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An Investigation of SHG Response from the CNT/Peptide Interface as a Function of Variant Peptide Concentrations and Tunable Wavelengths by Using a Monochromator

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Abstract The carbon nanotubes (CNT) was fabricated on the $Si/SiO_2/Co$ substrate by chemical vapor deposition (CVD) method. After that, we dropped variant concentrations of peptide molecules on the CNT surface and measured the SHG intensity from the CNT/PEP interface. We found that the SHG intensity was maximum for all concentrations of peptide molecules at 532 nm when we tuned the wavelength manually by using monochromator. At the fixed SHG wavelength, the intensity was increased with the increase of peptide concentrations. This is because of the availability of the different types of C-bonds may produce chiral structure. This chirality behavior could be the reason for the generation of SHG signal with the increase of peptides concentrations on the CNT surface.

Keywords: *carbon nanotubes, peptides, second harmonic generation, chirality, interface*

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1. Introduction

Carbon nanotubes (CNTs) have been recognized originally by Sumio lijima in 1991 [1]. Graphene sheets are rolled up to prepare CNTs. CNTs have large variety of physical properties due to having different individual graphene layer. Due to having wide variety of mechanical strengths as well as electronic structures and outstanding optical properties CNTs can show potential electrical and optical applications [2]. Due to having many interesting features and applications in the field of electronics and optics, it needs quality characterization methods that are specific and cost-effective to determine the nonlinear optical property.

Now-a-days nonlinear techniques interestingly used extensively due to the probability of gaining remarkably large nonlinear optical responses from nanomaterials that can provide complementary information [3]. Second harmonic generation (SHG) is very promising nonlinear technique to explore electronic information from the nanomaterials. SHG methods are known to symmetry sensitive method and are not forbidden in noncentrosymmetric materials with in the electric-dipole approximation due to the interaction between light and matter [4]. However, SHG signals are not obtainable from centrosymmetric media [4]. When the incident light of frequency ω comes to the asymmetry medium, the light of frequency 2ω will be generated. This phenomenon is SHG. In addition, when incident light of frequency ω comes to the symmetry medium, the light of frequency 2ω will not be generated in electric dipole approximation. Therefore, SHG spectroscopy is sensitive to surface and interface where the spatial symmetry is broken. In case of our growing CNT, it is randomly grown on the substrate and the peptide molecules are also randomly distributed as irregular film on the CNT surface. So, the surface is noncentrosymmetric and can generate SHG.

Okawara et al. investigated the CNT film surface grown on SiO_2 substrate by SHG technique. They used 1064 nm wavelength of laser light as fundamental radiation and observed the alignment of the grown CNT film after analyzing the SHG signal [5]. Some other researchers found that the SHG signal generated from CNT due to having local imperfections, deformation, chirality that resulted from nonracemic assembly at the internal structure of CNT [6,7,8,9]. L. De Dominicis et al. investigated single-walled carbon nanotube surface by SHG technique and found that the main source of SHG generation is the structural defects or chirality [10,11]. S. Fujii et al. observed the SHG signal from the monolayers of cyclic peptides which is self-assembled [12]. Nakayama et al. observed the SHG signal from helical peptides attached with chromophore to evaluate self-assembled monolayer structure of a stereocomplex of helical peptides [13]. The SHG signal was observed from the different types of peptides and polypeptides that carries polarizable groups. The strongest SHG signal was found from monopeptide and dipeptide derivatives of p-nitrophenylalanine [14].

Above literature reveals that many researchers have been investigated individually either CNT or peptide surface by SHG technique. However, very limited study could be found on CNT/Peptide interface by SHG method. So, we intended to check the SHG responses from CNT/PEP samples having different concentrations of peptides. The main purposes of our work were to measure SHG intensity as a function of manually tunable wavelength and concentration of peptide molecules. As the SHG method is new to apply for investigating the peptide molecules, it is our great interest to observe the SHG response from CNT/PEP interface. Interestingly we found that, the SHG intensity was increased with increasing the concentration of peptide molecules at the wavelength of 532 nm.

2. Experimental Procedure

Synthesis of carbon nanotube (CNT) using ethanol as a source of carbon by chemical vapor deposition (CVD) method has been discussed elsewhere in our previous publications [15,16]. After synthesizing the CNT we dropped different concentrations of peptide molecules. Then we measured the SHG signal from the CNT/PEP interface as a function of variant peptide concentrations and manually tunable wavelengths. In SHG measurement, a mode-locked Nd^{3+}:YAG picosecond laser was Pulse width and repetition rate were 30 ps and 10 Hz respectively, recorded at the output of the excitation source. The sample was kept on to the automatic rotation stage to measure the SHG signal. The incident light having photon energy of 1.17 eV was illuminated on the samples at an angle of 45° after passing through a prism, mirror, half-wave plate, polarizer, 2ω cut filter and a lens in different experiment for individual samples. To avoid damaging the sample, the average energy of the incident beam was maintained approximately 50 μJ/pulse. The reflected radiation (including SHG signal) was passed through a pre-settled lens, ω cut filter, output polarizer, depolarizer, lens, monochromator and finally by a photomultiplier tube and processed in PC. We manually tuned the wavelength of reflected SHG signal using monochromator to observe the resonance from the CNT/PEP interface for variant concentrations of peptide molecules. The optical setup for SHG measurement is shown in Figure 1.

