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Study of Nano Composite Polymer Material using Spectroscopic Technique

K. Y. Rokde[1], P.B.Dahikar[2], M.J.Hedau[3], S. M.Ghatode[3], S.S.Shende [4]

[1]Department of Electronics, S.M.M.Science College, Nagpur, India [1]

[2]Department of Electronics, Kamla Nehru College, Nagpur, India[2]

[3]Department of Electronics, Shivaji Science College, Nagpur, India [3]

[4]Department of Electronics, J.M.Patel College, Bhandara, India [3]

E-mail:- ***krokde@yahoo.com***

Abstract

This paper describes the how the spectroscopic technique is useful for nano composite polymer material. Spectroscopic techniques are widely used in the study of optical properties of different materials including nonmaterial, nano composite material and polymer material. The different techniques are usually based on measuring absorption, scattering or emission of light that contains information about properties of the materials. Commonly used techniques include electronic absorption (UV-vis), photoluminescence (PL), infrared red (IR) absorption, Raman scattering, dynamic light scattering, as well as time-resolved techniques, such as transient absorption and time-resolved luminescence. Other more specialized techniques include single molecular spectroscopy and nonlinear optical techniques such as second harmonic or sum frequency generation and luminescence up-conversion. These different techniques can provide different information about the molecular properties of interest. Impedance spectroscopy technique at a constant frequency is used to determine the dielectric properties of the composites at low temperatures. The materials of polymer were analyzed by X-ray diffraction (XRD). In this paper several common spectroscopic techniques are reviewed with emphasis on their principle of operation as well as spectral interpretation. The main objective is to explain how one can get useful physical information about the nanomaterials under study from the optical spectrum measured experimentally. Many times in composite materials, a polymer material is used because polymers are flexible, easy to fabricate and superior in dielectric break down strength. This type of composites has high capability of energy storage and can be used in capacitors and energy storage device. Dielectric materials have very low electrical conductivity but can support large electrostatic fields. Dielectric ceramics are used to make capacitors, resistors, and insulators.

KEYWORDS: Optical spectroscopic; nonmaterial; impedance spectroscopy, polymer material.

Introduction

Electronic absorption or UV-visible spectroscopy is one of the simplest and yet most useful optical techniques for studying optical and electronic properties of nonmaterial's. This technique is based on the measurement of light absorption by a sample, typically using commercially available spectrometers at reasonable cost. As illustrated in Fig. (a), the intensity of light from a light source, e.g. a lamp, is

measured by a light detector, e.g. photodiode, photomultiplier tube (PMT) PMT or charge coupled device (CCD) detector, without (blank) and with a sample between the light source and detector. If the sample absorbs light at some wavelength, the transmitted light will be reduced. The intensity of the transmitted light plotted as a function of light wavelength will give a spectrum of the sample absorption. Most spectrometers cover the wavelength range from about 200 nm to 800 nm. Extending the measurement beyond 800 nm is possible but usually requires different light source, optics, and detector.

BLOCK DIAGRAM

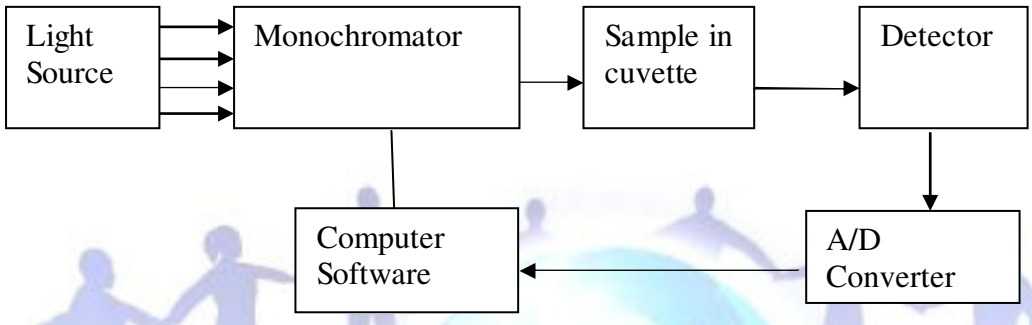


Fig (a) Schematic diagram of key components of a typical UV-vis spectrometer that includes a light source, e.g. a lamp, monochromator to disperse the incident light, sample cuvette and holder, detector, e.g. PMT, photodiodes or CCD, analog-to-digital (A/D) convertors, and computer with software to control the scan of the monochromator and data acquision

