Nanostructures SnO and SnO_2 Low Density Targets for Laser Produced Plasma EUV Source

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Abstract

Due to high demand of debris free and high conversion efficiency target for EUV lithography source, We introduce in this article Low-density nanomaterials tin dioxide and tin mono oxide targets for this source. The targets were prepared by refluxing and hydrothermal methods using $SnCl_2$. $2H_2O$ as a precursor. SnO_2 spheres like and SnO sheets like images were observed from scanning electron microscopy. The crystal structures of SnO_2 and SnO were confirmed by X-Ray diffractions. EUV signal from SnO target at low Nd:YAG energy pulses were more stronger than SnO_2.

Keywords

EUV; LPP; Mass-limited Target; Debris Mitigation

Introduction

Extreme ultraviolet lithography is the most promising candidate for the next generation lithography tools used in the semiconductor industry to manufacture microchips with feature size less than 32 nm. However, several challenges in the development of EUVL have significantly delayed its commercial introduction concerning printing node size less than 32nm.

Laser-produced plasma is an attractive way for EUV light source due to its compactness and high emissivity with a highly intense emission. Since the Mo/Si multilayer coated mirror used in EUVL system shows very high reflection of about 70% around 13.5nm wavelength, most development efforts focus on in-band (2% bandwidth) centered at this wavelength, the number one challenge is to develop a powerful, long lifetime, clean and stable EUV light source to be used in an EUVL.

Various materials, such as Li, Xe and Sn were used as a target for EUV source, among them Sn is the most prominent target material for 13.5nm wavelength with high conversion efficiency (CE). Thus much effort has been devoted to the development of the tin-based EUV light source. However, debris emitted from tin plasma damage and contaminates the EUV collecting mirror and degrades mirror reflectivity. To over come this problem, low density nano structure materials was introduced, and low-density foam doped with Sn were investigated by several groups, to generate relatively monochromatic EUV with keeping similar conversion efficiency, It has been proved that low-density tin oxide is an important target material for producing narrow extreme ultraviolet (EUV) emission with a high conversion efficiency.

There are two main oxides of tin: stannic oxide SnO_2 and stannous oxide SnO. The applications of tin oxides include their use as catalysts, gas sensors, heat reflection filters, transparent conducting coatings, and anode materials. Several methods were employed in order to get the new low density target. Nano-structured tin-based targets have been fabricated by the pulsed-laser ablation method; layer-by-layer template technique; template-free hydrothermal method and thermal evaporation method, liquid crystalline template method were also introduced for the fabrication of density-controlled tin targets.

In this article, we fabricated two new types of tin nanostructures target that are stannous oxide and stannic oxide by using hydrothermal method. We studied the emission characteristics of EUV radiation signals from these two targets.

Experiment Details

Preparation of Low-Density Tin Dioxide and Tin Mono Oxide by a Combination of Refluxing and Hydro-thermal Method

1) Materials

Sodium hydroxide NaOH, Stannous chloride dihydrate $SnCl_2$. $2H_2O$ with a 98% purity, the ethanol was used without further purification, Distilled water.

2) Target Fabrication

Low-density tin dioxide and tin mono oxide target for laser produce plasma EUV source have been prepared from a solution mixtures of $SnCl_2$. $2H_2O$ and NaOH by the combination of refluxing and hydrothermal method.

For SnO_2: 1g $SnCl_2$. $2H_2O$ solved in 0.35M NaOH solution and then refluxed it for 15 hours at 100°C. Thereafter transfer the solution to Teflon lined stainless steel autoclave, sealed it and put it into oven at 200°C for 15hours. After cooling down the autoclave at the room temperature naturally, the resulting precipitate was centrifuged and thoroughly washed with ethanol several times, thereafter dried the sample at 70°C for 10hours.

