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Study of Optical properties of Alpha and Nd:YAG Laser Irradiated Cellulose Nitrate Polymer

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Abstract: Samples from cellulose nitrate (CN-85) sheets of 0.3 mm thickness irradiated with low and high doses of alpha particles have been post exposed to Q-switched pulsed Nd:YAG laser. In this present work, the effect of laser irradiation on the structural properties of CN-85; have been investigated using absorption and fluorescence. The absorption spectra of only alpha irradiated and Nd:YAG laser irradiated samples are studied and optical band gap energy of the samples are calculated. Optical band gap energy measurements for high doses are more significant as compared to low doses. The increase in the band gap energy might be due to hardening of material which happens as a result of crosslinking of the polymer.

Keywords: Optical band gap energy, Nd:YAG laser, CN-85 (SSNTD).

1 Introduction

When heavy charged particles pass through dielectric solids, they leave a narrow and permanent trail of damages with diameter of about 100 $\AA$ and length equal to the range of the particles in the solid. During chemical etching the damaged regions, are more reactive than the surrounding (undamaged areas) and form permanent tracks that can be seen in an optical microscope. These solids are known as nuclear track detectors (SSNTD) and the more common commercially available SSNTDs include the polycarbonates (MK-E; MK-DE), the polyallyldiglycol carbonate (CR-39) and the cellulose nitrates (CN-85). These detectors are applied in different branches of science such as in the engineering, micro-pore membrane technology, nuclear physics, dosimetry, radiography and earth sciences [1,2,3,4].

Cellulose Nitrate (C6H8O8N2) CN-85 plastic track detectors have extensively been used in a variety of studies and are considered suitable for the detection of α-particles from radon gas and Uranium [5,6]. Many researchers have carried out their research for alpha irradiated CN-85 in last few years on different aspects. Al-Saad et al. in 2001 [7] studied the He-Ne laser (at 0° angle) transmission through etched CR-39 and CN-85 detectors that were irradiated with alpha particles or neutrons. Arif et al. in 2004 [8] reported about track registration characteristics of low-energy protons in CN-85. They have investigated the track registration parameters like critical angle of etching, etch rate ratio and etching efficiencies for application over proton energy. Jassim in 2009 [6] calculated optical density for CN-85 and CR-39 plastic detectors and α-particle radiography. He found that optical density to its maximum value happen for CN-85 detector in a shorter etching time than that required for CR-39. It is found that SSNTDs are good candidates for -particle radiography.

Cohen-Fritzsche-Ovshinsky model [9] described the band structure of amorphous solids which was further improved by Mott and Davis [10]. The optical absorption spectra provide very useful information for the investigation of optically induced transitions and an insight into the energy gap and the band structures of materials. The optical absorption coefficient measurements have generally shown an exponential dependence on the photon energy [11]. The absorption coefficient is a property of a material which defines the amount of light absorbed by it. The inverse of the absorption coefficient is the average distance traveled by a photon before it gets absorbed. The existence of a sharp well defined lattice absorption edge E_g is given by;

$$E_g = \frac{hc}{\lambda} \tag{1}$$

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where E_g is energy gap, h is Plank's constant and c is velocity of light. In amorphous material the absorption edge is less sharp and not well defined. Thus, in the analysis of the variation of the optical absorption with photon energy or with wavelength, an equation which matches the experimental data needs to be assumed. Tauc [12] showed that the absorption co-efficient is calculated from the absorbance A as given below;

$$\alpha(\lambda) = 2.303At^{-1} \tag{2}$$

where t is the sample thickness. In the crystalline and amorphous materials, the optical absorption dependence on the photon energy and it is expressed by the following relationship [12, 13].

$$\alpha h\nu = A(h\nu - E_g)^m \tag{3}$$

where A is an energy independent constant, E_g is the optical band gap and m is a constant to determine the type of optical transition (m = 1/2, 2, 3/2,3) for allowed direct, allowed indirect, forbidden direct and forbidden indirect transitions respectively.

