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Comparison of EUV Radiation signal from Nd:YAG laser produced pure Sn and low density SnO2/CNTs nanocomposites plasma

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Abstract

EUV Light source is the major part of EUV lithography. The target need for this source should provide high conversion efficiency, debris free and maximum absorption of laser light. We introduced first time low density SnO2/CNTs nanocomposites target and compared EUV radiation signal from Nd:YAG Laser produce Sn and SnO2/CNTs nanocomposites plasma. 140nm thick Zirconium (Zr) filter was used to stop UV-IR light emitted from the plasma and passed only EUV light and AXUV-100 silicon photodiode was used to detect the EUV signal. The target were synthesized by hydrothermal method and mounted by hydraulic pellet press. The nanocomposites targets were investigated by X-ray diffraction, Field emission electron microscopy. For low laser pulse energy, pure Sn and SnO2/CNTs nanocomposites targets shown approximately same EUV signal.

Keywords: *LPP, EUV source, SnO2, CNT, hydrothermal, low density target*

1. Introduction

Extreme ultraviolet lithography (EUVL) [1] is a promising technology for the fabrication of next generation semiconductor chip whose node size is less than 32nm [2]. EUV lithography need EUV light (13.5nm) emission source to be debris-free with high conversion efficiency [3]. A laser-produced plasma (LPP) emission source is one of the most reliable technologies to fulfill the requirements. Various materials, such as Li, Xe and Sn were used as a target for EUV source [4], among them Sn is the most prominent target material for 13.5nm wavelength with high conversion efficiency (CE). Laser-produced Sn plasma[5], especially low density Sn plasma[6], is an attractive 13.5 nm light source. Generally speaking, a target with higher concentration produces a higher EUV emission energy but due to Strong self-absorption of the 13.5 nm emission, CE becomes lower, because of optically thick plasma. In addition a high concentration tin target produces a significant amount of debris, which causes a serious problem of damaging a set of focusing optics or condenser mirrors in a vacuum chamber. In contrast a low concentration tin target can minimize the debris emission and reduce the self- absorption [7] To overcome this problem, low density nanostructures materials [6,8,9], and low-density foam doped with Sn were introduced [10].

We present in this article low density SnO_2/CNTs composites target for laser produce plasma EUV source. The use of Carbon nanotubes (CNT) with SnO_2 as composites because of high absorption of CNT of Nd:YAG laser light[11]. The target was synthesis by wet chemistry approach. The EUV radiation signals were studied by different pulse energies of Nd:YAG laser with AXUV100 silicon photo detector.

2. Experimental

2.1. Target fabrication

First of all 150mg MWCNTs refluxed with mixtures of 20ml concentrated HNO_3 and 20ml concentrated H_2O_2, at 120^{o}C for 10hours in order to generate the functional groups which act as nucleation sites for the target material. 150mg $SnCl_2.2H_2O$(98.5%, Feng Chuan Chemical& Enterprise CO., LTD.) solved in 40ml distilled water by stirring for 5hours and then added the functionalized MWCNTs solution and again stirring for 2hours for homogeneously mixing of both the solutions. Thereafter transferred the obtained solution to Teflon lined stainless steel autoclave, sealed the autoclave and kept into the oven at a temperature of 150^{o}C for 15hours. After cooling down to the room temperature naturally, the resulting precipitate was centrifuged and thoroughly washed with distilled water and ethanol several times, thereafter dried the sample at 70^{o}C for 20hours. The targets were prepared by making pellets using Hydraulic pellet press (EQ-YLJ-24T) from the composites sample. The crystal structure and morphology of the sample were investigated by X-Ray diffraction using X'Pert PRO MPD with CuKα radiation (λ=1.5406Å), field emission scanning electron microscopy (S-4800) with EDS.

2.2. EUV setup

A schematic of our experimental setup for EUV source is given in Fig.1. It consists a stainless steel high-vacuum chamber. First of all for producing plasmas, we were used Nd:YAG laser of 1.064 μm wavelength, 7 ns pulse duration, repetition rate f_{rep} up to 10 Hz, M2 = 2.5. In this setup, a 127 mm focal length lens was used to focus the laser pulse onto the pure tin and tin based composites target to generate the EUV plasma source. The chamber was evacuated with a molecular pump to a pressure less than 10^{-5} Torr. The laser spot size was finely tuned by the focusing lens on the target position that is round about 150μm.

