

The preliminary studies on preparation and characterization of bulk nanoporous zinc as a laser target candidate to generate soft x-ray

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Abstract: Bulk nanoporous metal has become a reliable source to replace liquid as source to generate EUV lithography which have debris problem to tackle. A solid yet low density porous material promised a low melting point and low plasma density. The plasma density of bulk nanoporous Sn and SnO₂ profile plays a key role in the generation of 13.5 nm light for an extreme ultraviolet lithography (EUVL) source from laser produced plasma (LPP). The success of this preparation method might solve problems related to EUV lithography, or even soft X-ray (XUV) lithography. In this paper, we present the preliminary result of preparing such ideal low density target in form of bulk metal porous.

Keywords: EUV lithography, bulk nanoporous, laser produce plasma

1. Introduction

EUV lithography is the next generation lithography for more compact, with node size as small as 40nm integrated circuit (IC) fabrication process. This technology has attracted attention of the industry compared to E-beam lithography for its possibility to apply in mass production which is ideal commercially. With EUV, the fabricating rate of wafer can reach 100 wafers per second. However, to achieve the requirements, a reliable laser source with power can reach up to 100 W and repetition rate of 300Hz is needed. As for the time being, liquid target has been the leading prospect for major LPP research around the world. However, there are problems such as debris and on maintaining the stability of the metal liquid which have temperature of several hundred degrees Celsius, not to mention to find suitable candidates for the jet sprayer. The system will definitely cost more compared to a more stable and less debris solid state target. The resulting outcomes also expected to involve various aspects, to increase frequency shot on source, that source can be turned continuously in different surface to obtain optimum wavelength. These are the framework in determining problem to such system source before configuring the solution.

As an effort to counter these problems, this paper presented the solution on the very fundamental base, the

target itself. This paper presents the preliminary result of preparing ideally low density target that should fulfill the low density plasma requirements for LPP and offering more stable and reliable source target for the EUV laser system. Taking into account that the repetition rate of the laser system mention before, we are aiming for a cylinder shaped target that will rotate while being irradiated by the driver laser, thus guaranty high repeating rate and a uniform surface ablation of the target surface. The porous bulk material needed is prepared by sintering powdered metal and metal oxide.

Sintering offers the flexibility of making the target into desired shape. We are able to get porous form through material mixture and also by controlling certain parameters such as pressure, temperature and material ratio. Here, we proposed an unconventional yet novel method in achieving the porosity which involved the organic binder. Organic binder selection is also a factor that contributes to nanoporous.

The challenges that are being faced by EUV lithography just cannot be overcome by costly expenses, [1]. Continuous further study the possibility of reducing the cost for the EUV lithography project in the future can be achieved. Result from these studies might also open ways to other possible application, such as electronic devices. Porous oxide is an insulator, but in porous atomic configuration, it might behave as semiconductor. Therefore, a study on radiation plasma can also be

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benefited in other fields. In this paper, despite of Sn and SnO₂ target used in actual EUV lithography system, we use Zn. The reason is that Zn has the metal properties as Sn, even though differs in melting or boiling point. The other reason is that Zn is more sensitive to oxidation or chemical reaction compared to Sn, which makes it is perfect control experiment. Finally, zinc is also a candidate for soft x-ray (XUV) lithography [2].

process below melting point using sintering and compacting method.

Table 1 Sample preparation

(Compaction) /pressure	Diameter molding	(Sintering) /Temperature /Time	(ratio) /Zinc/Organic Binder
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2. Methodology

