Terahertz Spectroscopy of Modulation Doped Core-Shell GaAs/AlGaAs Nanowires

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***Abstract*—In order to realize many devices based on semiconductor nanowires, reliable doping is essential. For such devices, it is important that the electron mobility is not compromised by doping incorporation. Here, we show that core-shell GaAs/AlGaAs nanowires can be modulation n-type doped with negligible loss of electron mobility. Optical pump terahertz probe spectroscopy is used as a novel, reliable, noncontact method of determining the doping density, carrier mobility and charge carrier lifetimes for these n-type nanowires and an undoped reference. A carrier concentration of 1.10 ± 0.06 x 10^{16} cm^{-3} was extracted proving the effectiveness of modulation doping in GaAs nanowires. The room-temperature electron mobility was found to be high at 2200 ± 300 $cm^2V^{-1}s^{-1}$ with no degradation in comparison to undoped reference nanowires. In addition, modulation doping was found to enhance both the photoconductivity and photoluminescence lifetimes to 3.9 ± 0.3ns and 2.4 ± 0.1ns respectively, revealing that modulation doping can passivate interfacial trap states.[1]**

I. Introduction

To investigate the effects of doping on GaAs nanowires, modulation doped and undoped core-shell GaAs nanowires were photoexcited with a near-infrared laser of wavelength 800 nm and pulse duration of 35 fs at fluences between 0.46 and 225 μJcm^{-2}. The photoinduced conductivity was then measured as a function of both time after photoexcitation and frequency.[2] From these measurements, the doping density, carrier lifetimes and electron mobilities were then extracted.

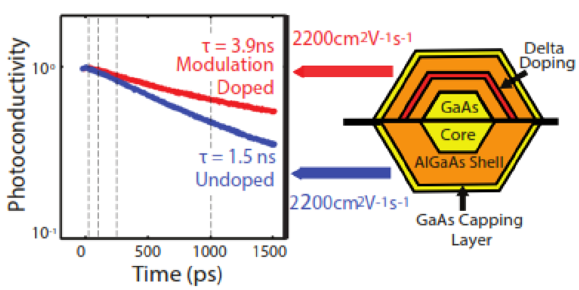

Fig. 1. Comparison of normalized photoconductivity decays (left) and a schematic diagram (right) for modulation doped and undoped nanowires.

II. Results

Figure 1 shows a schematic diagram of the modulation doped and undoped nanowire structure and presents the normalized photoconductivity decays for both samples. A monoexponential decay is observed, revealing that the carrier decay is purely due to monomolecular processes, for this case, trap-assisted recombination. Through fitting of carrier rate equations, a carrier lifetime of 3.92 ± 0.3ns was extracted for the modulation doped sample, in comparison to 1.5 ± 0.4ns for the undoped reference. This shows that modulation doping significantly increases the carrier lifetime of GaAs nanowires, suggesting passivation of interfacial trap states.

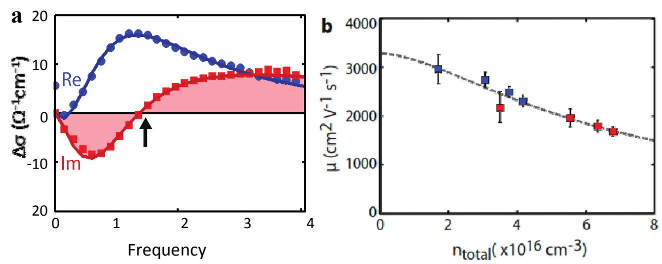

Fig. 2. Photoconductivity spectrum for modulation doped nanowires, fitted with a Lorentzian conductivity model (left). Electron mobilities against total carrier density for modulation doped (red) and undoped (blue) nanowires, fitted with an empirical, low-field model (right).

Figure 2 shows a photoconductivity spectrum for the modulation doped nanowires. It clearly shows a Lorentzian response with a localised surface plasmon resonant frequency in the terahertz range.[3] By globally fitting a Lorentzian model to spectra at different fluences, the electron mobilities and doping concentration could be extracted. The doping concentration was found to be 1.10 ± 0.06 x 10^{16} cm^{-3} and the electron mobility to be 2200 ± 300 $cm^2V^{-1}s^{-1}$ for both the doped and undoped samples at similar carrier densities, as shown in Figure 2. No significant degradation in the electron mobility is seen due to modulation doping.

III. Summary

Modulation doping is an excellent way of controlling conductivity in semiconductor nanowires while retaining a high electron mobility. Furthermore, OPTP spectroscopy offers a rapid noncontact method of characterizing and hence further improving the electrical properties of these heterostructures.

References

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