Up to the best of our knowledge, no research has been done on the variation of optical band gap for IR exposed alpha irradiated CN-85 samples at different energies and exposure time. Such studies may be helpful to investigate the semiconductor behavior of alpha irradiated CN-85 after IR exposure. In this present work, absorption spectra of alpha and Nd:YAG laser irradiated samples are studied and optical band gap of the samples are calculated.

2 Experimental

2.1 Sample Preparation

Samples of dimension 2.4 2.3 *cm* from cellulose nitrate (CN-85) sheets of 0.3 *mm* thickness were irradiated with -particles with various doses. Alpha irradiations were carried out using 0.1 micro Ci am-241 source. This source emits 5.49 MeV energy alpha radiations. The samples were irradiated in air at a normal incidence for 5 seconds at a distance of 2 *cm* from the source. We believe that radiation processing is a useful technology to induce suitable modification of materials. It is an important way to generate or enhance new properties in materials as well as new means of production.

2.2 Laser System Arrangement

Nd:YAG laser with its fundamental wavelength of 1064 *nm*, pulse width of 8 *ns* and frequency of 10 Hz was employed to irradiate the samples. Alpha radiated samples are irradiated with different laser pulses of 5, 10, 15, 20, 25 and 30 respectively. The laser energy is kept constant as 10 mJ. The distance between the laser and sample is almost 10 *cm*. After laser irradiation the samples are again examined for optical absorption and emission. The results are analyzed to observe the difference in absorption and emission graph before and after the laser irradiation.

3 Results & Discussions

The polymer samples are radiated with different exposure time of alpha-particles at room temperature. The radiated 6-samples are examined for optical absorption with UV-Visible Spectrophotometer UV-1650 PC and for optical emission with Spectrofluorophotometers RF-5301 PC. The absorption and emission spectrums are taken carefully. The samples information are tabulated in table (1).

3.1 Optical Absorption

When material absorbs a photon of energy greater than the band gap an electron is excited from valance band to conduction band leaving a hole behind it. When the electron and hole recombine through radiative recombination a photon is emitted. The optical gap can be calculated from the curves representing the square root of the quantity ($\alpha h\nu$) versus photon energy ($h\nu$) plot.

Figures (1 - 6) show the absorption spectra of alpha radiated samples before and after Nd:YAG laser irradiation. The laser was employed with different laser pulses of 10, 15, 20, 25, 30 and 35 at constant laser energy of 10 *m*J. The absorption spectrum of samples shows the relation between intensity and wave length before and after laser irradiation as shown in Figures (1 - 6).

Table 1: The information of samples used

No of Samples	Laser Pulses	Doses of alpha radiation
S1	10	1 hour
S2	15	2 hour
S3	20	3 hour
S4	25	4 hour
S5	30	5 hour
S6	35	8 hour

Table 2: Values of optical band gap energy before and after laser irradiation

No of Samples	Eg Before Laser (eV)	E_g After Laser (eV)
S1	4.21	4.29
S2	4.21	4.34
S3	4.23	4.33
S4	4.24	4.37
S5	4.25	4.36
S6	4.28	4.38

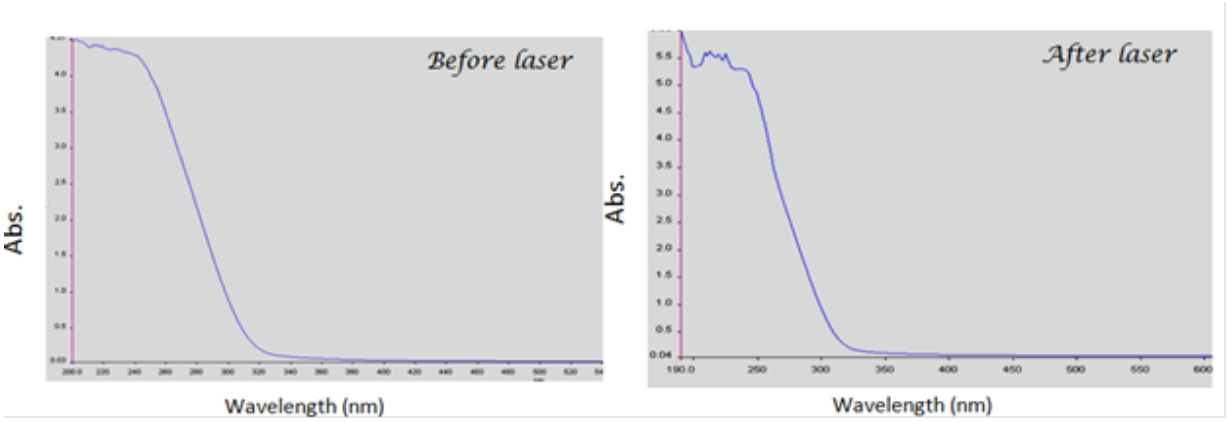

Fig. 1: absorption of Sample 1 (1 hr).