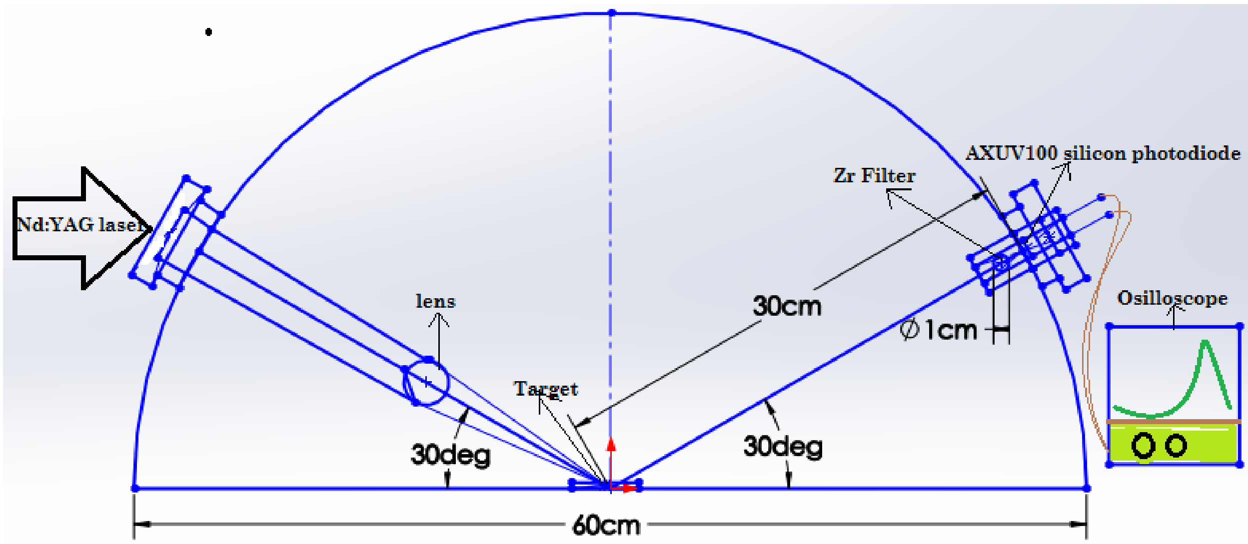

Figure 1 schematic of Experimental setup for EUV source

3. Results and Discussion

Fig.2a, b show FESEM images and Fig.2c is the EDX of the composites sample respectively. When MWCNTs treated with a mixtures of HNO_3 and H_2O_2, functional groups like COOH, C=O, C-OH etc generated on its surface [12] and these functional groups acted as nucleation sites for target materials. Fig.2b the higher magnification FESEM images shows highly dense and uniform SnO_2 nanoparticles deposited on its surface