POLYMER COMPOSITE MATERIALS: The polymer composites used as dielectric materials for power energy storage devices. The particular focus is on materials: polymers serving as the matrix, inorganic fillers used to increase the effective dielectric constant, and various recent investigations of fictionalization of metal oxide fillers to improve compatibility with polymers. Electrical power energy storage plays a key role in mobile electronic devices, stationary power systems, hybrid electric vehicles, and pulse power applications. In particular, there is a growing need for capacitors that can accumulate a large amount of energy and then deliver it nearly instantaneously. This kind of “pulse power” is needed for a variety of military and commercial applications. Over time, these applications demand ever higher energy and power densities as well as higher rate capability. Dielectric materials can be used to store electrical energy in the form of charge separation when the electron distributions around constituent atoms or molecules are polarized by an external electric field.

The need for power energy storage systems with high energy density has led to the development of polymer composite systems that combine the process ability and breakdown field strength of the polymer with the high dielectric constant of ceramic fillers. Ideally, the fillers help to increase the effective dielectric constant of the

composite system without compromising the high inherent breakdown strength of polymers. Moreover, increasing the effective dielectric constant must be achieved without an unacceptably large increase in dielectric loss (i.e., energy dissipation). In reality, the objectives of high dielectric constant, high breakdown field strength, and low dielectric loss are not likely to all be achieved; the best solution will be a compromise. Consequently, much research is being carried out to develop improved polymer composite materials through a better understanding of the physical phenomena governing composite dielectric permittivity and breakdown field strength of the power devices.

Techniques and Methods

(A)**PHOTOLUMINESCENCE AND ELECTROLUMINESCENCE SPECTROSCOPY:** At the fundamental level, the principle underlying photoluminescence (PL) spectroscopy is very similar to that of electronic absorption spectroscopy. They both involve electronic transition of initial and final states coupled by the electrical dipole operator. The main difference is that the transition involved in PL is from a higher energy level or state to a lower energy level. There is also an important practical difference between the two techniques in that PL is a zero background experiment, i.e. no signal detected when there is no PL, which is in contrast to absorption spectroscopy that is a nonzero background experiment. Zero-background experiments are intrinsically more sensitive than nonzero background experiments. Therefore, PL is typically more sensitive than electronic absorption measurement. A typical PL spectrum is just a plot of the PL intensity as a function of wavelength for a fixed excitation wavelength. A photoluminescence excitation (PLE) spectrum, however, is a measure of PL at a fixed emission wavelength as a function of excitation wavelength. To a good approximation, PLE is similar to the electronic absorption spectrum as long as no complications are involved, e.g. involvement of multiple overlapping excited states or formation of excimers (excited dimmers). PLE is useful for studying samples for which electronic absorption spectrum is challenging to obtain, e.g. due to low transmission as a result of thickness or high concentration of the sample.

(B) INFRARED (IR) AND RAMAN VIBRATION SPECTROSCOPY: Infrared and Raman are two common vibration spectroscopy techniques useful for characterizing structural properties such as vibration frequencies of molecules and phonons as well as crystal structures of solids. Since they often have different selection rules for transitions, they are complementary. IR spectroscopy is based on the measurement of transmitted IR light through a sample. The absorbance measured as a function of

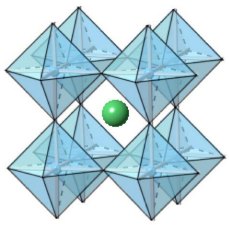
frequency contains information about the vibration or phonon modes or frequencies of the sample. The key components for an IR spectrometer are similar to that of UV-visible spectrometer except that the light is in the IR and the detector and optical components such as gratings and mirrors all need to be appropriate for IR light. Various commercial spectrometers, including FTIR (Fourier transform IR), are usually available in most institutions. The sample for IR spectroscopy measurement needs to be thin or dilute enough so Beer's law is valid or saturation can be avoided, similar to UV-visible spectroscopy

Methodology of Polymer Composite Materials

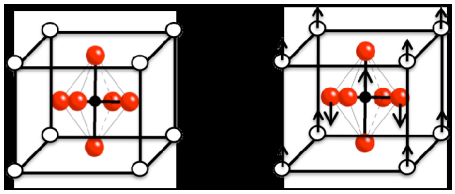
In the methodology of polymer composite material only one material mentioned in this paper.

