# Terahertz time-domain spectroscopy of ZnO nanostructures

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Semiconductor nanostructures have been an area of growing interest in various photonic and nanoelectronic applications. As a wide bandgap semiconductor, ZnO has potential applications in short-wavelength light emitting devices and transparent conducting solar cells [1]. Extensive progress has been made in the synthesis of ZnO nanoscale materials in recent years. Using terahertz time-domain spectroscopy (THz-TDS), we study the far-infrared spectroscopic properties of various structures of ZnO which include nanoparticles, nanowires, tetrapods and bulk powder. Simple effective medium theory (EMT) is applied to extrapolate the dielectric and optical properties of ZnO nanoscale materials [3-5].

The THz system used in our measurements is a photoconductive switch-based THz spectrometer which is aligned into an 8f confocal geometry in order to achieve a 3.5-mm frequency-independent beam waist, as well as the excellent beam coupling between the transmitter and receiver [2]. The sample to be studied is placed in a cell made of a 640-μm-thick, p-type silicon wafer and is positioned at the beam waist of the THz-TDS system. Both the reference and the sample pulses in the time domain are Fourier transformed to obtain the corresponding complex amplitude spectra. Taking the ratio of the amplitude of the sample spectrum to reference spectrum gives us the effective absorption of the THz beam by the sample, and the refractive index is obtained by the phase shift [3]. Using the simple EMT, we determine the dielectric and optical properties of these nanostructures. The index and the power absorption coefficients of the ZnO nanostructures are derived from the real and imaginary parts of the frequency dependent dielectric function given by the simple EMT model, $\varepsilon(\omega) = f\varepsilon_{ns} + (1-f)\varepsilon_h(\omega)$ [5], where $f$ is the filling factor determined by ratio of the volume of the ZnO structures to volume of the cell that holds them, $\varepsilon_{ns}$ and $\varepsilon_h$ are the frequency-dependent complex dielectric constants of the nanostructures and host material, and $\varepsilon(\omega)$ is the measured effective dielectric constant of the composite material which includes nanostructures and air. The increased absorption of the nanostructures is mainly attributed to the confinement of the electronic states and the scattering effect. The filling factor which rather depends on the pressure applied, is found to affect the absorption coefficients and the refractive indices. We are currently working on the density-dependent properties of various ZnO nanostructures.

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## References

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