Carbon Nanotube Doped Tellurite Glasses

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Abstract

In the past it was observed that buck ball doped glasses showed enhanced optical nonlinearities. However, carbon nanotubes are much more stable than buck ball and should be a better choice for that purpose. Therefore we decided to investigate the possibility to produce carbon nanotubes doped tellurite glasses and measured their optical nonlinearities. Tellurite glasses already have a larger nonlinearity compared to silica, and other, glasses. We produced TeO_2-ZnO tellurite family glasses doped with multi wall Carbon Nanotube (CNT). The CNTs acquired from Carbolex were vigorously mechanically mixed with the tellurite glass precursors and melted in platinum crucible around 650^{o}C in a controlled atmosphere inside an electrical induction furnace. We used the lowest temperature possible and controlled atmosphere to avoid the CNT oxidation. The glass melt was cast in a stainless steel and thermally treated at 300^{o}C for 5 hours to relieve internal stresses. The samples were than cutted and polished to perform the optical characterization. We measured refractive index and thermo physical properties, such as vitreous transition T_g, crystallization onset T_x and melting T_f temperatures. Raman spectroscopy showed the possible presence of CNTs.

1. Introduction

A carbon nanotube (CNTs) – carbon atoms arranged in tubes with diameters of a few nanometers was discovered by S. Iijima [1]. These nanotubes exhibit remarkable mechanical and electrical properties that have been used to produce ultra-strong fibers and electron sources for displays amongst many other applications.

Very recently, they have been shown to have interesting optical properties as well. In particular, they show strong nonlinearity when exposed to high-intensity light, meaning that there are applications in wavelength conversion, optical switching, and mode-locking.

The combination of high nonlinearity with high damage threshold and potentially low cost is attractive, and in 2004 the first application (mode-locking in an ultra fast pulsed laser) was reported by Alnair Labs in Japan.

Researchers at Southampton, led by Dr Wei H Loh, will tackle the encapsulation of carbon nanotubes into chalcogenide glasses, for integrated photonic and electronic devices [2].

Transparent silica glasses containing single walled CNTs was produced by Dimaio et al using sol-gel technique with purpose of study non-linear optical properties[3].

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Study of formation of single wall CNTs by using porous glass was reported by Aoki et al [4]. In this case the formation of single wall CNTs depends intrinsically of porous size.
Poly(3hydroxybutyrate) (P(3HB))/Bioglass® composites incorporating multiwalled carbon nanotubes (MWCNTs) have been successfully prepared by the solvent casting technique by S K Misra et al [5].
In this work we report the introduction of CNTs inside tellurite glass with posterior objective of study non-linear optical properties. Due to low melting temperature of this glass system, TeO2-ZnO was used with objective of avoids CNTs oxidation.

2. Materials and Methods

A method for fabrication of CNTs doped with tellurite glass was used by the melting process. The CNTs was acquired from Carbolex and vigorously mechanically mixed with the tellurite glass precursors ($75TeO_2$ -25ZnO (%mol)) and melted during 30min in platinum crucible around 650^oC in a controlled atmosphere inside an electrical induction furnace. We used the lowest temperature possible and controlled atmosphere to avoid the CNTs oxidation. The glass melt was cast in a stainless steel and thermally treated at 300^oC for 5 hours to relieve internal stresses. The samples were than cutted and polished to perform the optical characterization.
Diverse glass samples doped with CNTs with different composition (between 0.1 and 0.5 in weight percent) were fabricated using this method.
For thermal characterization we used a DTA Shimatzu equipment with thermal rate of 10^oC/min. The refractive index was characterized by a Metricon equipment using a prism coupler with standard deviation of 0.0001. The structural characterization was realized by Raman scattering equipment with a 785 nm laser.

3. Results and Discussions

In figure 1 we show the thermogram of DTA analysis of the tellurite glasses with different CNTs composition, we can observe that the characteristics events as glass transition temperature T_g, crystallization onset temperature T_x and melting temperature T_f were dependents of the CNTs doping. In (a) in this figure we observe these events, with two crystallization peaks; in (b) we can see that the glass transition temperature from the first peak increase and the second peak disappear. However with sample (d) we observe that the first peak disappears and appear only the second peak. Until this moment, we can not understand this behavior.