(A) BARIUM TITANATE (BATIO3): The most widely investigated oxide in the field of dielectrics; barium titanate was first studied in the 1950s. Barium titanate (BT) belongs to a group of materials that crystallize with the perovskite structure, as shown Figure, and that have the general composition of *ABO3*. Many other ferroelectric ceramics Such as BT, lead titanate (PbTiO3), PZT, PLZT, PMN, and potassium niobate (KNbO3) also belong to the perovskite family. Barium titanate exists in the paraelectric cubic phase above its Curie point of about 130 °C, while in the temperature range of 0 °C to 130 °C, the ferroelectric tetragonal phase is stable.

The dielectric properties of BT have been found to be grain size dependent. The room temperature dielectric constant of coarse grain (10 micron) BT ceramics is found to be in the range of 1,500–2,000, while fine grained (~1 micron) BT ceramics exhibit an enhanced room temperature dielectric constant of between 3,500–6,000.



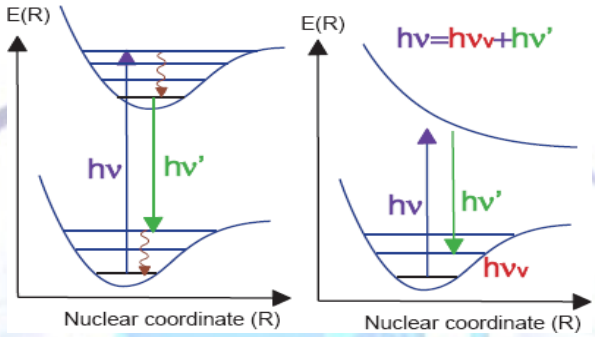
Figure(b). A cubic *ABO3* (BaTiO3) perovskite-type unit cell, with Ba2+ ions shown in green, and TiO6 corner-sharing octahedra in blue.



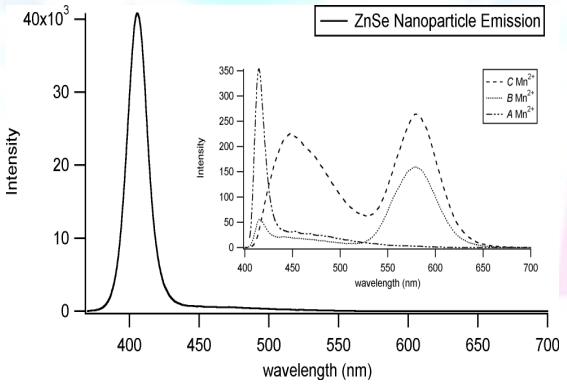
Figure(c): The crystal structure of BaTiO3 above the Curie point is cubic (left); below the Curie point the structure is tetragonal due to the displacement of the Ba2+(white) and Ti4+(black) ions relative to the O2-(red) ions as indicated by the arrows.

Result

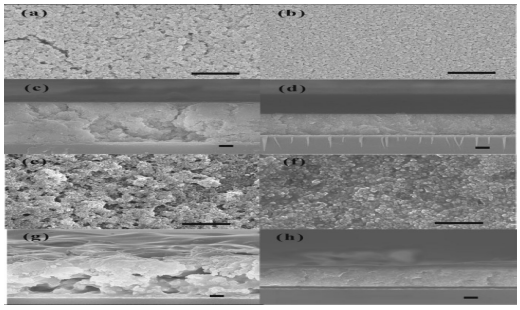
This Paper covers some of the most commonly used spectroscopy techniques including electronic absorption, luminescence, IR, Raman, as well as time-resolved techniques, such as transient absorption and time-resolved luminescence for nano composite polymer material. More specialized techniques such as single molecular spectroscopy and nonlinear optical techniques have also been briefly discussed. This spectroscopy technique will be very useful for studying high rated power electronic devices.



