

PAPER • OPEN ACCESS

## Analysis of the Machining Depth over Time in Wet Etching for Fabrication of Invar Thin Film Shadow Mask

To cite this article: G C Moon *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **205** 012021

View the [article online](#) for updates and enhancements.

You may also like

- [The influences of different filler metals on the microstructure of Invar Fe-36Ni alloy multi-layer multi-pass MIG welding](#)  
Xiaohong Zhan, Zhenxin Zhu, Tingyan Yan et al.
- [Investigations on density and surface roughness characteristics during selective laser sintering of Invar-36 alloy](#)  
Navneet Khanna, S Mistry, R A Rahman Rashid et al.
- [Electrodeposition of Invar Fe-Ni Alloy/SiC Particle Composite](#)  
Tomio Nagayama, Takayo Yamamoto and Toshihiro Nakamura



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Analysis of the Machining Depth over Time in Wet Etching for Fabrication of Invar Thin Film Shadow Mask

G C Moon<sup>1</sup>, W K Choi<sup>1</sup>, S H Kim<sup>1</sup>, S G Choi<sup>1</sup> and E S Lee<sup>2</sup>

<sup>1</sup>School of Mechanical Engineering, Inha University, Incheon 22212, Republic of Korea

<sup>2</sup>Department of Mechanical Engineering, Inha University, Incheon 22212, Republic of Korea

moonk8924@naver.com

**Abstract.** Invar is made up of 64% iron and 36% nickel. Invar has a characteristic of low thermal expansion coefficient that hardly causes a change of dimension according to temperature change. It is used for shadow mask fabrication by using this feature. Shadow mask is an important element for enhancing the pixels of the display. Therefore, Wet etching is an important machining technique because it is economical and mass-producible to make shadow mask. In this study, the machining depth was compared and analyzed with the machining time by using a 30 $\mu$ m invar thin film. As the machining time increased, the machining depth of the hole increased and a perfect hole array occurred when the machining time was 5 minutes. Through the same processing conditions, a 5.5-inch large-area shadow mask with uniform hole size was fabricated.

## 1. Introduction

The shadow mask is an important element for enhancing the pixels of the display, the smartphone and the VR, which are regularly drilled with hundreds of small holes of the same size and mounted on the inner surface of the panel. The shadow mask uses the electron beam injected from the electron gun to reach the fluorescent surface of the inner surface of the panel, and the temperature is high. When deformation occurs in a small hole due to high temperature, red, green, and blue fluorescent dots are not accurately deposited. Therefore, an invar consisting of 64% iron and 36% nickel having a low thermal expansion coefficient will be used. Various machining methods are used to fabricate shadow masks. Laser machining has a problem of taper generation and burrs during machining, removal of burrs is in itself a great challenge for producing zero-defect high density pixel counts and Water jet and Electric discharge machining (EDM) clearly them from entering the current state-of-the-art of making mask.<sup>[1]</sup> Electro chemical machining (ECM) has difficulty in making a rectangular shape and an over cause a dimensional error.<sup>[2]</sup> which makes it difficult to manufacture accurate shadow masks and takes a long time to process. Recently, many studies have been attempted to improve spray etching technologies for micro-electronics manufacturing.<sup>[3-5]</sup> There are many advantages in wet etching. There are no burrs on the edges of the parts, while the substrate is not subjected to either heat or physical deformation. In addition, extremely small features can be obtained and the dimensions can be controlled precisely and wet etching is used to fabricate shadow masks, enabling rapid mass production.<sup>[6]</sup> Wet etching is the most commonly used method for fabricating shadow masks. However, wet etching has a problem that the workability greatly changes according to the processing conditions. In this study, a dry film pattern with a size of 120  $\times$  80 $\mu$ m is prepared through a photomask of a 30 $\mu$ m invar thin film and the time of hole generation is determined by comparing and analyzing the variation of the processing depth with time of the spray type etching. The 5.5-inch large-area shadow