4 Photoluminescence

Figures Figures (9 - 10) show the emission spectra of alpha radiated samples before are after laser radiation. It can be seen from fig (9) that there is little change in the Photoluminescence spectra before and after laser irradiation but fig (10) shows remarkable change in the Photoluminescence spectra before and after laser irradiation. This difference is due to longer alpha exposure. At longer alpha exposure there are more damages in the structures. The exposure time of alpha radiation was in hours and these samples are irradiated using Nd:YAG laser with different laser pulses of 10, 15, 20, 25, 30 and 35 at constant laser energy of 10 mJ. The combine plot of emission is depicted in Figure (11). The emission spectra of samples show the relation between intensity and wave length before and after laser irradiation as shown in Figures (9 - 10). It is clearly seen the difference in emission intensity of the samples before and after laser. These changes attribute to the structural modification in samples due to alpha + laser irradiation.

5 Conclusion

Pre irradiated with low and high doses of alpha irradiated samples were post exposed with laser. It is found that CN-85 polymer is good candidates for detection of -particle. A significant change in band gap values of CN-85 alpha and laser irradiated samples are noticed. The band gap of the samples are calculated from absorption curves using tauc equation

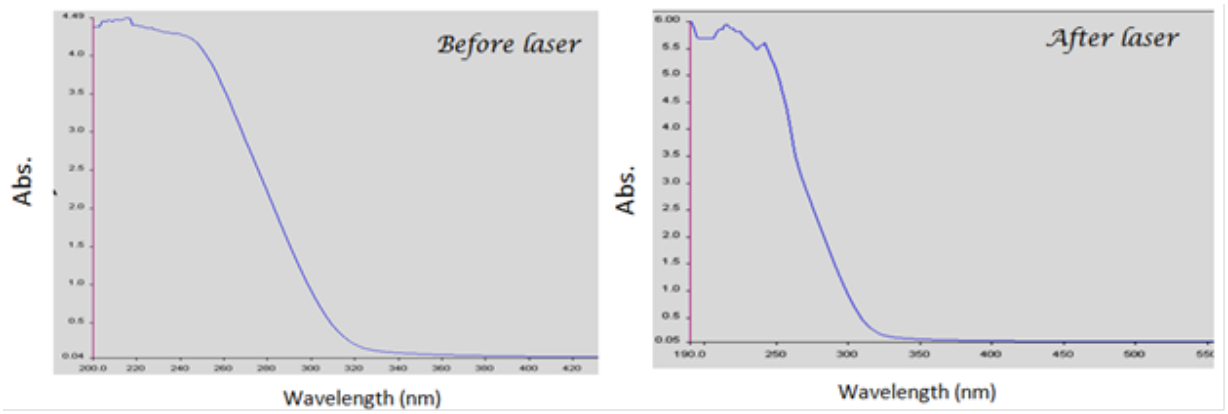

Fig. 2: absorption of Sample 2 (2 hr).

