EFFECT OF SOLVENT ON NON–LINEAR SYNCHROTRON ABSORPTION OF MULTI–WALLED CARBON NANOTUBES (MWCNTS) WITH DNA/RNA FUNCTION

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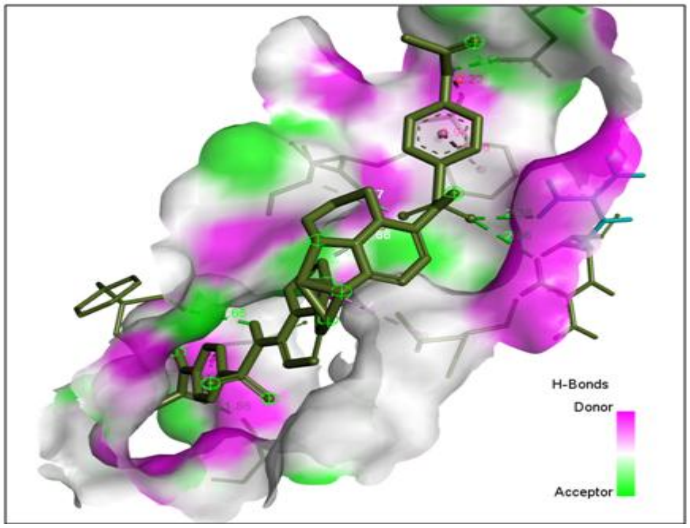
GRAPHICAL ABSTRACT: *The effect of solvent on non–linear synchrotron absorption of Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function in toluene and dimethylformamide solvents is investigated. Multi-Walled Carbon Nanotubes (MWCNTs) show the optical limiting property as a suspension in these solvents. To investigate the non–linear synchrotron absorption, attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectroscopy and second harmonic line of synchrotron Nd:YAG with 665 (nm) wavelength were used. The obtained results show that the sample, as suspension, in the toluene solvent is of higher non–linear synchrotron absorption than in dimethylformamide (DMF) solvent.*



Modelling of multi-walled carbon nanotubes (MWCNTs) with DNA/RNA function complex.

Keywords: Attenuated Total Reflection–Fourier Transform Infrared (ATR–FTIR) Spectroscopy, Non–Linear Synchrotron Absorption, Optical Limitation, Multi-Walled Carbon Nanotubes (MWCNTs), DNA/RNA Function

1. INTRODUCTION

Carbon nanotubes (CNTs) have been widely interested due to their special physical properties and high potential applicability [1–23]. CNTs are the largest one–dimensional carbon molecule in which, every single carbon atom is related to three other carbon atom through a covalent bond. The valence electron of each carbon atom is free to make a π bond along the tube. The existence of C=C double bond in CNTs creates π electron around the walls of CNTs. Therefore, investigation of the non–linear optical properties of CNTs is predictable [24–77]. To investigate the non–linear optical properties of CNTs, they are used as a suspension in organic solvents. The main problem for solving CNTs is that they are not soluble in solvents. To solve this problem, Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA functions are used. DNA/RNA function (COOH) solves easily in polarized solvents. Hence, Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function easily diffuse in organic solvents and make a suspension. CNTs show limiting property in suspension form; i.e. act as an optical limiting agent. Optical limiting is an important non–linear phenomenon which can be used to protect sensitive optical tools such as the human eye from strong synchrotron emission. Non–linear synchrotron absorption that leads to optical limiting has been widely investigated by numerous researchers for various nanoparticles. The aim of the current paper is to study this phenomenon for carbon nanotubes [78–105]. In the current research, non–linear synchrotron absorption of Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA functions in the form of a suspension in toluene and dimethylformamide solvents are reported. To investigate the non–linear synchrotron absorption of carbon nanotubes, attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectroscopy using the second harmonic of continuous Nd:YAG synchrotron with 665 (nm) wavelength is used. It is observed that carbon nanotubes in the form of a suspension in toluene solvent have higher non–linear synchrotron absorption than in dimethylformamide solvent

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2. EXPERIMENTAL RESULTS

2.1. Materials

In the first step, Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function with 95% purity and 5–15 (nm) outer diameter and 3–5 (nm) inner diameter were supplied from Pishgaman Nano Mavad Iranian Co. These nanotubes are produced by CDV method and for this work, dimethylformamide and toluene with boiling points of 153 and 110.6º C, respectively, were used.