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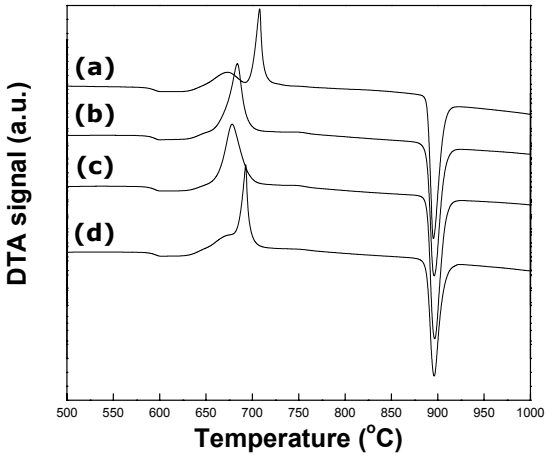

Fig. 1 DTA thermal analysis of the samples. In (a) glass without CNTs, (b) 0.1 wt%; (c) 0.3 wt% and (d) 0.5 wt%.

Using a Metricon prism coupler equipment was measured the refractive index of each tellurite glass composition at three wavelengths (633, 1305 and 1536 nm). We observe in figure 2 that all samples present high refractive index when compared with silica glass and the CNTs addition not modifies these values. We can observe that the nonlinear optical properties with this type of glass may be very high due the linear refractive index scale with the nonlinear refractive index.

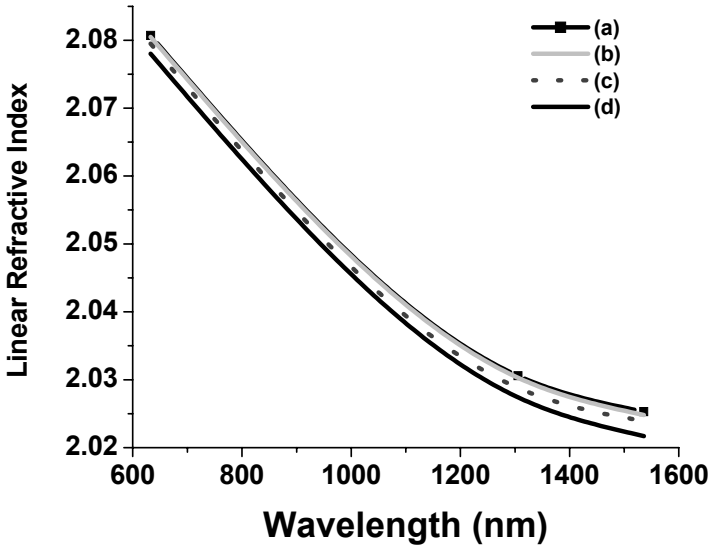

Fig. 2 Linear refractive index of the samples. In (a) glass without CNTs, (b) 0.1 wt%; (c) 0.3 wt% and (d) 0.5 wt%.

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With Raman scattering measurement we observe the presence of CNTs in only one composition as is show in figure 3. The picks around 1520cm^{-1} and 2300 cm^{-1} would be attributed to CNTs presence.

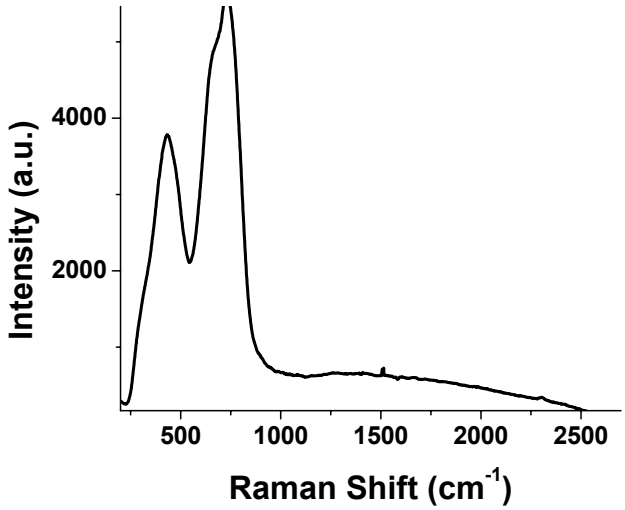

Fig 3 Raman intensity for Tellurite glass with CNTs at 0.5 wt%.

4. Conclusions

In this work we present the preparation and characterization of CTNs doped tellurite glass system TeO_2-ZnO by thermal analysis, linear refractive index and structural characterization by Raman scattering. We observe that this new glass presents high refractive index with the presence of CTNs and may be present a very and interesting nonlinear optical property that at the moment is being measurement in our laboratory. In the future we think use a High Resolution Transmission Electron Microscopy with objective of observe this CNTs in the tellurite glass matrix

5. Acknowledgments

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