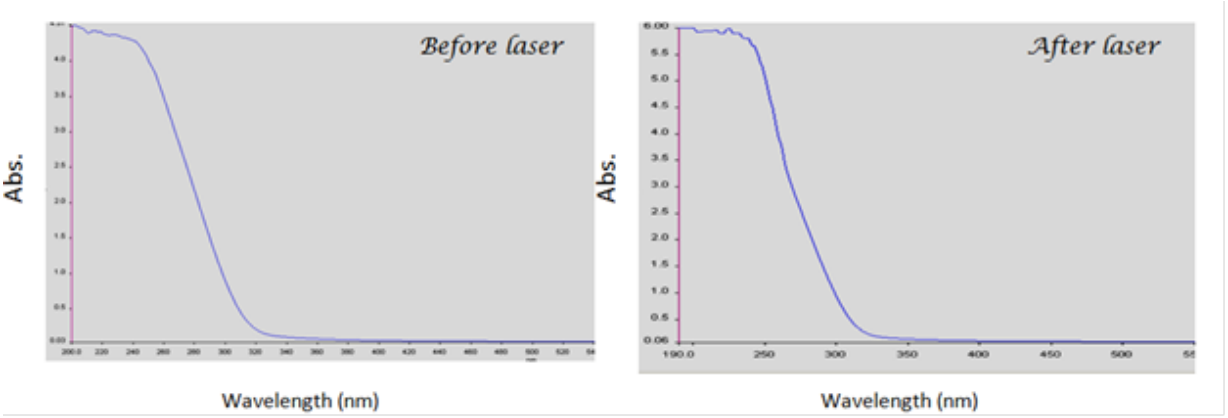

Fig. 3: absorption of Sample 3 (3 hr).

at different laser pulses. Optical band gap energy measurements for high doses are more significant as compared to low doses. We believe that the increase in the band gap energy is due to hardening of material which happens as a result of crosslinking of the polymer. More investigations are needed in this area to get complete information of such samples at different doses and laser pulses.

Acknowledgement

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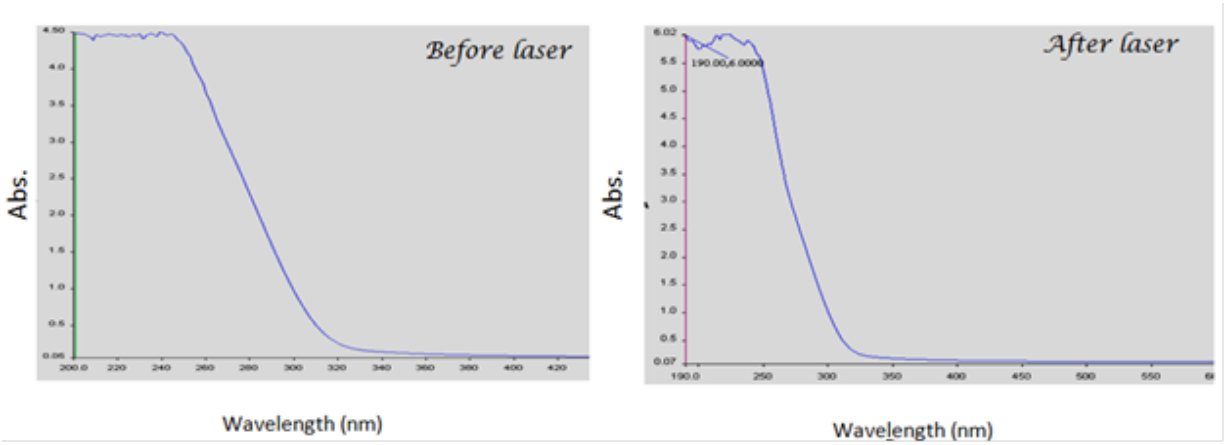

Fig. 4: absorption of Sample 4 (4 hr).

