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Variation in Refractive Index of Iodine Doped Poly (Methyl Methacrylate)

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Abstract

Poly (methyl methacrylate) (PMMA) and iodine hybrid matrixes have been prepared and characterized. Refractive index measurement was done at 390, 535, 589, 590, 635 nm wavelengths. The results showed that the refractive index of the composite varies nonlinearly with the doping concentration at low iodine concentration or in the region of nanoparticle formation and is also dependent on thermal annealing.

Keywords: *Refractive Index, Dispersion, Cauchy's equation*

1. Introduction

Quantum dots [1,2], which have size-dependent linear and non-linear optical properties can be put to technological use in photonics for telecommunications. Nonlinear optical properties of crystalline nanophases [3-5] are used inside a transparent host compatible with silica based telecommunication technology. There is a distinct possibility of nanocrystals being put to good use in nanotuned refractive index materials. The present study takes up nanostructured Iodine doped PMMA and finds out the influence of nanoparticles and thermal annealing on the refractive index 'RI' of the material. Abbe's number and Cauchy's constant have been calculated from the acquired data.

2. Experimental Details

Using a solvent evaporation technique, using benzene (AR) as a solvent, nanocrystals of various sizes have been grown [6]. Poly (methyl methacrylate) (Du Pont) was the host material and Iodine (Aldrich) the dopant. Different particulate sizes were obtained by dissolving PMMA in benzene and taking different percentages of Iodine- as a dopant -by weight, ranging from 0.1 % to 10.0%. Thin films were obtained by evaporating the solutions on glass substrates. Optical absorption studies were conducted on the samples using a Systronics spectrophotometer, Model 106. Refractive index measurements - at 390, 535, 589, 590, 635 nm wavelengths - were done by an Abbe's refractometer. Refractive index measurements was also done on samples treated to thermal annealing at temperatures of 40^0C, 70^0C, 100^0C, 130^0C for three hours. The analysis of data from the optical absorption study and that of the refractive index was done by using Mathematica™ [7].

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3. Results and Discussion

The Tauc plots Fig.1 of samples show that the visible thresholds of 0.1 to 1.0 % by weight of Iodine doped samples are showing a tendency to blue-shift relative to bulk PMMA, suggesting the formation of nanometer-sized I_2 particles in samples [6]. The host (bulk) was found to have an optical band gap of 2.99 eV and the 0.1, 0.5 and 1.0 % samples are found to have band gaps of 3.024, 2.995, and 3.020 eV respectively. The samples having 5.0 and 10.0 % I_2 do not exhibit the formation of nanocrystals.

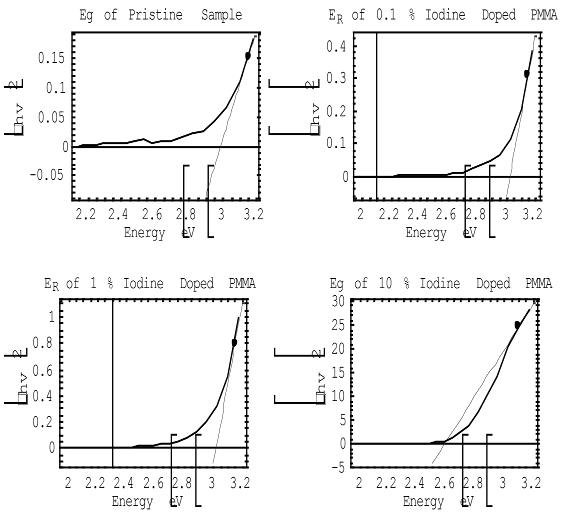

Fig. 1 Tauc plots of Iodine doped PMMA samples.

Fig. 2 shows plot of refractive index versus doping concentration of iodine doped PMMA samples. Two distinct features are seen in a single RI plot Fig. 2, a non linear portion at low iodine concentrations while a linear segment at high concentrations. The experimentally determined refractive index of the doped polymers did not follow a simple mixture law [9]. A fitting of the data set shows the fit equation to be

$$\text{FitEqn} = a.D - b.\,\text{Exp}\,[-c.\,D] + e\ldots \quad (1)$$

This empirical fit equation for unannealed PMMA with 'D' as the doping concentration and {a=0.000327051, b=0.00258182, c=2.69508, e=1.45271} is quite effective when applied to the experimental data set. This fit equation has a non linear component added to a linear term. The linear term would be as expected of a system obeying a mixing rule. The nonlinear term provides a negative contribution to the refractive index and it is predominately effective in the region where there is nanoparticle formation [6]. Fig.3 shows the experimental refractive index curve (continuous line) along with the computed curve (discontinuous line) from the fit equation.

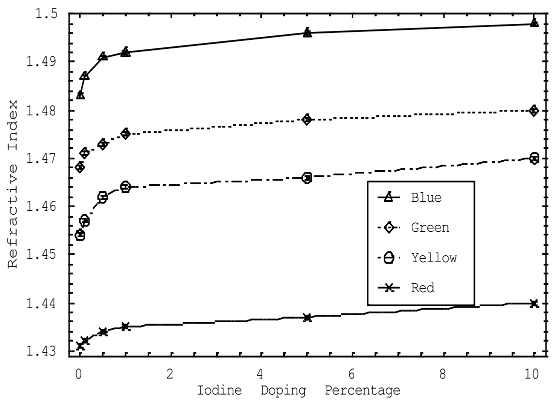

Fig. 2 Refractive Index plot of Iodine doped PMMA at different wavelengths

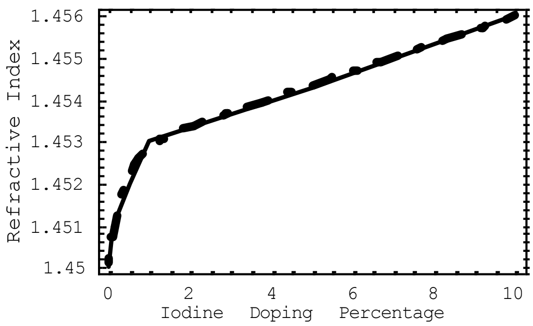

Fig. 3 Experimental and computed refractive index plot

Fig.4 shows a graph of refractive index as a function of percent by weight of Iodine doping at different thermal annealing temperatures for Na-D line. The nature of the graph depicts increase in the refractive index with annealing temperature.

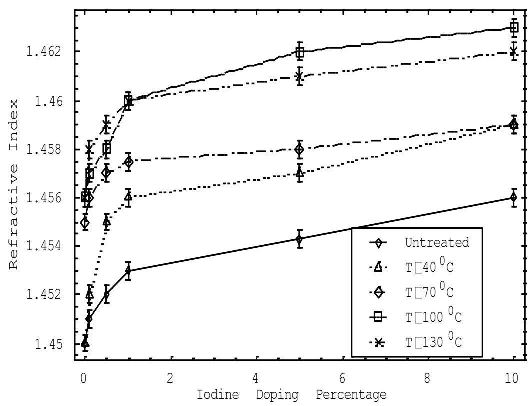

Fig.4 Refractive Index plot of Iodine doped PMMA at different annealing temperatures for sodium D line.

6. Conclusions

It seems that nanoparticle formation in Iodine doped PMMA and thermal annealing modify refractive index of the host. In the development of optical polymers, it is often required to have polymers with refractive indices within a certain range. Polymeric materials are currently being investigated to both widen the physical properties and reduce the capital requirements in the production of photonic crystals [3-5].

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