For SnO: 2g $SnCl_2$. $2H_2O$ solved in 0.35M NaOH solution and then refluxed it for 15 hours at 100°C. Thereafter transfer the solution to Teflon lined stainless steel autoclave, sealed it and put it into oven at 200°C for 15hours. After cooling down the autoclave to the room temperature naturally, the resulting precipitate was centrifuged and thoroughly washed ethanol several times, thereafter dried the sample at 70°C for 10hours.

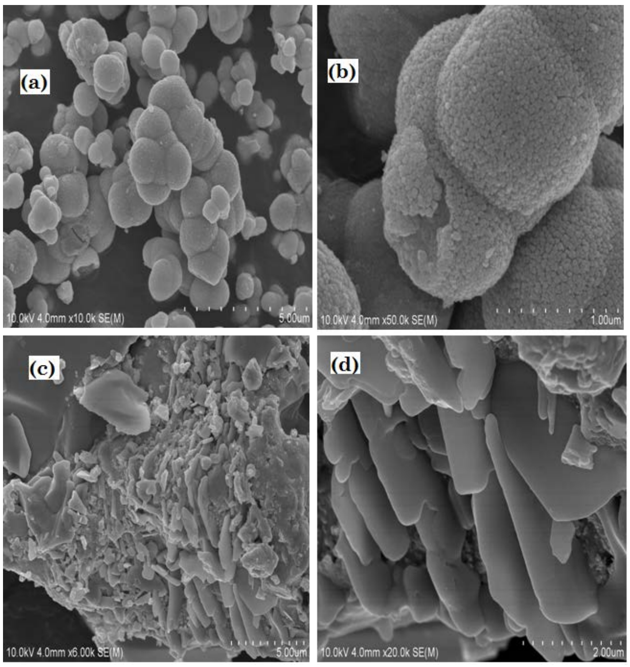

FIG. 1 FESEM IMAGES OF (a, b) SnO_2 SPHERES LIKE (c,d) SnO SHEET LIKE WITH DIFFERENT MAGNIFICATION RESPECTIVELY.

Results and Discussion

Cracterization FESEM and XRD

The morphologies and sizes of the resulting samples were observed and characterized by field emission scanning electron microscopy(FESEM) (S4800, with a accelerating voltage of 10kV). The crystalline structure of the targets were examined by an X'Pert PRO MPD X-Ray diffraction (XRD).

Fig. 1a,b show FESEM images of SnO_2 spheres like with uniform diameters were about 10μm and Fig. 1c,d SnO sheets like structures with thickness about 50nm and length about 10–50μm respectively.

Fig. 2 shows the XRD patterns from the synthesized tin oxide samples which demonstrates the SnO_2 spheres like structure that match well with the standard XRD data file of SnO_2 (JPDS 01-21-1250) (ICSD data) and SnO sheets like structure which agree as well with the standard XRD data file of SnO (JPDS 01-072-1012)(ICSD data). No obvious refection peaks from impurities were detected for both samples, providing evidence of the high purity of the final product. The peaks were also sharp indicating high crystallinity of both SnO_2 spheres like and SnO sheets like nanostructure.

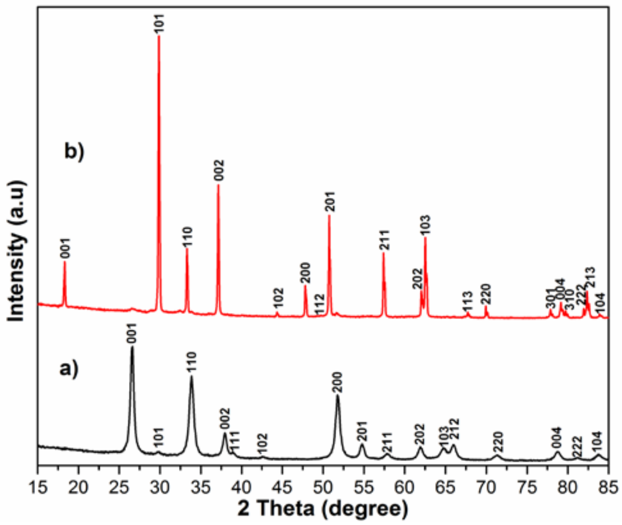

FIG. 3 XRD PATTERNS OF HYDROTHERMALLY PREPARED a) SnO2 and b)SnO.