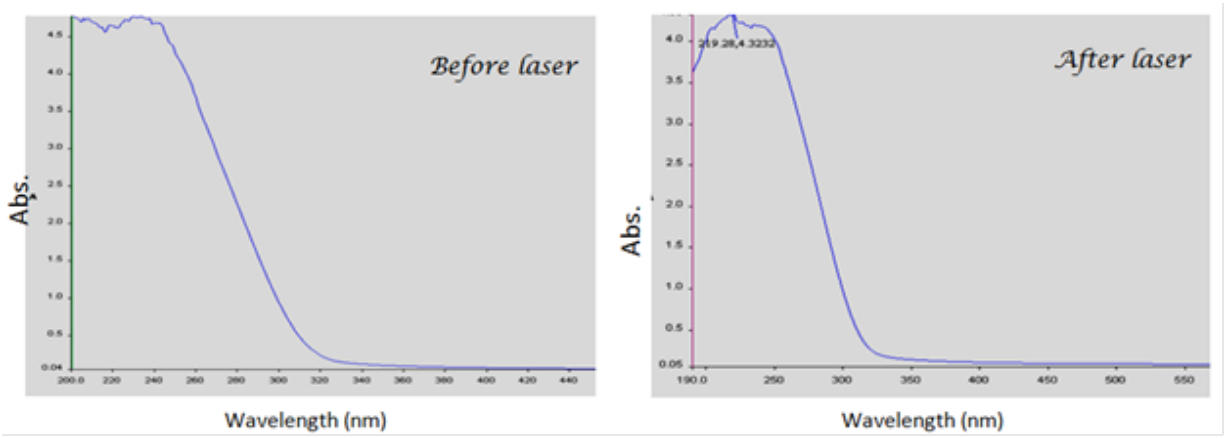

Fig. 5: absorption of Sample 5 (5 hr).

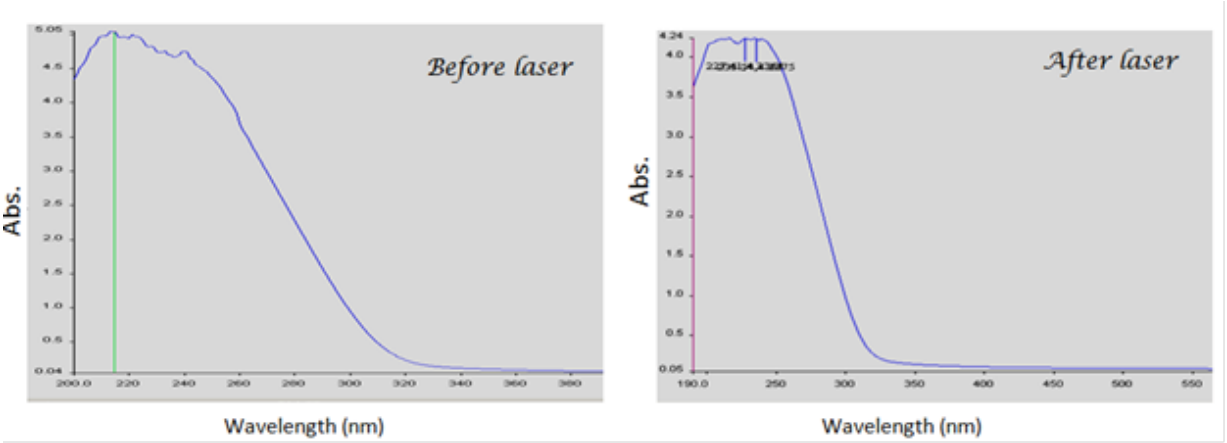

Fig. 6: absorption of Sample 6 (8 hr).

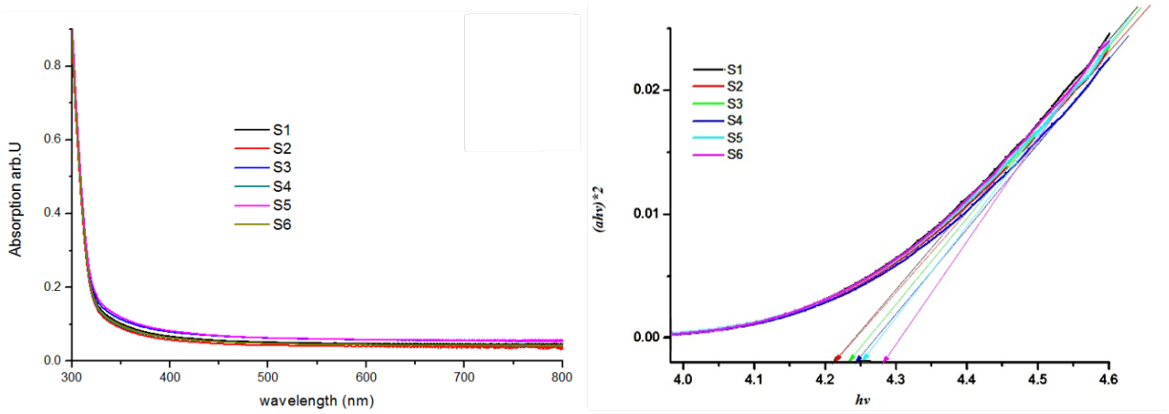

Fig. 7: a) absorption of all samples before irradiation, b) Tauc plot of calculated band gap energy before laser irradiation