3. Results and Discussion

Figure 2 reveals that the highest SHG intensity has been observed at 532 nm of SHG signal when we tuned the wavelength manually by using monochromator for all concentrations of peptide molecule. Here, the highest SHG intensity has been recorded from the CNT+10μM peptide molecules which is the maximum concentration of peptide molecules dropped on the CNT surface.

Figure 3 exhibits the increasing SHG intensity as a function of increasing concentration of peptides on the CNT surface. We observed that the SHG intensity was increased with increasing the peptide concentrations at the wavelength of 532 nm by introducing 1064 nm of laser light as an incident beam due to the chirality nature of peptide molecules. The maximum intensity observed from the CNT+10μM Peptide sample. The highest SHG intensity was recorded for all concentrations of peptide molecules at 532 nm according to Figure 2.

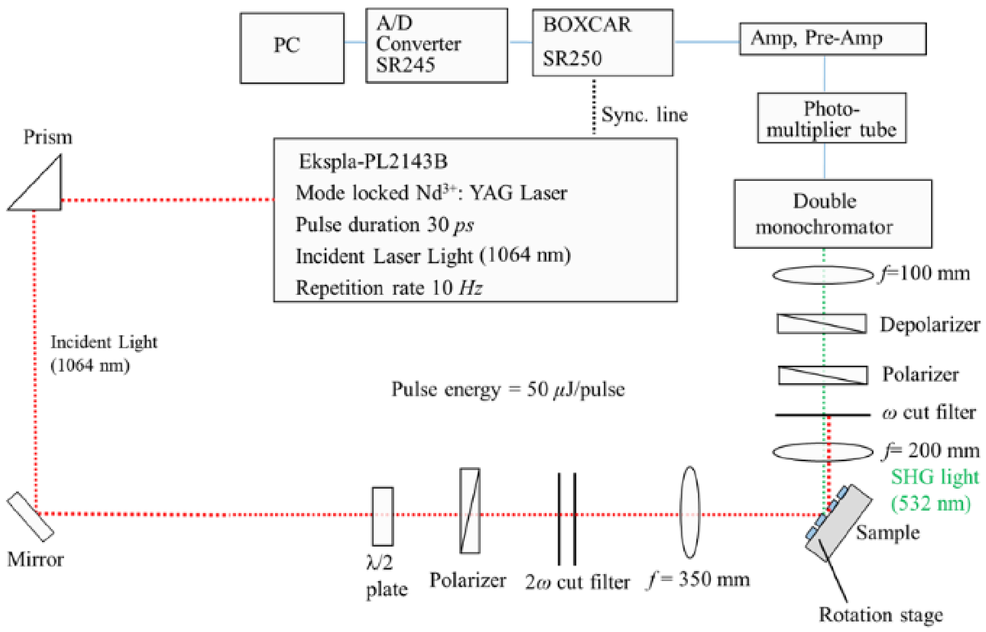

Figure 1. Optical setup for measuring SHG intensity from bare CNTs, CNTs/PEP with variant concentration of peptides and different wavelength tuned manually by using monochromator

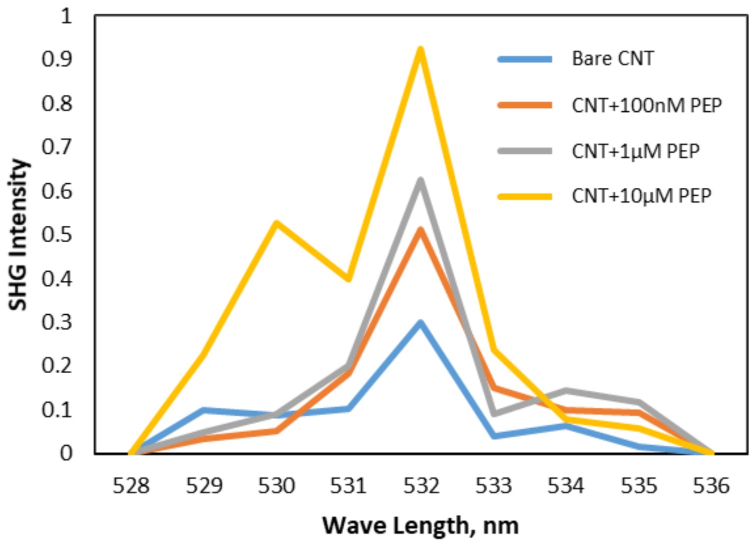

Figure 2. SHG intensity from CNT/PEP interface as a function of increasing concentrations of peptide and tunable wavelength

