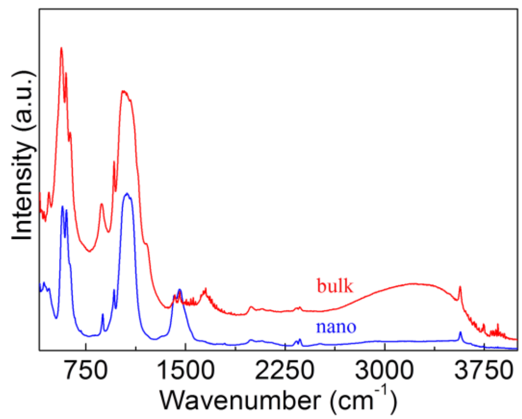
Research

There has been a considerable research interest in materials, especially composite materials, in recent years and one of the challenging problems facing materials research is their accurate characterization. For example, the thermal properties, the nonlinear absorption coefficients, the electrical properties, and the elastic constants are important parameters that need to be measured for various applications. The experimental program in my laboratory exploits photoacoustic spectroscopy (UV/VIS/FTIR), conventional absorption spectroscopy, fluorescence spectroscopy, and scanning electron microscopy to study materials in a nondestructive manner. The resonant ultrasound spectrometer (RUS) and the atomic microscope available in Dr. Teklu's lab are used for nondestructive evaluation of materials.

Photoacoustic Spectroscopy: Photoacoustic spectroscopy (PAS) is a highly sensitive optical absorption spectroscopy technique. The major advantage of this technique is that both transparent and opaque samples can be studied with great accuracy. The principles and applications of photoacoustic spectroscopy are well documented in the literature [Allen Rosencwaig, Photoacoustics and Photoacoustic Spectroscopy, John Wiley & Sons Inc. 1981]. Briefly, the sample is excited to higher electronic excited states by intensity modulated light radiation. Nonradiative decay to the ground state leads to heat generation modulated at the same frequency, which in turn leads to pressure oscillations in the gas that surrounds the sample. The pressure oscillations are sensed by a microphone, processed and plotted as a function of wavelength. The strength of the acoustic signal is proportional to the amount of light absorbed by the sample and there is a close correspondence between PA spectrum and the conventional optical absorption spectrum (see *J. Chem. Educ.,* **86**, 1238-1240 (2009)).

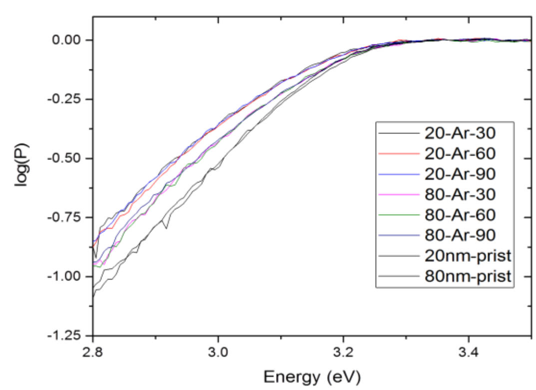
Biopolymers: Surgeons generally use metal pins and screws for tissue fixation. More recently, certain kinds of polymers are preferred over metals for the osteointegration of implants. However, the biodegradability of polymers is not always fast and the osteointegration may take longer time. It has been reported that the addition of hydroxyapatite (HA) can improve the biointegration rate of artificial parts placed inside the body. Hydroxyapatite is a form of calcium phosphate consisting of calcium, phosphate, and hydroxide ions. It is used for implants in bone because it is chemically similar to natural bone. In this regard, we have been investigating (in collaboration with Dr. Nicole Levi-Polyachenko at Wake Forest School of Medicine) HA-doped polymers for medical applications (for example, nanohydroxyapatite (nHA) composites of POC (poly (diol citrate)), Poly(glycerol sebacate) (PGS), etc.).

Another set of materials we are currently interested is Chitosan-Ag films. Chitosan is a naturally occurring biodegradable polymer. Despite the remarkable properties of chitosan, its application in medicine is limited due to its poor mechanical strength. One way to overcome this shortcoming is by adding other polymers or nanometer-sized metallic particles. We are in the process of synthesizing and characterizing a set of Chitosan-Ag polymers. One of our recent studies revealed that hexagonal Ag NP were beneficial for generating mild hyperthermia and aided in the intracellular delivery of fluorescently labeled dextran, while yielding the best delivery for the higher molecular weight dextran.