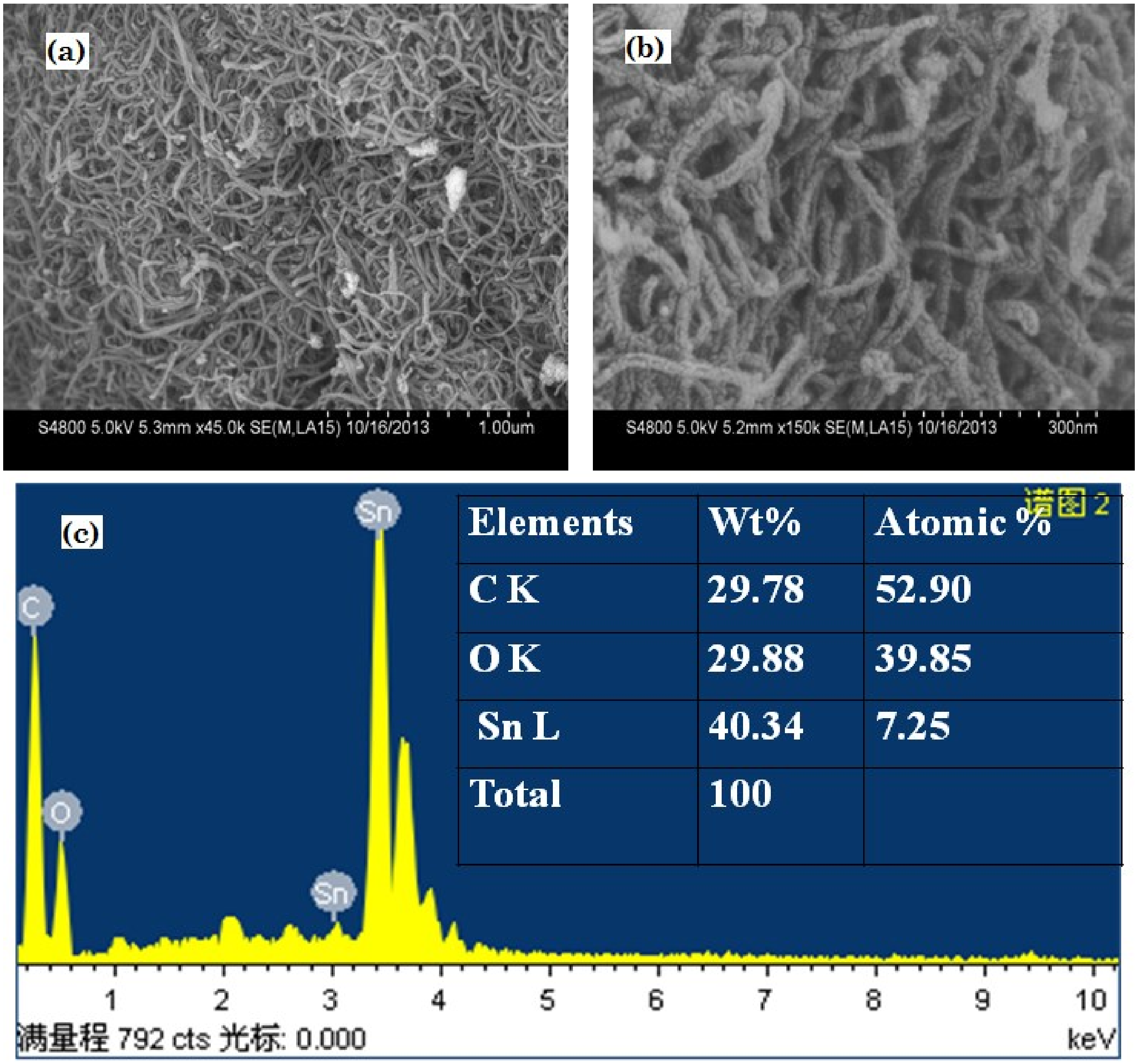

Figure 2 FESEM images of (a,b) SnO_2/CNTs composites and (c) its EDX

The X-ray energy dispersive spectroscopy (EDS) analysis in the Fig.2c, exhibit the expected peaks of carbon, oxygen and tin, and no peaks of Chlorine and other elements in EDS figure, implying the high purity of the SnO_2 and MWCNTs nanocomposites.

The XRD patterns were carried out of as received MWCNTs Fig.3a and SnO_2/CNT nanocomposites Fig.3b.