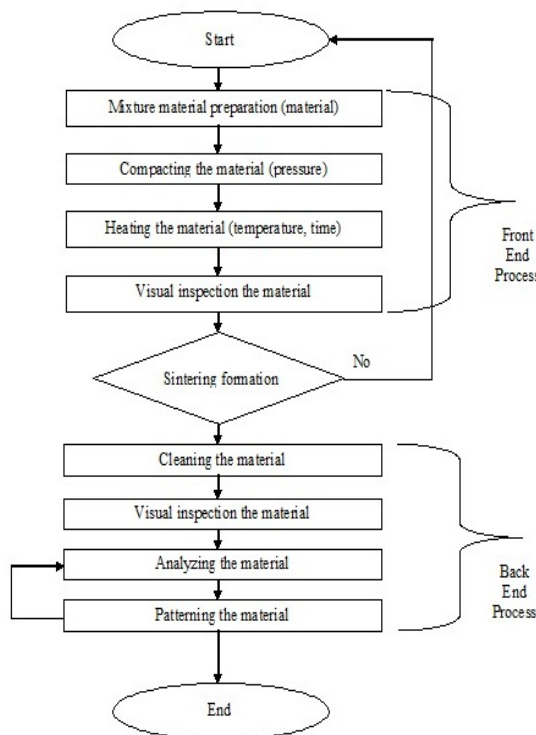


Fig. 1 Flow chart

Preparation to fabricate the nanoporous zinc

Nanomaterials have been the core focus to fabrication research because the subset of nanostructure materials possess unique surface, structural and bulk properties that underline their important uses in various fields such as ion exchange, separation, catalysis and sensor. In this experiment, an unconventional methods were used to fabricate the laser target, by integrating two different materials namely zinc powder with starch. In the first part of this experiment, the mixtures of zinc powder with starch are blended. Next, the mixture of both materials will be compacted and through the heating

Powder mixing process

In this process, the zinc powder and starch are weighed under certain weight. Once the selected powders are weighed, the powder must be thoroughly blended together to ensure maximum dispersion of the particles for optimal mechanical properties. In order to achieve discrete particle reinforced microstructures, the reinforcing phase must be spread out throughout the matrix phase. After being weighed out to the designated amounts, the powders are poured into single glass jar and lid is closed tightly. The method for blending the powders is shaking the dry powders by hand. This mixing technique is accomplished by repeatedly shaking the jar back about 5 minutes. The samples are prepared in this project, each sample have different powder doses ratio in order to get porosity of zinc target perhaps after sintering process where the starch would evaporate.

Powder compacting process

Powder compacting process is a process whereby mixed powder from previous step will be compacted into a die or mould through the application of high pressure to get desired solid shape.

Sintering process

Sintering process is the process for making objects from powder, by heating the material in a sintering furnace below its melting point which reference as solid state sintering until the its particle adhere to each other. Sintering is traditionally used for manufacturing ceramic objects, and has also found uses in such fields as metallurgy.

Analyzing process

The XRD analysis of target as bulk material was performed in order to discriminate between the powders to identify unknown substances. Besides that, the structural analysis was indicated by SEM.

3. Results and Discussion

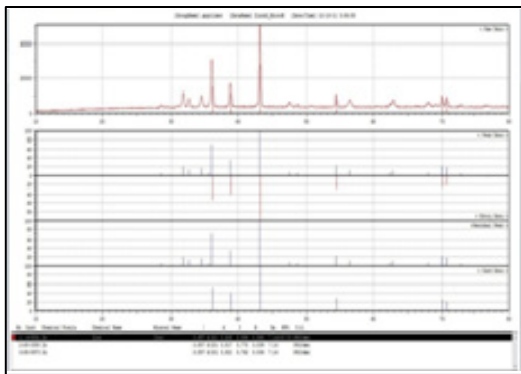
Result

Structure after compaction

The structure analysis found the formation between zinc and organic binder had good formation with certain ratio. Although the ratio of organic binder was increased, the effects of formation depend on the ratio. In this case, the samples achieved good formation without crack or deformed.