Photoacoustic spectra of nano and bulk HA

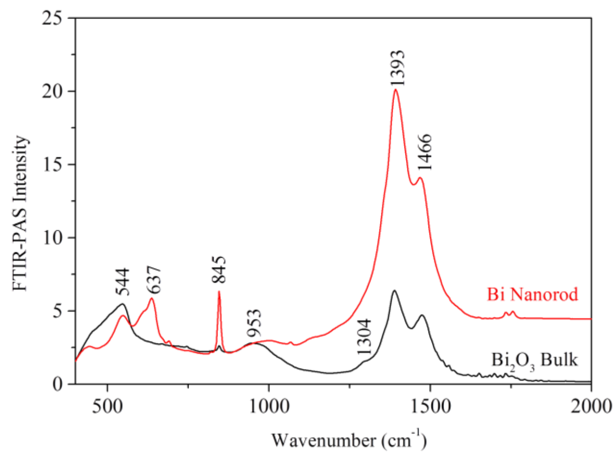
Materials for Energy Applications: Nano-sized zinc oxide (ZnO) materials are of recent interest because of their potential applications in developing optoelectronic and energy devices. ZnO based materials have the ability to operate at higher temperatures and is a promising material for solar energy applications. We have been investigating a set of ZnO materials in collaboration with Dr. Appararo Rao's group at Clemson University. Through photoacoustic spectroscopy we study the contribution of defect levels on the absorption behavior of a pure zinc oxide samples



Photoacoustic spectra of ZnO (20 nm and 80 nm) particles annealed with Ar at 30, 60, and 90 min.

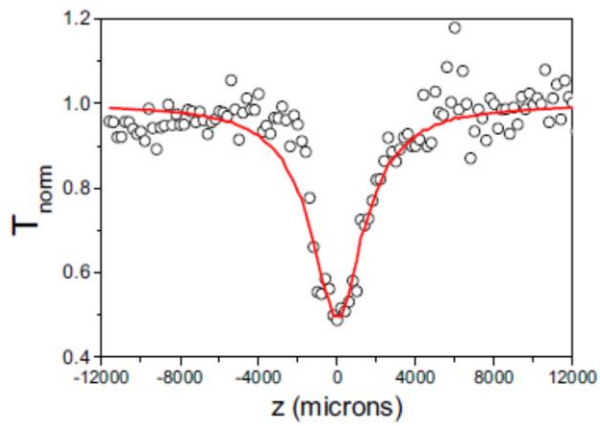
annealed under argon atmosphere.

It has been reported that the quantum confinement effects in bismuth induce semimetal-to-semiconductor (SM-SC) transformation for rods with diameters below 14 nm. One important application of such a material is in the making of excellent thermoelectric materials as the thermoelectric efficiency of Bi nanorods increases upon decreasing its diameter. In order to understand the confinement effects on the bandstructures of Bi nanorods, we have prepared 10nm bismuth nanorods in Dr. Rao's lab at Clemson University. The high resolution electron microscopic investigations raveled excellent Bi nanorods with a 2 nm layer of Bismuth Oxide (Bi_2O_3) around it. The absorption characteristics of bulk Bi, bulk Bi_2O_3, and 10 nm Bi nanorods were measured using the Fourier transform infrared (FTIR) photoacoustic spectroscopy (PAS) technique. The infrared data clearly show excellent agreement between the spectral features of bismuth nanorods and bulk Bi_2O_3 powders. Our spectral evidence reveals that the oxide layer plays a significant role in the spectroscopic properties of Bi nanowires. We would like develop various types of Bi nanowires (possibly, oxide-free) with 5nm, 40nm, 100nm, and 200 nm diameters to have a systematic understanding of the role of quantum confinement effects on the L-T transition in Bi nanorods.



Photoacoustic spectra of nano and bulk Bi_2O_3

Nonlinear Spectroscopy: There are also opportunities in the lab to investigate the nonlinear optical properties of novel materials in order to realize them for potential optical limiting applications. In particular, optical limiters are materials that exhibit linear transmittance below a threshold value and attenuate the amount of transmitted light beyond this threshold. In collaboration with Dr. Reji Philip (Raman Research Institute, India), we have used 800 nm laser pulses from a Ti:Sapphire laser (100 fs) to measure, for example, the optical nonlinearity in chitosan (CS) films doped with multi-walled boron nitride nanotubes (MWBN). Two-photon absorption coefficients (β) of CS–MWBN films have been measured at 800nm by Z-scan. While chitosa n with 0.01% MWBN doping gives a β value of 0.28×10^{-13} m/W, 1% doping results in a higher β value of 1.43×10^{-13} m/W, showing nonlinearity enhancement by a factor of 5.



Open aperture Z-scan data for chitosan-MWBN (1%) film.

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