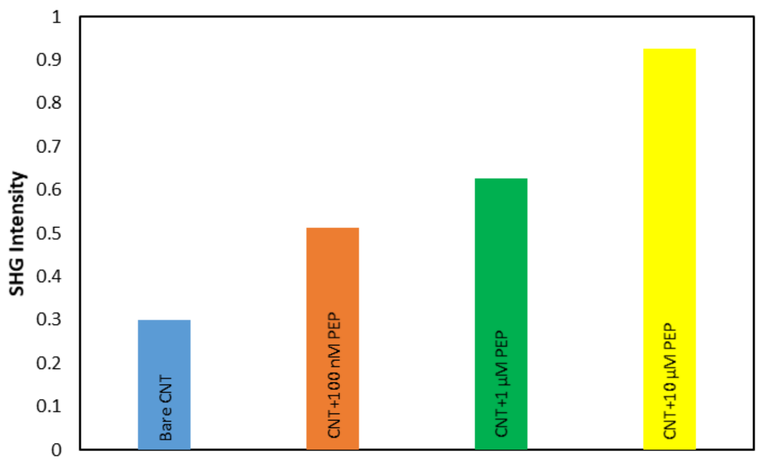

Figure 3. SHG intensity from CNT/PEP interface with increasing concentrations of peptide at 532 nm

Peptide molecules contain large C-C chain structure and many other bonds such as C-C, C-H, O-H, N-H, C-O etc. The number of these bonds are increased with the increase of peptide molecules. These bonds may create chirality. So, Probably, these bonds are responsible for increasing dipoles at the interface region causes strong SHG signal [15]. The interaction between the electric field of incident laser light and the dipoles of the peptide molecule also increased as the concentrations of peptides on CNT increased gradually. So, the SHG intensity enhanced with increasing the peptide concentration although the intensity is not much significant.

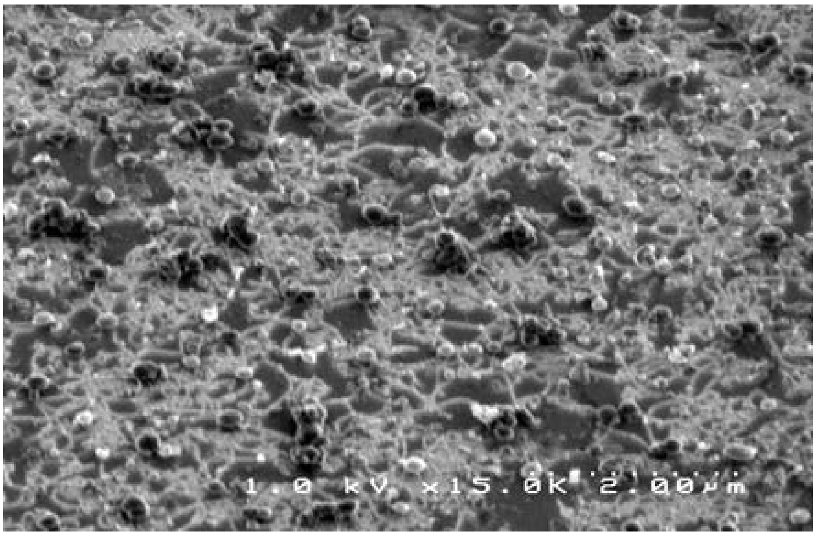

Figure 4. SEM image of CNTs fabricated on $Si/SiO_2/Co$ substrate

We conducted the SEM analysis to confirm the fabrication of CNTs. Figure 4 shows that, the CNTs were grown on $Si/SiO_2/Co$ substrate adopted from our previous research article [16]. We observed comparatively week signal from bare CNTs and this is due to the presence of amorphous carbon on the $Si/SiO_2/Co/CNTs$ surface according to SEM image. These huge amounts of existing amorphous carbons are possible candidate for the generation of weak SHG signal from bare CNTs shown in Figure 2 & Figure 3. The magnification of the SEM image was 2μm.

4. Conclusions

In this study, the CNT was fabricated on the $Si/SiO_2/Co$ substrate by chemical vapor deposition (CVD) method. Then we dropped variant concentrations of peptide molecules on the CNT surface and measured the SHG intensity from the CNT/PEP interface. We found that the SHG intensity was maximum for all concentrations of peptide molecules at 532 nm when we tuned the wavelength manually by using monochromator. At the fixed SHG wavelength (532 nm), the intensity was increased with the increase of peptide concentrations.

So, the peptide molecules can generate SHG due to having different types of chemical bond. These chemical bonds exhibit chirality nature that may be the possible candidate for generating SHG signal. In this research, the measurement of SHG intensity from CNT/PEP interface was our physical interest only.

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