2.2. Non–Linear Optical Measurement

To investigate non–linear optical properties of Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function, attenuated total reflection–Fourier transforms infrared (ATR–FTIR) spectroscopy can be used. The attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectroscopy is a method for determining the sign and value of the refraction coefficient and non–linear synchrotron absorption coefficient. Since its introduction by Alireza Heidari *et al.*[1], this method has been effectively used to measure optical non–linearities [106–149]. Compared to other methods, this method is very sensitive and simple and is able to simultaneously measure the value and sign of non–linear parameters of the material. In this technique, a ray with Gaussian intensity distribution is focalized using a lens in z-direction [150–187]. The sample move from the focal point in the z-direction and the transition intensity from a window measures by a photodiode in far-field as a function of z. When the sample moves along the focalization of ray, self–focalization ($n2>0$) or self–devocalization ($n2<0$) of wave face and hence, the intensity of transited ray, is changed. For ($n2<0$), the transition curve has a peak for the sample located before the focal point and a valley for a sample located after focal points. For ($n2>0$), it is vice–versa. To measure non–linear synchrotron absorption coefficient, attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectroscopy with an open window is used so that by scanning the sample around the focal point, its synchrotron absorption value is measured by a photodiode as a function of z. For positive non–linear synchrotron absorption coefficient ($\alpha2>0$), the obtained curve has a valley during the transition of the sample from the focal point and for ($\alpha2<0$), synchrotron absorption curve has a peak. To do this, carbon nanotubes with DNA/RNA function were suspended in dimethylformamide and toluene solvents. It should be noted that DNA/RNA function (COOH) help for easily diffusion of CNTs in organic solvents. synchrotron beam Nd:YAG was focalized by a 10 (cm) lens. Samples were attached to a moving base which was controlled by computer to regulate the position of samples along z-axis compared to the focal point.

3. RESULTS AND DISCUSSION

Dimethylformamide and toluene solvents are appropriate solvents for diffusing Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function due to their polarization. In the current research, 0.5 (mg) carbon nanotubes were suspended in 10 (ml) solvent. The concentration of samples was equal for both solvents and they were stable for a few hours. The obtained results from attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectroscopy was recorded (Figures (1) and (2)).

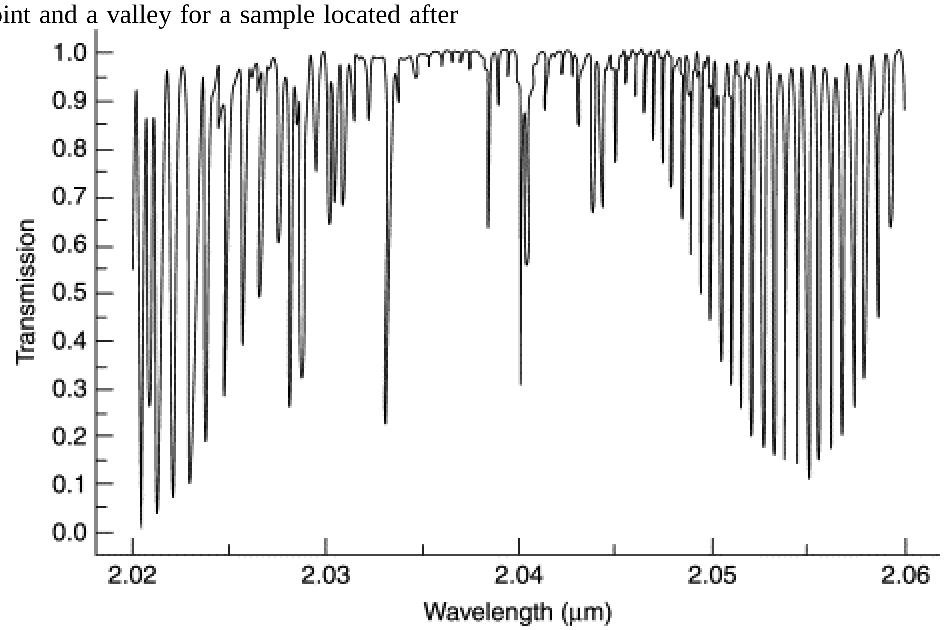

Figure (1): Attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectrum related to the transition from the open window (which shows non–linear synchrotron absorption) is illustrated for the sample in toluene with 0.5 (mg) percent in 10 (ml) with synchrotron power of 12 (mw) at 665 (nm) wavelength against distance.