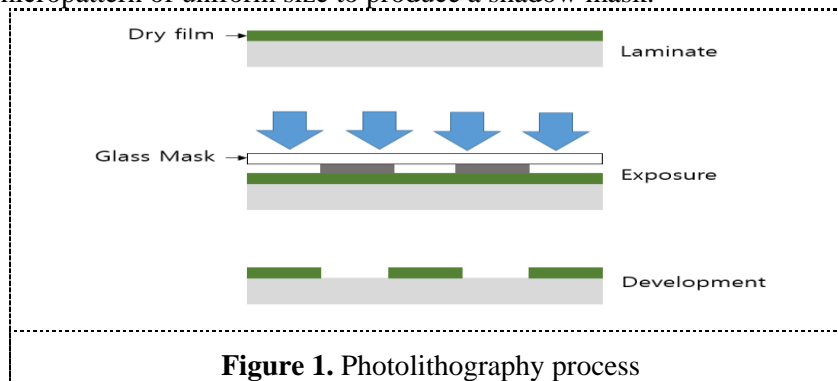
mask was fabricated at the determined machining time of 5 minutes by analyzing the change of the machining depth with time.

## 2. Experimental details

### 2.1. Photolithography

Figure.1 shows the process of making a pattern on an invar using photoresist. Laminating was carried out using a dry film manufactured by Hitachi Ltd. under the conditions of a laminating temperature of 110°C and a laminating speed of 1 m/min. After laminating, the holding time was 10 minutes so that the adhesion of the dry film and Invar completely took place. After the holding time, the glass mask was placed on the stepper coated with the dry film and the exposure was performed for a time of 90 seconds.

In the patterned portion of the glass mask, UV light is not received during exposure, and the dry film is not cured and is peeled by reaction with a developing solution of 4 wt%. This yields a dry film pattern with a micropattern of uniform size to produce a shadow mask.

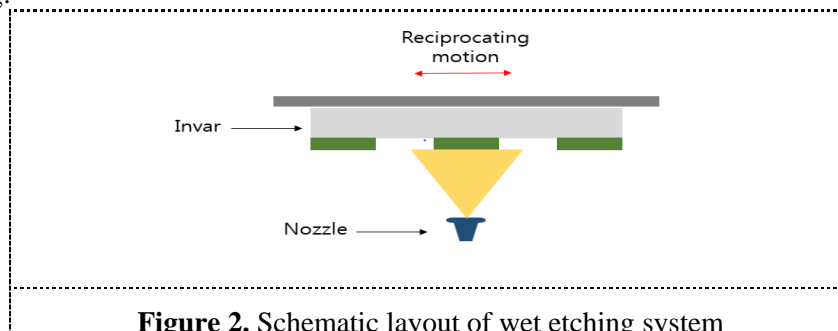


### 2.2. Wet etching

*Fe* and *Ni* constituting the Invar are processed by etching reaction with an aqueous solution of ferric chloride ( $FeCl_3$ ). The  $Fe^{3+}$  ions contained in the aqueous solution of nickel chloride are adsorbed while diffusing to the metal surface. The adsorbed  $Fe^{3+}$  ion reacts with *Fe* and *Ni* constituting the invar and reacts as shown in equations (1) and (2).



After the reaction, the ions desorbed from the metal surface are released. Microhole machining is performed as these chemical reactions are repeatedly performed. Figure. 2 is a schematic view of the spray-type wet etching system used in the experiment. Generally, there is a problem that a new  $FeCl_3$  aqueous solution must be supplied in order to perform a chemical reaction in the wet etching process. Spray is used to smoothly supply  $FeCl_3$  aqueous solution to the invar surface. In addition, by applying pressure, the processing in the depth direction is performed while reducing the isotropic property of the wet etching.