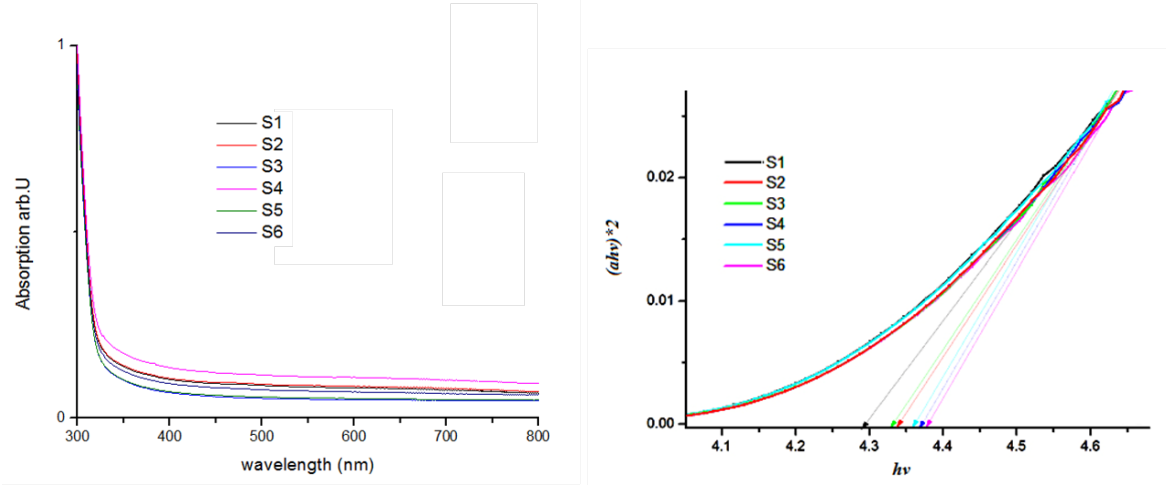

Fig. 8: a) absorption of all samples after irradiation, b) Tauc plot of calculated band gap energy after laser irradiation

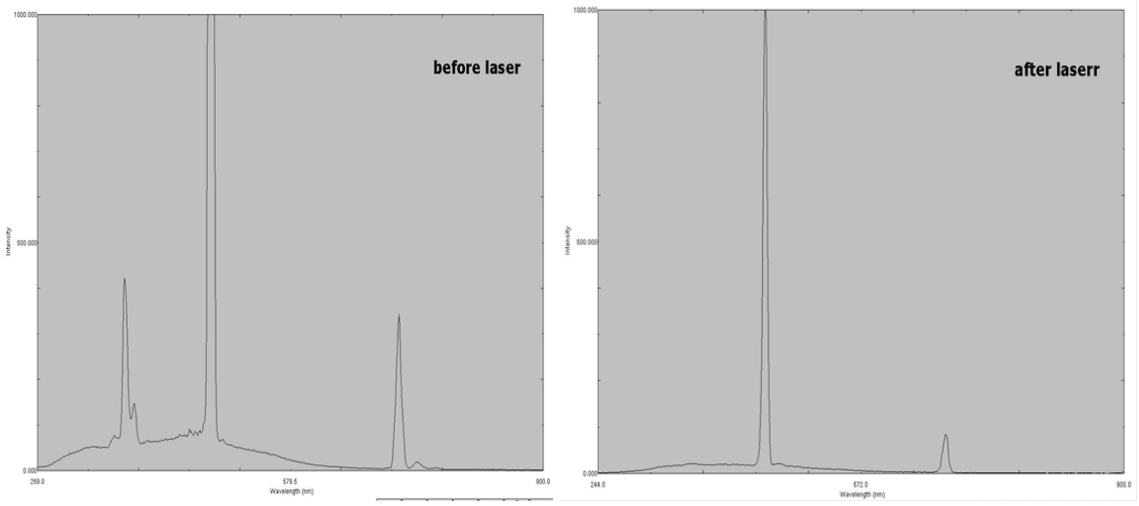

Fig. 9: Emission of Sample 2 (2 hr).