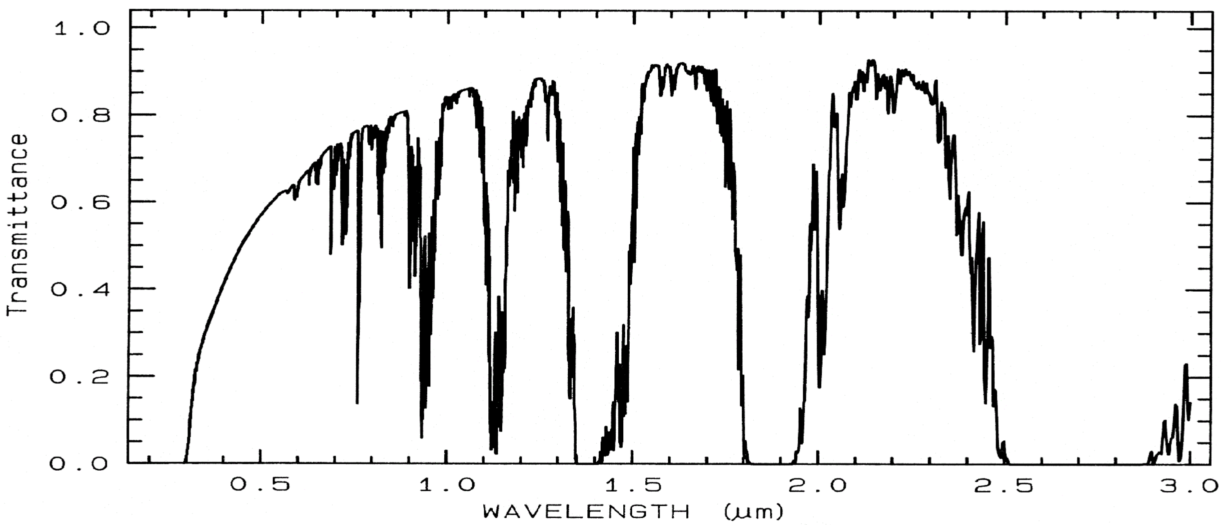

Figure (2): Attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectrum related to the transition from the open window (which shows non–linear synchrotron absorption) is illustrated for the sample in dimethylformamide with 0.5 (mg) percent in 10 (ml) with synchrotron power of 12 (mw) at 665 (nm) wavelength against distance.

In the next step, the intensity of the incident synchrotron was increased while the concentration of the sample was kept constant, the experiment was repeated, and the obtained results were recorded. Figures (3) and (4) are illustrated for the sample in toluene and dimethylformamide, respectively, with synchrotron power of 18 (mw) at 665 (nm) wavelength against distance.

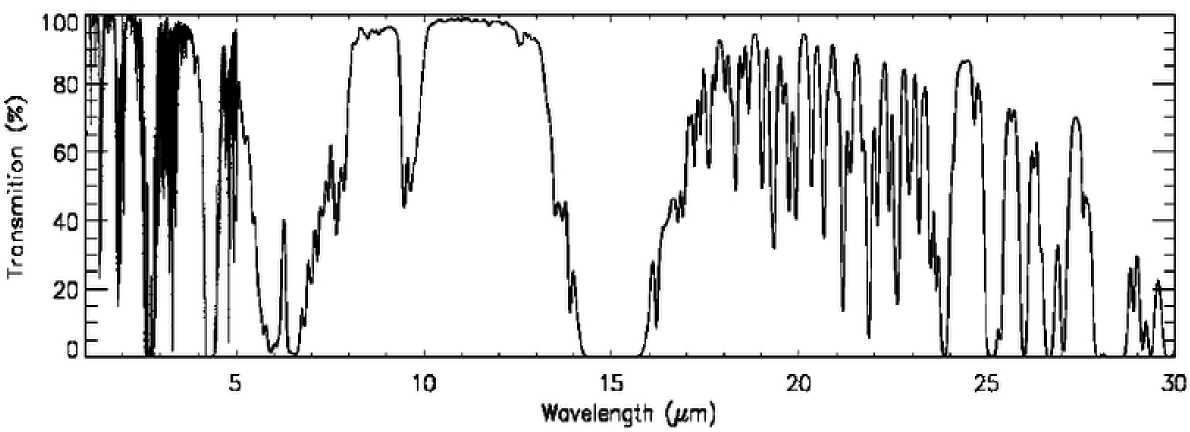

Figure (3): Non–linear absorption of the sample in toluene.