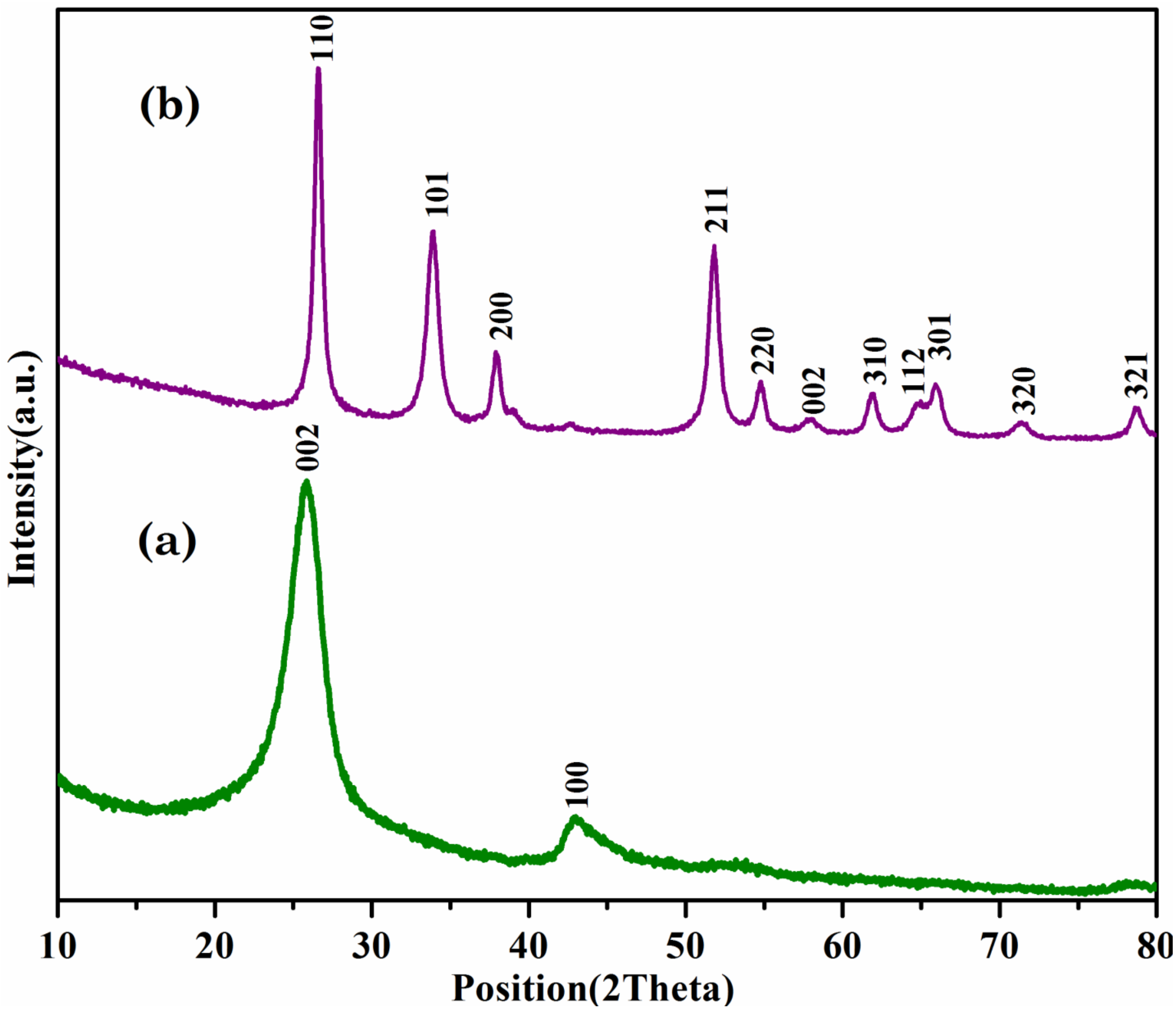

Figure 3 XRD patterns of (a) as received MWCNTs (b) SnO_2/CNT nanocomposites

The presence of SnO_2 crystalline nanoparticles in the entire product were confirmed by XRD. All the diffraction peaks were correlated with standard values of tetragonal rutile SnO_2 (JCPDS 41-1445) with average lattice constant of a=4.77Å and c=3.17Å. It can be difficult to identify the main diffraction peak of MWCNTs in Fig.3b, because the main peak of tetragonal rutile SnO_2 (110) with interlayer spacing of 0.334nm (JCPDS 41-1445) almost overlaps with the main peak of carbon (002) with interlayer spacing of 0.339nm (JCPDS 41-1487). No characteristics peaks of other tin containing compounds in XRD pattern of Fig.3b were identified, indicating high purity of SnO_2 in the product[13,14].

EUV signal detection system consists of a silicon photodiode (AXUV100 PTB/NIST calibrated) is placed in order to get the pulse-shape of the EUV light, Zr filter (PTB/NIST calibrated) of 140nm thickness was placed at a distance of 10mm from the AXUV100 photodiode as shown in Fig.1 in order to stop the diode response to visible, IR and UV light which are emitted from the laser produce tin and tin composites plasma. The transmission spectrum of solid (Zr filter of 140nm thickness) and gas (with chamber pressure of 5.5×10^{-5}torr) for EUV radiation [15] as shown in Fig. 4a,b respectively.

