POLYMER NANOCOMPOSITE FILMS OF ZnO AND ZnO/MWNT FOR NONLINEAR OPTICAL APPLICATIONS

A Thesis submitted

in partial fulfillment for the Degree of

Doctor of Philosophy

by

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JANUARY, 2015

ABSTRACT

The diverse applications utilizing nonlinear optical processes have imparted the requirement to invent materials possessing optical nonlinearity. However, the implementation of these materials can be accomplished only if films are fabricated by employing appropriate fabrication technique. Even though a large number of materials having nano meter size are nonlinear optical active in their colloidal form, the device fabrication of these materials is still not so popular. Polymer nanocomposite films are better candidates in this regard because apart from the desired properties, they can provide optical transparency.

The present investigation focuses on the fabrication of polymer nanocomposite films with the help of nanoparticles and transparent polymers and analyzes their nonlinear optical properties. Zinc oxide and multiwalled carbon nanotubes are two excellent materials to experiment with, in this regard. Both of these materials are known for their linear and nonlinear optical properties. A hybrid of these two materials is therefore expected to exhibit excellent nonlinear optical properties compared to their counterparts. Transparent polymers like polymethyl methacrylate and polystyrene are utilized as the matrices for preparing polymer nanocomposites. Films are fabricated with the help of spin and dip coating techniques.

Initially ZnO nanoparticles are synthesized from zinc acetate salt by solution precipitation method. Two types of ZnO nanoparticles are synthesized with the help of two different capping agents - polyethylene glycol and polyvinyl pyrrolidone. Detailed characterisation of these samples is performed to analyze their properties. The nanoparticles prepared with polyvinyl pyrrolidone is named as ZnO nanotops owing to their top like structure and these nanoparticles are proven to be good reverse saturable absorber, on investigating with open aperture Z-scan technique. Polymer nanocomposites of polymethyl methacrylate and the ZnO nanotops are synthesised and films are fabricated with the help of dip and spin coating technique. These films are found to be reverse saturable absorbers and posses larger nonlinear absorption coefficient compared to the nanotops in colloid form. The spin coated films exhibit improved nonlinear absorption compared to the dip coated films of same ZnO loading concentration. Based on the TGA analysis of the films, the reason for the same is explained. The nonlinear absorption coefficient of the spin coated films increased with the increase in loading concentration of the nanotops. An effective two photon absorption resulting from two photon absorption and excited state absorption is found to be the mechanism behind the exhibited optical nonlinear absorption (*Applied Physics Letters,* 2012).

Improved dispersion of the nanoparticles in the polymer matrix facilitates uniformity and optical transparency when films are fabricated. With the help of two kinds of dispersing agents (oleic acid and triton) polymer nanocomposite films of polymethyl methacrylate and ZnO nanotops are prepared so as to enhance their

uniformity and optical transparency. These films exhibit enhanced linear and nonlinear properties compared to the films prepared without the help of dispersing agent. Triton is found to be a better dispersing agent. The films exhibited a transition from reverse saturation to saturation of absorption with increase in loading concentration of ZnO nanoparticles incorporated in them. Dominance of two step absorption, two photon absorption and free carrier absorption is observed in these films. Apart from that, Pauli blocking is observed as the mechanism behind the saturation of absorption in films with higher loading of the nanotops. Films with tunable saturable and reverse saturable absorption nature could be thus fabricated enabling them for applications in optical limiting, optical bistable devices and laser mode locking (*Applied Physics Letters,* 2014).

Films with considerable nonlinear absorption coefficient and lower saturation intensity are required for applications involving protection from the hazards of high intensity lasers. Optical transparency is a desirable factor for transparent laser protection coatings. This lead to the fabrication of polymer nanocomposite films of ZnO nanotops with polystyrene employing spin and dip coating techniques. Another set of films with ZnO nanotops and a blend of polystyrene and polymethyl methacrylate are also fabricated with spin coating technique. The spin coated films prepared with ZnO nanotops and a blend of polystyrene and polymethyl methacrylate serve as better nonlinear absorbers and have better quality, uniformity and transparency (*Optics Letters,* 2014).

Multiwalled carbon nanotubes are fascinating materials with a wide range of applications in almost all fields. They have been identified to possess good nonlinear absorption property also. This motivated the synthesis of a hybrid material from ZnO nanotops and acid functionalised multiwalled carbon nanotubes. The hybrid is found to exhibit a fifth order nonlinear absorption behaviour due to cascaded one photon absorption. Films of the hybrid with polymethyl methacrylate are prepared with the help of spin coating technique. A comparative study has been carried out on the nonlinear absorption property of these films with another set of films prepared from the hybrid and a blend of polystyrene and polymethyl methacrylate. As expected, these films also exhibited a fifth order nonlinear optical property with considerable value of effective three photon absorption coefficient.

In total, the present investigation succeeded in fabricating good quality polymer nanocomposite films with considerable nonlinear absorption coefficient and low saturation intensity. The study highlights the synthesis, fabrication and characterisation techniques for efficient device fabrication of nonlinear optical materials like zinc oxide, multiwalled carbon nanotubes and their hybrid.