The crystallite size of the SnO_2 and SnO structure has been calculated according to Debye–Scherrer formula:

$$Dc = \frac{K\lambda}{\beta \cos\theta}$$

where K = 0.9 is the shape factor for tetragonal, and λ is the Xray wavelength (1.5406 A° for Cu Kα) and β is FWHM (full-width at half-maximum or half-width) in radians and θ is the position of the maximum of diffraction peaks.

Using the above equation, the crystallite size of approximate 25.75 nm for SnO_2 shphers like and 60.2 nm for SnO sheets like were obtained.

Production and Measurement of EUV Light

Our experimental setup consist of a vacuum chamber, a Nd:YAG laser with an maximum output power 850mJ, 1.064 μm wavelength, 7ns pulse duration. Made pellets (using Hydraulic pellet press (EQ-YLJ-24T) from both the samples for target that are placed at the center of the chamber. Vacuum is generated in the chamber upto 10^{-4} Pa with vacuum pumps. The plasma were generated by striking the Nd:YAG laser pulse at the target with a BaF2 condenser lens.

EUV signal detection system consists of a silicon photodiode (International Radiation Detectors AXUV100) is placed in order to get the pulse-shape of the EUV light, infront of AXUV photodiode there is Zr filter with a thickness about 140nm at a 10mm distance from the photodide used to block the diode response to visible, IR and UV light from the plasma. The transmission spectrum of Zr filter for EUV radiation with a thickness of 140nm as show in fig. 3.

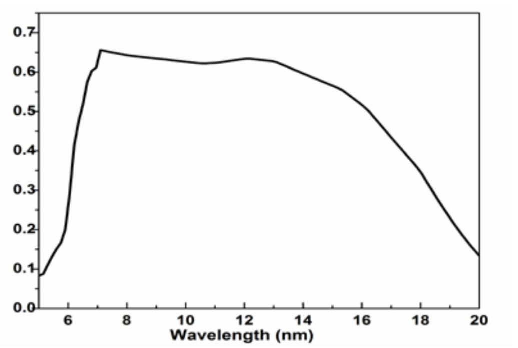

FIG. 3 The transmission spectrum of Zr filter.

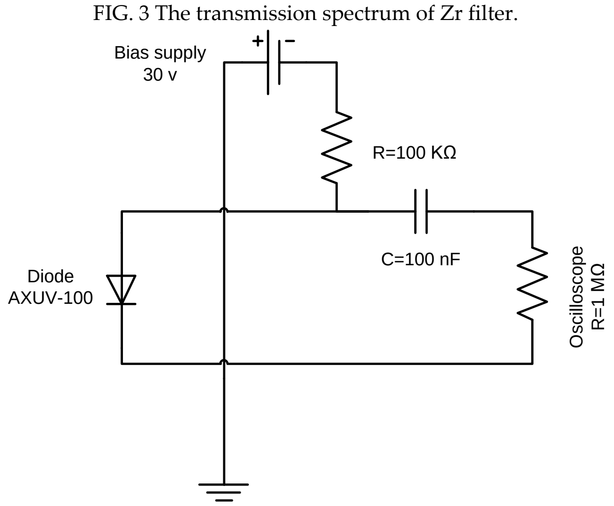

FIG. 4 SCHEME FOR BIASED OPERATION OF THE DIODE. THE DIODE IS CONNECTED TO A STORAGE OSCILLOSCOPE VIA A BIAS ELECTRONICS CIRCUIT.