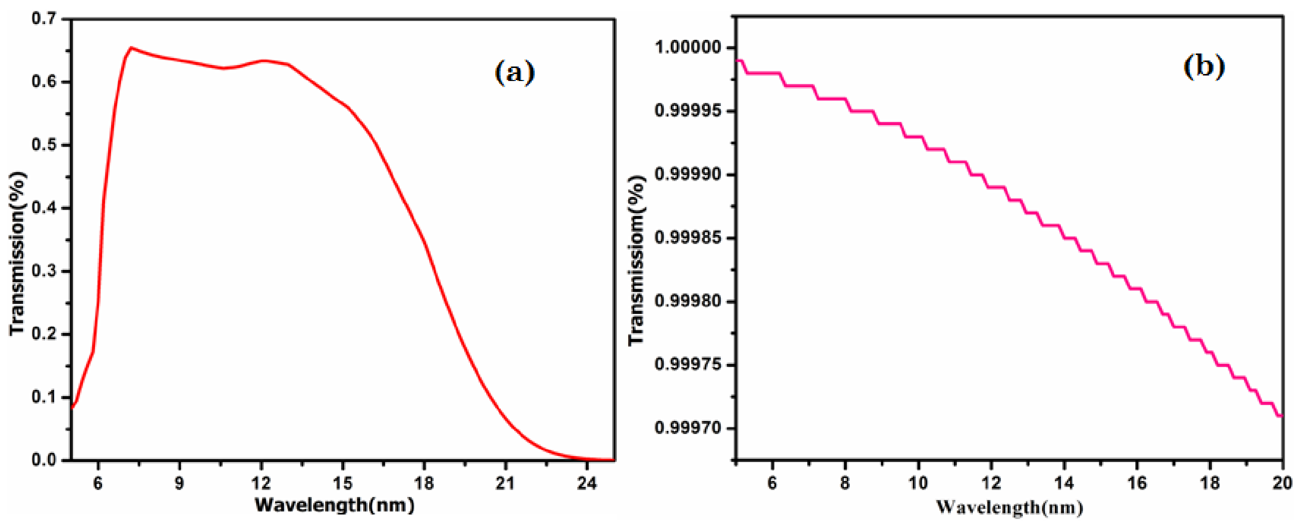

Figure 4 Transmission spectrum for (a) solid (Zr filter, 140nm thickness) and (b) gas (with chamber pressure of 5.5×10^{-5}torr) for EUV radiation

When laser pulse struck the target, the output EUV signals were very weak and much noise, so in order to improve the signal quality the AXUV-100 photodiode was electrically connected to a bias circuit as shown in Fig.5. In which the diode was connected to the 1MΩ input impedance of a 1 GHz, 5 Gs/s storage oscilloscope through a reverse bias of 30V to improve the time response of the diode and to reduce saturation effects. The values of R and C in the bias circuit were optimized for the fastest diode response and the highest saturation level for pulse lengths in the range from µs to ms. It is noted that these pulse lengths are typical for laser produced EUV light source

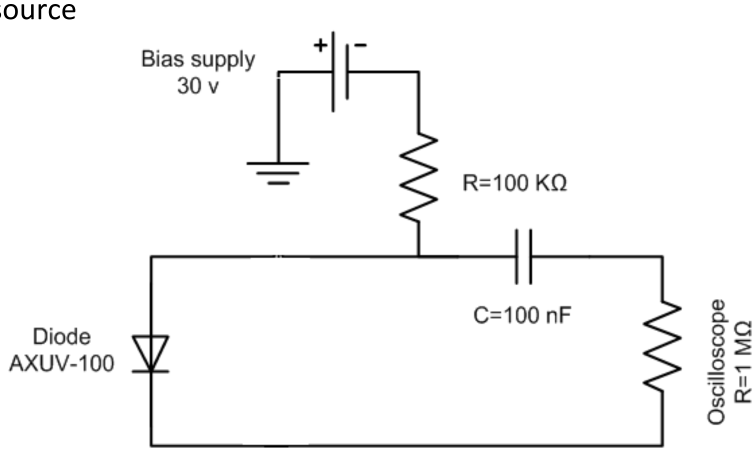

Figure 5 Scheme for reverse biased operation of the AXUV-100 photodiode.

Pure tin (Sn) and SnO_2/CNTs nanocomposites targets were struck by different Nd:YAG laser pulse energy (60 mJ, 85 mJ and 115 mJ). Fig.6a-f shown that the areas of obtained EUV radiation signal were quite strong for pure tin target at high pulse energy as compare to SnO_2/CNTs nanocomposites targets but at low laser pulse energy it is approximately same. Because target with higher concentration produces a higher EUV emission energy but due to Strong self-absorption of the 13.5 nm emission, CE become lower and also high concentration tin target produce large debris that can reduced the efficiency of the optics in the chamber[7]. So low density SnO_2/CNTs nanocomposites targets absorbed more laser light [11], low self absorption EUV light due to thin plasma and the conversion efficiency of EUV source could become higher using this target[16]. We are working on these targets for other parameters of EUV source that we will present in future articles.