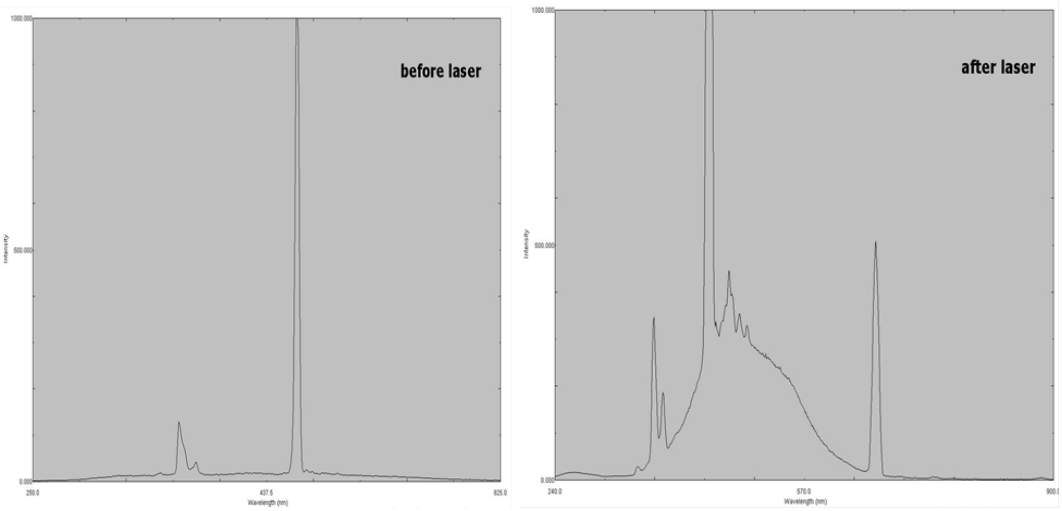

Fig. 10: Emission of Sample 6 (8 hr).

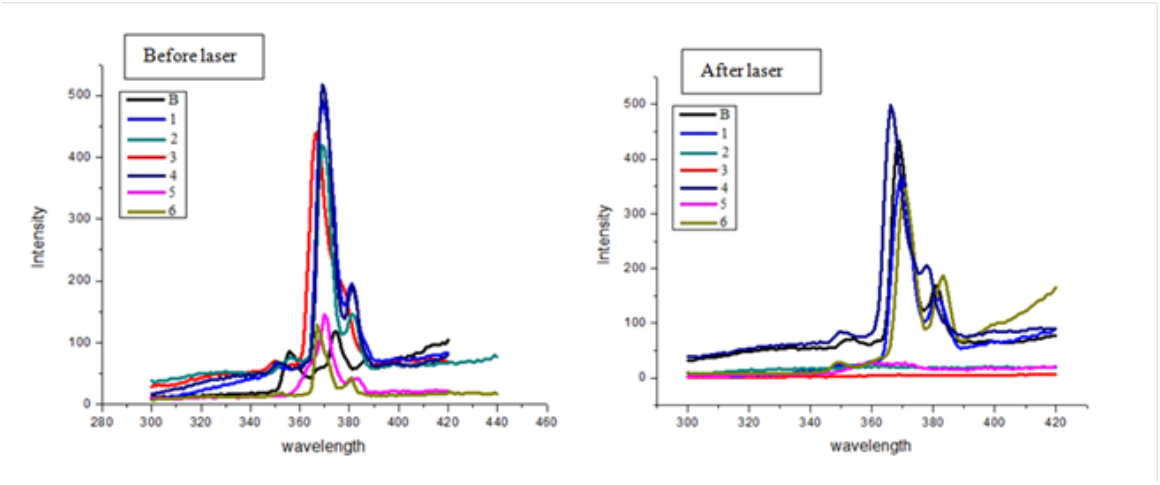

Fig. 11: Emission of Sample 1-6 where B stands for reference sample without irradiation.

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