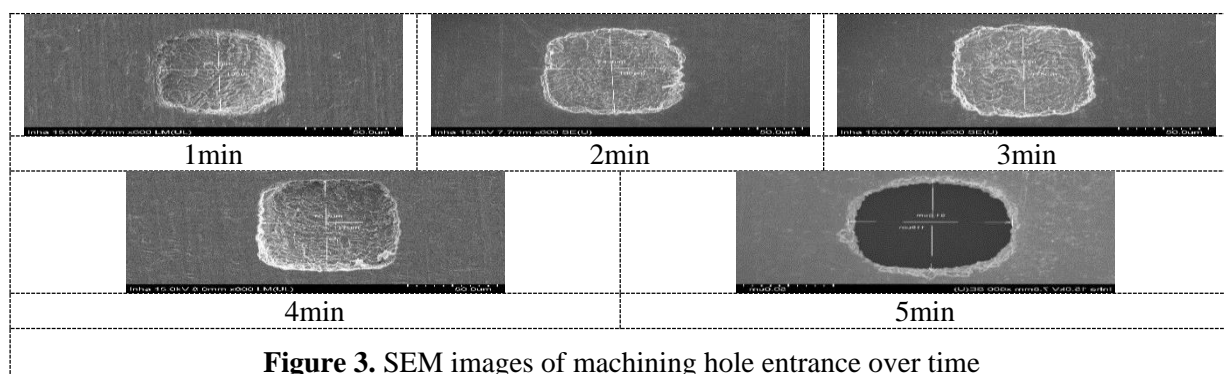
### 3. Results and Discussion

When spray etching is performed, the depth of machining is compared with time. By comparing and analyzing the depth of machining, the machining time is determined so that machining is performed by the depth to be machined. Table.1 shows machining conditions for sprat wet etching. We compared the hole size and the depth of hole according to the change of time for the shadow mask production.

**Table 1.** Experimental machining conditions.

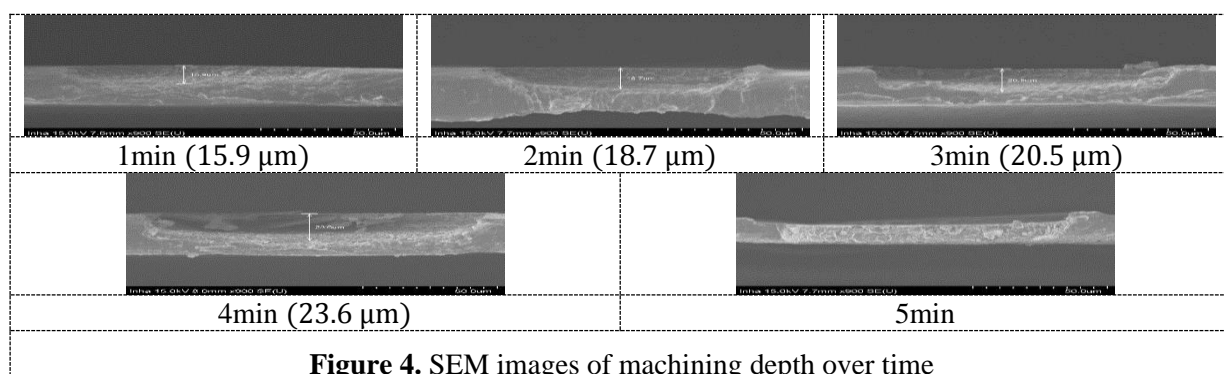
Conditions	Values
Etchant	30wt% FeCl <sub>3</sub>
Pressure	0.08MPa
Temperature	35 °C
Machining Time	1, 2, 3, 4, 5min

Figure. 3 represents the size at the entrance of the hole over time. The size at the entrance of the hole with time increases gradually. This is due to the isotropic characteristics of the wet etching. The isotropic properties are not machined only in the depth direction but in all directions. Because of this isotropic characteristics, when the machining time is too long, it will be affected by the machining between the adjacent holes, and the dry film will be detached and the accuracy of the machined shape will be decreased.