Structure after sintering

The samples preparation found the certain samples crack cause the evaporation of organic binder during sintering process. In this case, the sample with more organic binder easily cracked or crumbled cause of evaporation organic binder. Moreover, the distribution of organic binder influences the structure of the samples.



a)

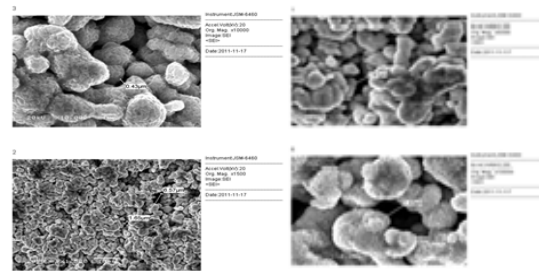
04-0831	Quality *	Zn			
CAS Number:	7440-66-6	Zinc			
Molecular Weight:	65.38	Ref: Swanson, Tadge, Natl. Bur. Stand. (U.S.), Circ. 539, 1, 16 (1953)			
Volume[CD]:	30.43				
Dx:	7.136	Dm:	7.050		
Sys:	Hexagonal				
Lattice:	Primitive				
S.G.:	P6 ₃ /mmc (194)				
Cell Parameters:					
a	2.665	b	c	4.947	
α		β		γ	
SS/FDM:	F20-55(0182,20)				
U/cor:	3.80				
Rad:	CuKα1				
Lambda:	1.5405				
Filter:	Ni				
θ:step					
Mineral Name:					
Zinc syn					

2θ	Int	h	k	l	2θ	Int	h	k	l	2θ	Int	h	k	l
36.295	53	0	0	2	82.098	23	1	1	2	116.37	11	1	1	4
38.991	40	1	0	0	83.761	5	2	0	0	124.04	5	2	1	0
43.230	100	1	0	1	86.553	17	2	0	1	127.47	9	2	1	1
54.333	28	1	0	2	89.916	3	1	0	4	131.83	2	2	0	4
70.053	25	1	0	3	94.695	5	2	0	2	138.19	1	0	0	6
70.657	21	1	1	0	109.12	8	2	0	3	138.93	9	2	1	2
77.024	2	0	0	4	115.79	6	1	0	5					

b)

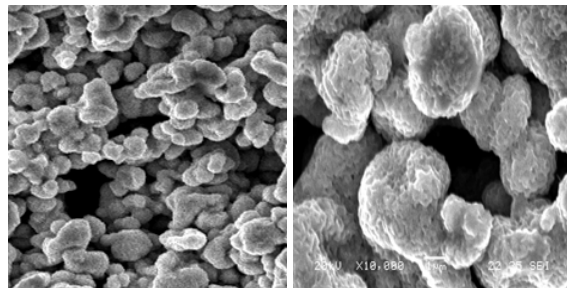
Fig. 2 a) Phase formation, b) PCPDF information. XRD analysis

Based on the XRD diagrams above display the zinc give has the highest peak which clearly is the dominant elements. But there are also peak is high apart from the zinc because the zinc oxide also displayed relatively high peak. This is because zinc has been oxidized during sintering process. The oxidized of samples overcome or reduce the problem by the flow of gas argon. The phase of zinc or other elements can analyze by the degree theta and intensity. In figure 2 a) show the peak formation zinc. In this phase the match of zinc formation can see in figure 2 b) by PCPDF information. PCPDF information shows the degree and intensity of the zinc element. However this is an initial preparation step direction of zinc as control experiment.



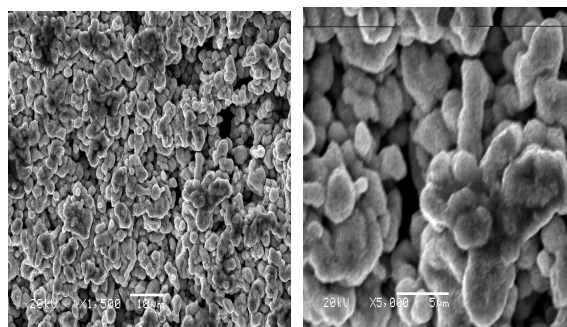
a)

b)



c)

d)



e)

f)

Fig. 3 a) and b) the measurement structure porosity. c),d),e) and f) the structure porosity sample. SEM analysis.

Result from SEM analysis found pore sized as small as 0.43um. This is good yield to obtain bulk nanoporous itself and a reliable solution from liquid condition. From the result, it is believed that if the parameters and the environment of the sintering process are controlled, a

smaller pore size yet rigid materials can be achieved. The uniformity of the pore size, even though not being one of this research main aims, might be resulted if appropriate parameters applied.

