mobility. The first method consisted of measuring the Seebeck coefficient, S, of sulfur-doped InAs nanowire. The second reference method consisted of analyzing an InAs homojunction tunnel diode and the third reference method utilized data of an InAs/Si heterojunction tunnel diode using TCAD simulations. The results are plotted in Figure 1b with the data points from the references measurements indicated by arrows. In summary we identified growth conditions and suitable dopants for InAs nanowires grown selectively in mask openings which is an important step towards the the fabrication of devices.
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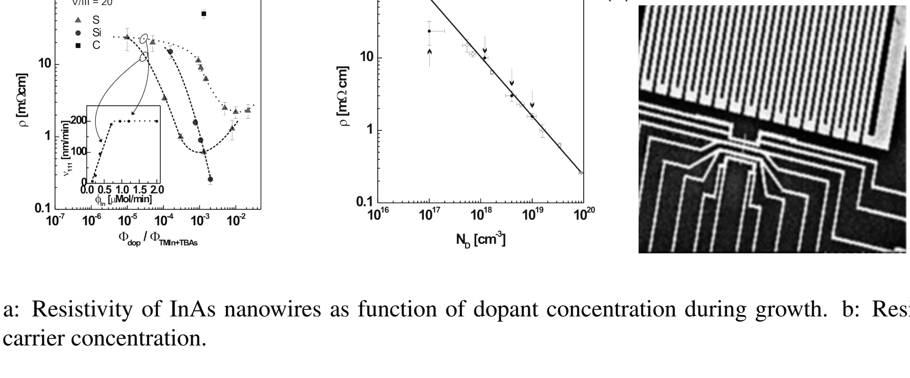

Figure 1: a: Resistivity of InAs nanowires as function of dopant concentration during growth. b: Resistivity as function of carrier concentration.