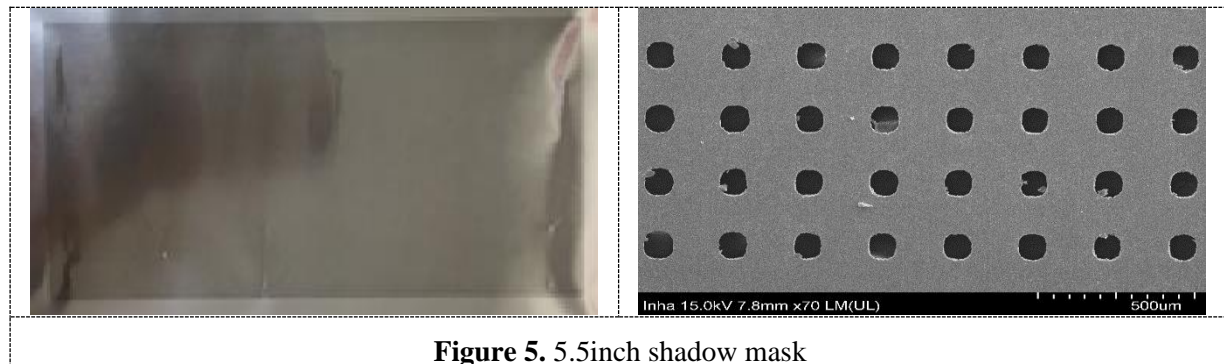
**Figure 3.** SEM images of machining hole entrance over time

Figure.4 shows the depth of machining over time. The machining depth gradually increases with time. When wet etching is used, the change in machining depth with time is analyzed to determine the time at which holes are generated. The removed invar material in axis direction is the biggest in the first minute of spray wet etching, which is the least contact area of the etchant with the surface of the invar, which is anisotropic rather than isotropic. After 1 min, the depth of machined hole on invar film gradually decreases, because the isotropic characteristic of the wet etch process allows the process to be performed in all directions.



**Figure 4.** SEM images of machining depth over time

This suggests a high efficiency and good accuracy in creating a micro-hole array by comparing the machining rates of the hole's inlet and processing depth over time. Using a 5-minute machining time to generate a hole array, a 5.5-inch large area shadow mask can be fabricated as shown in Figure 5.



**Figure 5.** 5.5inch shadow mask

#### 4. Conclusions

1. The inlet of the hole with time becomes larger due to the isotropic nature of the wet etching. The size of the hole gradually increased, but in the 5 minutes that the hole was created, it became  $91.6\mu\text{m}$  in width and  $119\mu\text{m}$  in height.
2. A hole with a thickness of  $30\mu\text{m}$  was produced when the etching time was 5 minutes due to the chemical corrosion reaction of the etchant and the impact force of the spraying pressure.
3. A shadow mask with a uniform size can be generated when the processing time of the processing time 5 minutes in which the hole having the pattern of  $120 \times 80\mu\text{m}$  is generated is generated.

#### 5. Acknowledgments

This research was supported by the Strengthening competitiveness business of industrial clusters funded by the Korea Industrial Complex Corporation.

#### 6. References

- [1] Sundaram N Kumar, Robin John, Scott Lauer, White Little and Bob Dual 2015 Electroforming Technology for Manufacturing Thin Metal Masks with Very Small Apertures for OLED Display Manufacturing *Symposium Digest of Technical Papers* **46** 211-214
- [2] Xiaolei Chen, Ningsong Qu, Hansong Li and Zhengyang Xu 2016 Electrochemical micromachining of micro-dimple arrays using a polydimethylsiloxane (PDMS) mask *Materials Processing Technology* **229** 102-110.
- [3] D S Jin, K H Chun and E S Lee 2016 Analysis of the current density Characteristics in through-mask electrochemical micromachining for fabrication of micro-hole arrays on invar alloy film *Chinese Journal of Aeronautics* (preprint CJA 764)
- [4] Geissler M, Schmid H, Michel B and Delamarche E 2003 Selective Wet of Microcontact printed Cu Substrates with Control over the etch Profile *Microelectronic Engineering* **67-68** 326-332
- [5] A Visser And M Buhlert 2001 Theoretical and practical aspects of the miniaturization of lead frames by double sided asymmetrical spray etching *Journal of Materials Processing Technology* **115** 108-113
- [6] Jeong H C, Kim D J, Choi G M and Kim D J 2009 The Effect of Spray Characteristics on the Etching of Invar Alloy with  $\text{FeCl}_3$  Solution *International Journal of Precision Engineering and Manufacturing* **10** 107-114,