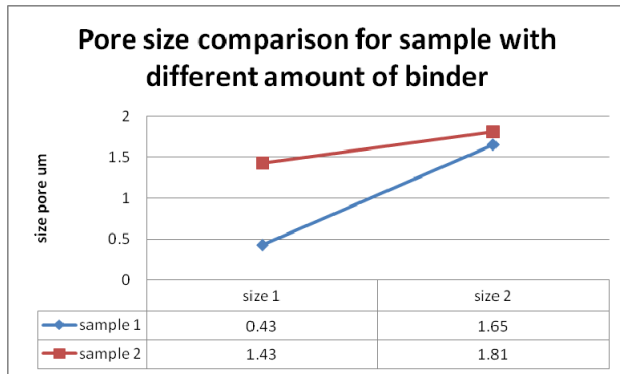


Fig. 4 Pore size comparison

Figure 4 exhibit comparisons between samples 1 which have less amount of binder with sample 2. The graph shows that the less amount of binder used the smaller pore size would be. Even though the use of less binder in the sample might cause the zinc atoms would have direct contact and became a more dense crystal structure, thus eliminating the pores that we are intended to create in the first place. The reduction number of pores would bring a high density bulk. These results compare only on the amount of binder. More binder in the sample might means the sample can sustain a larger pressure in the compaction process. The result of comparison and characterization of other parameters such as compaction pressure, temperature, and time will be discussed in the future.

Discussion

The process of preparing bulk nanoporous spells opportunity to study more detail on source material as suitable target. There are challenges of getting source material that fit for 13.5nm wavelength EUV lithography source with low and containable debris. The challenges are related with technical method to get structure dimensional for 32nm circuit width or below require decision accuracy in IC. This is the different EUV lithography challenge compared conventional optical lithography. Laser wavelength effect is one of the important aspect but other challenge is the mask accuracy to form structure desired. The state also need impervious environment from air. This is part of challenge for production process EUV lithography to tackle. The suitable optic framework selection is also a task to handle. The biggest challenge is procured source material that is suitable to produce wavelength that is effective without debris apart from challenge stated previously. However the zinc source selection this time is initial study for the project to gauge structure bulk nanoporous itself before further study by different type of source. The

zinc also has potential as target radiation plasma for soft x-ray. With this study at least enabled us to study related matter source that is suitable in EUV lithography later. Through initial study from the structure zinc that find out is pore size is formed through experiment process. There is an early picture that experiment successfully implemented but there is still needs to investigate the porosity that is subtler suitably for EUV lithography source. In fact, the zinc actually is also used as plasma source like has been talking about in coherent sources of XUV radiation: soft X-ray lasers and high-order harmonic generation [2]. EUV also dubbed as XUV which is known as soft x-ray that proportional wavelength in 1nm to 100nm wavelength. However wavelength is more extreme below 13.5nm known as EUV. XRD test also be implemented to know level structure the zinc after the experiment carried out.

4. Summary

From EUV lithography exposure new dimension for future semiconductor industrial that more competitive with high technology emerge. In this project actually gives early exposure experiment on bulk nanoporous as either physical form that is suitable as a source material. By making source material as bulk nanoporous, it is believed that the debris problem could be tackled.. This is an initial finding towards the goal to replace source material from liquid which faced debris problem. Having another target which have the same or lower density but with a different physical state sounds very promising. EUV lithography has the capacity to become the leading tools to fabricate device that is more complex and deluxe in cheap price. Early expectation of the project is an effort to use Sn and SnO₂ in the future further experiments. To counter the high frequency shot problems, we propose to fabricate a rotating nanoporous zinc, Sn and SnO₂ target. Based on road map semiconductor that imagine new dimension for high-tech device production, EUV lithography is crucial. Zinc can also be classified as a plasma source radiation target in XUV, opening doors to new studies, along with Sn which already have been known as a 13.5nm light source target.

Acknowledgement

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