The AXUV-100 diode was electrically connected using the scheme illustrated in Fig. 4 in which the diode was connected to the 1MΩ input of a 1 GHz, 5 Gs/s storage oscilloscope through a reverse bias voltage of 30V applied to improve the time response of the diode and to reduce saturation effects. R and C values in the bias circuit were optimized in order to get the fastest diode response with the highest saturation level for pulse lengths in the range from 10ns to 1μs. These pulse lengths are typical for laser produced EUV light source, like is the case for our Nd:YAG laser which pulse duration is about 7ns.

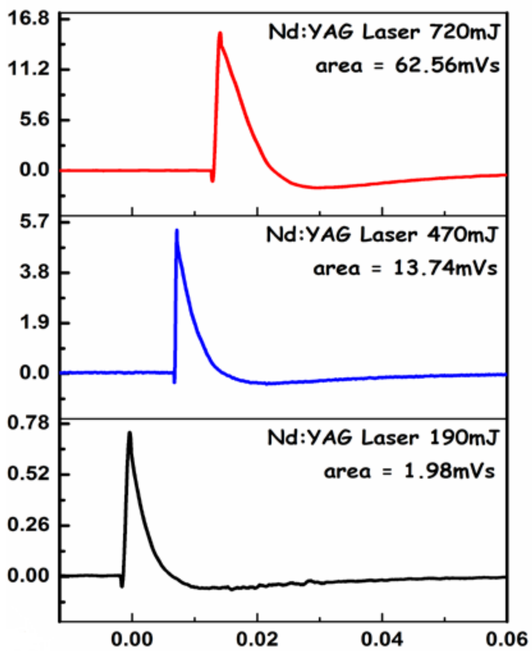

FIG. 5 PHOTODIODE RESPONCE FOR SnO_2 SPHERES LIKE TARGET.

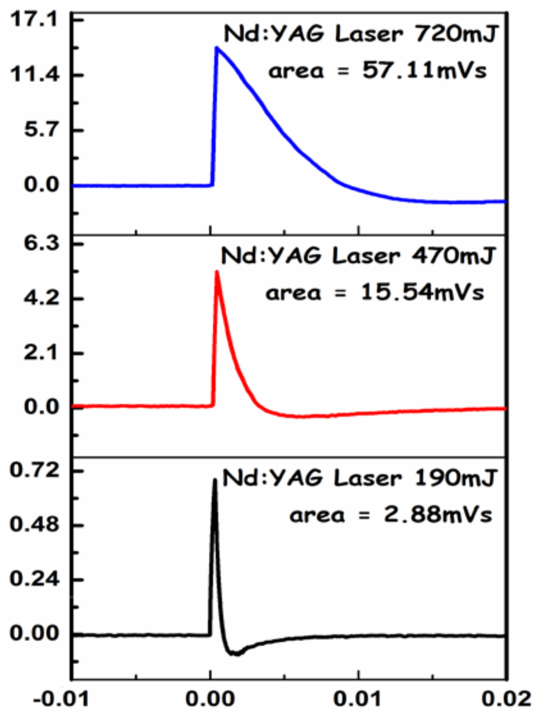

FIG. 6 PHOTODIODE RESPONCE FOR SnO SHEETS LIKE TARGET

Measurements were carried out for both SnO_2 spheres like and SnO sheets like nanostructure for differents energy values of the Nd:YAG laser (190 mJ, 470 mJ and 720 mJ) and the areas where calculated for each case. Fig. 5 and fig. 6 show the photodiode response for SnO_2 and SnO target respectively. We noticed that the area of the signal is higher for SnO for low laser pulse energy 190 mJ than SnO_2 target. we will keep working on these target for other parameters of EUV source that we will present in future articles.

Conclusion

In summary, the EUV source targets that are SnO2 and SnO synthesized by a combination of refluxing and hydrothermal method shown high response for different laser energy pulses. SnO nanostructure target shown more stronger signal at low energy pulse than SnO2. This indicates that from different types of tin based nanostructures we can improve the conversion efficiency of EUV source at 13.5nm wavelength.

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