Terahertz Characterisation of undoped and doped ZnO nanowires

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Abstract

In recent times, many novel applications for usage in the terahertz (THz) frequency range are being suggested and developed. Similarly, many novel materials are also being studied for prospective applications in these areas [1]. In this context, nanostructured forms are of great interest because they can provide broad spectrum of photonic characteristics [2]. However, these characteristics are not very straightforward to predict. One of the interesting nanomaterials that evolved recently is zinc oxide (ZnO) nanowires, which is a one-dimensional (1D) nanostructure. However, the performance of nanomaterials-based devices are severely affected by their structure. While sintered nanoparticle films may provide a more efficient electron transport channel, nanowires may give a more direct connection between the source of photogeneration and the conducting substrate [3]. ZnO nanowires having a hexagonal wurtzite structure can be employed as a wide-band-gap semiconductor to construct dye-sensitized solar cells which exhibit a wide energy bandgap of 3.45 eV and a large exciton binding energy (60 meV) at room temperature. However, there are ample scopes to understand the characteristics of the ZnO nanowires in order to employ it for the development of various applications in the terahertz domain.

Therefore, in this work, we focus on the characterization of undoped zinc oxide (ZnO) nanowires, 5% Ni-doped ZnO nanowires, and 5% Cu-doped ZnO nanowires at the THz frequency domain [6]. Here, the nanowire samples are grown by chemical bath deposition. The peak intensity, strain, crystal size, position, and width, as well as full-width at half-maximum (FWHM) data of the nanowires are identified through XRD characterization. Further, the refractive index, absorption coefficient, Optical density, and conductivity properties of undoped and doped ZnO nanowires are determined by the THz- time domain spectroscopy (TDS) measurements and extracted by employing the Drude-Lorentz model [4]. The schematic of the THz-TDS measurements of ZnO nanoparticle-based thin films are shown in figure 1A. Fig.1 B) represents the measured terahertz time-domain pulses after passing through the different ZnO samples (undoped & doped). These transmitted THz pulses were detected in the time domain using the typical pump-probe principle.

Several optical parameters are extracted from these measured THz pulses. The real part of the refractive index of undoped ZnO nanorods, Ni-doped ZnO nanorods, and Cu-doped ZnO nanorods are fairly constant in the range 0.2-0.8 THz. The refractive index of Cu-doped ZnO is greater than the Ni-doped ZnO and undoped ZnO nanowires. In the whole frequency range, the real part of the refractive index of Cu-doped ZnO is higher than that of Ni-doped ZnO and undoped ZnO nanowires. Also, we obtain lower absorption and less conductivity for all the samples. The real and the imaginary part of conductivity is significant for the full spectral range up to 0.8 THz. We observe that the 830 nm thick Cu-doped ZnO sample is much more conductive than the Ni-doped ZnO (900 nm) and undoped ZnO (940nm) nanowires. Based on

our present data, the optical conductivity of the samples is found to be thickness dependent, at least throughout the range of this study. This is most likely due to small perturbations in the deposition techniques as well as a variable ratio of bulk contributions to interface contributions like surface state electrons [3]. We believe the current study will help to understand THz behaviour of ZnO nanorods with different doping elements.

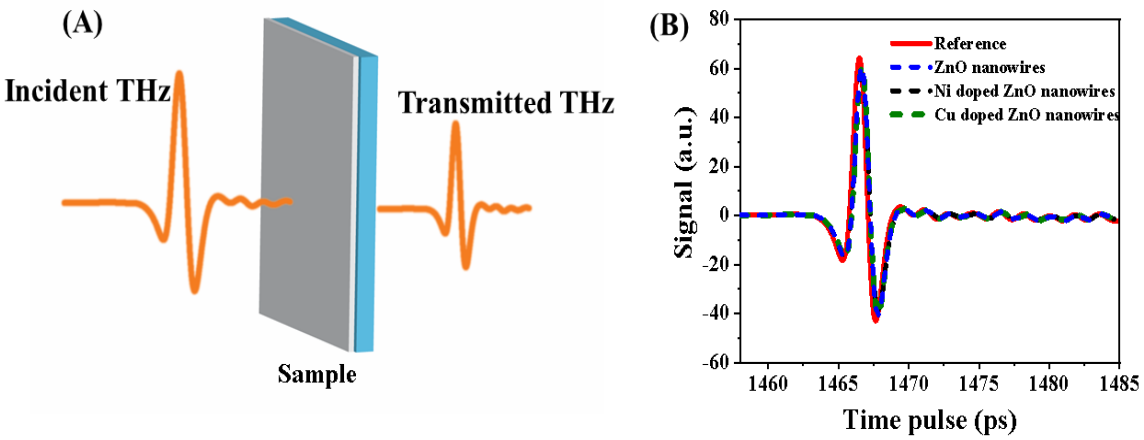

Fig.1. a) Schematic representation of THz-TDS on nanowire samples b) The THz pulses are measured after transmission from the samples.

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