Fig(d). Schematic illustration of electronic transitions in a diatomic molecule with two different excited state potential energy curves: bound (left) and repulsive (right). The long vertical arrows indicate electronic transition while the shorter red arrows indicate Vibrational transition or IR absorption in the ground electronic state.



fig(e). Comparison of the luminescence spectra of undoped and Mn2+-doped ZnSe nanoparticles samples A, B and C with increasing level of Mn2+ doping when going from A to B to C.



Fig(f): Surface and cross-sectional SEM images of spin-coated nanocomposite thin Films of BaTiO3

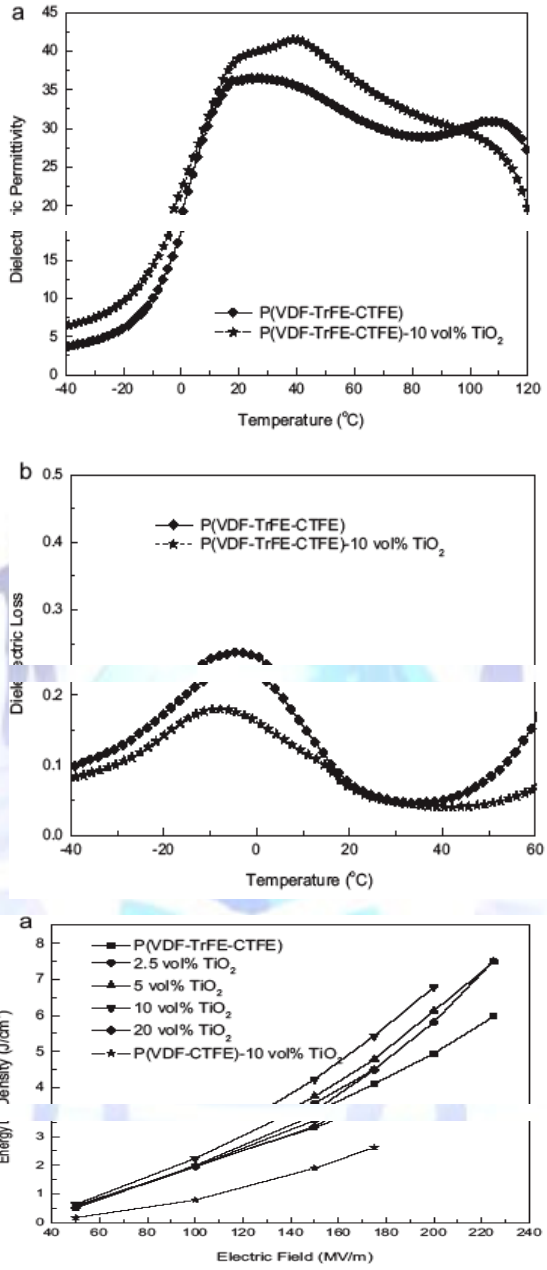


Fig. (g) Temperature-dependence of the dielectric constant of the polymer and Nanocomposite measured at 1 kHz. (b) Temperature-dependence of the dielectric loss of the polymer and nanocomposite measured at 1 kHz. (c) The stored energy density of the polymer and nancomposites as a function of the applied field.

Conclusion

This More specialized techniques such as single molecular spectroscopy and nonlinear optical techniques have also been briefly discussed. Selection of these different techniques for applications depends on the information of interest. In further applications, many specific examples of applications based on these various

techniques will be used to demonstrate how to extract physical information from the measured spectrum.

From the work reported in this review, we conclude that significant strides have been made in the development of polymer composites and nanocomposites with greater energy storage capacity and higher energy density. Still, much more work needs to be done to begin designing polymer composite dielectrics from first principles, rather than by mixing components in the hopes of finding improved properties. For the foreseeable future, the leading edge of research in this area will continue to focus on better understanding the nonomaterial and structure of the polymer-filler interface and its influence on composite dielectric permittivity and breakdown field strength.

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