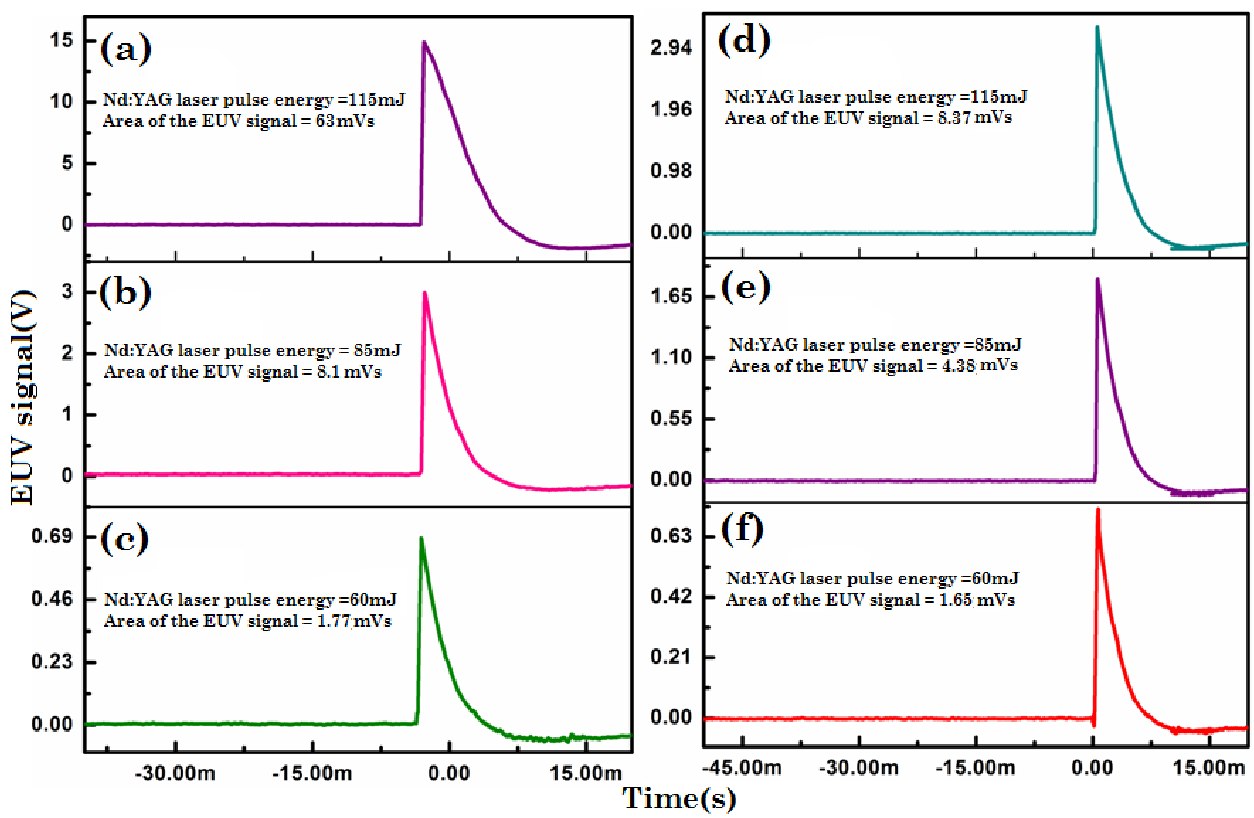

Figure 6 AXUV100 photodiode response for laser pulse energy (a-c) for pure Sn and (d-f) for SnO_2/CNTs nanocomposites.

4. Conclusion

In summary, we compared pure tin and SnO_2/CNTs nanocomposites target for 13.5nm EUV emission from laser produce plasma. Different Nd:YAG laser pulse energies were used for both the targets. For high pulse energy pure tin target shown strong EUV signal as compare to tin composites target but for low pulse energy the emitted EUV signals were approximately same. This indicates that clean and high conversion efficiency of EUV source can be possible from SnO_2/CNTs nanocomposites target for 13.5nm emission wavelength.

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