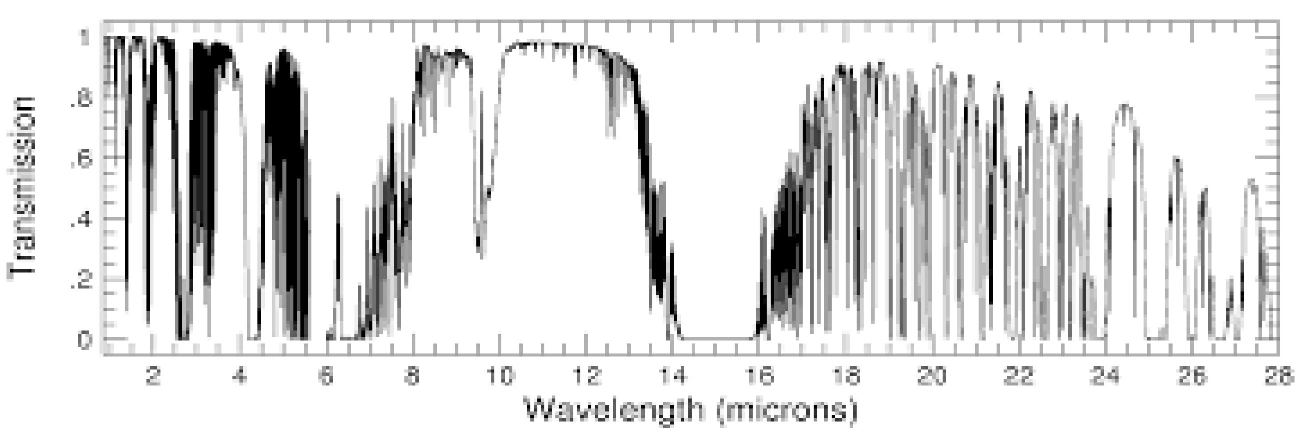

Figure (4): Non–linear absorption of sample solved in dimethylformamide

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Regarding Figures (1) and (2) with synchrotron power of 12 (mw), it can be seen that non–linear synchrotron absorption of the sample in toluene is more than in dimethylformamide. In addition, similar results can be obtained by comparing Figures (3) and (4), which is due to the following reasons:

(i) In low synchrotron power, boiling bubbles of solvent are created and developed because of the transferring of thermal energy from carbon nanotubes to the solvent;

(ii) In high synchrotron power, steam bubbles of carbon nanotubes are created and developed. There are two inherent effects on optical limitation: (a) structure and (b) solvent properties. Regarding the structure, it can be said that the limiting effect is sensitive to the set diameter of nanotubes. Nanotubes with large set sizes have more effect than the effect of thermal energy transferring to the solvent. The host solvent also is of special contribution in showing the limiting effect. For example, carbon nanotube diffused in a solvent with a low boiling point show a low threshold of limiting and better limiting effect [188–206]. This issue is observed in graphs related to toluene that have a lower boiling point than dimethylformamide. It should be pointed out that inductive boiling bubbles in solvents with a low boiling point are growing up speedily and hence, they lead to fast reaching of solvent boiling point to the critical size in a short time which in turn leads to fast limiting response [207–269]. Meanwhile, non–linear synchrotron absorption observed in the current research is two photons of synchrotron absorption. The reason for more non–linear synchrotron absorption in toluene than dimethylformamide can be found in their linear synchrotron absorption [270–331]. Evaluation of the synchrotron absorption spectrum of samples by UV–VISIBLE spectrophotometer shows that maximum synchrotron absorption of toluene and dimethylformamide are happened at λ_{max}= 297 and 303 (nm), respectively. These wavelengths show that the toluene sample with λ_{max} = 297 (nm) is of more potential for non–linear two photons synchrotron absorption at 665 (nm) wavelength of the considered synchrotron. While dimethylformamide sample with λ_{max} = 303 (nm) is far away from non–linear two photons synchrotron absorption at 665 (nm) wavelength of considered synchrotron [332–375].

4. CONCLUSION

Investigation about the effect of solvent on non–linear synchrotron absorption of Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function in the form of a suspension in toluene and dimethylformamide solvents was performed by attenuated total reflection–Fourier transform infrared (ATR–FTIR) spectroscopy using continuous synchrotron at 665 (nm) wavelength. The obtained results show that Multi-Walled Carbon Nanotubes (MWCNTs) with DNA/RNA function in the form of a suspension in toluene with a lower boiling point than dimethylformamide is of more non–linear synchrotron absorption.

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