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Sample Preparation Effects on Surface Quality of Specimen Fabricated by Ion Milling Process

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***Abstract* -** Ion milling is used to prepare cross-sectional specimen of larger than 1 mm for the SEM analysis. A plasma ion source was used for ion milling and the quality of the milled surface was analyzed using a scanning electron microscope. If there was a space between the mask and the sample surface because the sample surface was not uniform, the sample can be damaged since the ion beam is spread when due to the beam diffusion when the ion beam is applied to the back side of the mask. A special pretreatment of the specimen eliminated this phenomenon. In the experiment, the ion beam size was 0.5 mm, the acceleration voltage was 7 kV, and argon gas was used as the gas.

***Keywords*:** Ion Milling, SEM, Sample preparation

1. Introduction

Sample preparation is often required before scanning electron microscope measurements can be performed [1]. Cutting and polishing are common preparation techniques to remove surface roughness and to obtain a flat surface. Such traditional mechanical techniques apply shear forces to the sample, which result in surface artifacts like scratches, smearing, delamination and other damages at soft materials. Cross sections prepared by cleaving or mechanical methods often induce damage and result in distorted internal structures

All these issues are circumvented with the latest ion milling techniques. These systems apply a broad low-energy Ar+ ion beam to sputter sample material from the sample and can be used both as cross section polisher and surface polisher. No mechanical stress is applied, which leaves extremely flat surfaces and cross sections without any artifacts. The ion milling creates cross sections created without applying mechanical stress to the sample, and analysis of sub-surface structures can be possible [2].

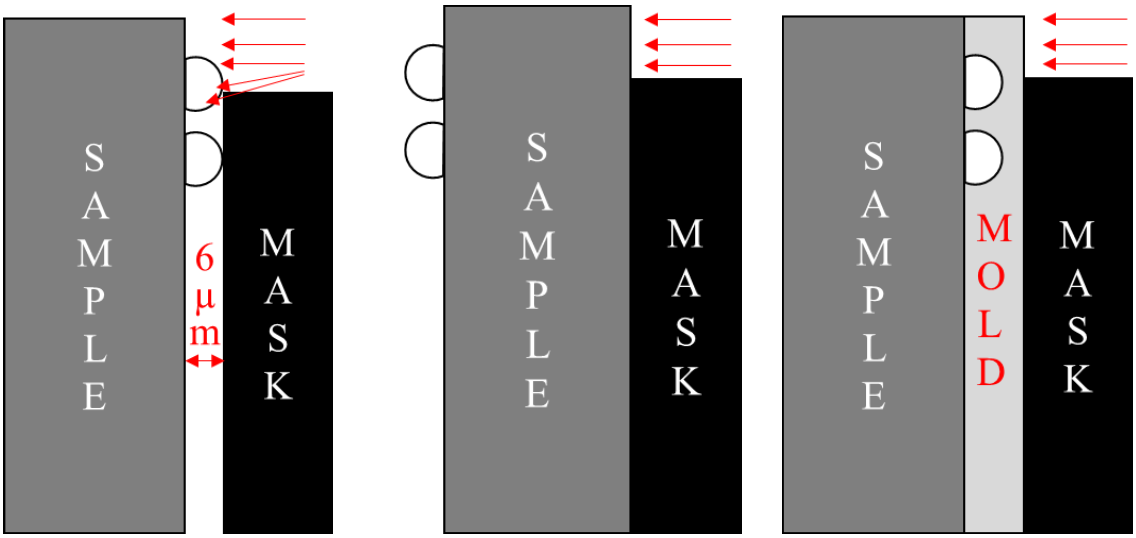
Recently, in the case of very thin and diverse thin film samples such as semiconductors and display materials, it is required to observe the thin film interface more clearly than before, and furthermore, to analyze the crystal orientation of the structure. In this situation, there was a difficulty in that the existing mechanical polishing pre-processing method has limitations and takes a lot of time to obtain a desired result. To improve this point, the ion milling method was used to prepare a precise sample, and as a result, it became possible to obtain a clear image and to analyze the crystal orientation of the tissue easily [3].

A focused ion beam (FIB) is often used to make cross-sections of small electronic devices. FIB is generally used to precisely machine a section with a depth of 0.1 µm to several 10 µm, and a wide ion beam is utilized to machine a slightly wider width of 0.1 mm to 1 mm [4]. Recently, an ion milling process has been widely used to fabricate a cross-section of a mask using a wide ion beam. A general ion miller is used to machine a 1mm cross-section of a specimen, but a new ion miller has recently been developed to process a wider cross-section [4]. Ion beam processing has the advantages of being able to precisely process a very small size, requiring no chemical reagents or etching compounds, no undercutting, and easy control of the etching rate. On the other hand, it has the disadvantages of being relatively expensive, slow etch rate, and there may be some radiation damage.

The flip chip bonding, which is utilized in the PCB, uses solder balls and if there is any problem in the process conditions of solder balls inside the PCB, since it is connected to the characteristics of the PCS, this small defects of solder balls causes failure of whole electronic devices. Therefore, it is necessary to be able to observe the cross section of the solder ball clearly in order to improve the process defects.

In this study, to observe the accurate installation of solder balls on the PCB, the PCB substrate was processed using the broad ion beam (BIB) used in the ion miller. Three cases of sample installation on the ion miller sample stage were prepared as shown in Fig. 1. It was to develop a way to see the accurate view of the solder ball location in the PCB.

In test 1 (Fig. 1 a), the sample with solder balls was attached to the mask of the miller. There was a space between the specimen and the mask because of the solder balls of 6μm radius. In test 2, the sample attachment was in reverse direction as shown in Fig. 1 b. The way was used to remove the gap between sample and mask of the miller. In test 3 (Fig. 1 c), the solder ball part was molded to make flat surface and the molding to eliminate the space caused by the solder balls between sample and the mask part. was attached to the mask by attaching it after molding.



(a) test1 (b) test2 (c) test3

Fig. 1: Test Sample Preparation

2. Experimental Procedure

PCB including microchips with solder balls were used as a test sample. Three sample preparations as shown in Fig. 1 were used for comparison of accuracy of ion milling process on the sample. In order to adjust the sample size to take into account the equipment specifications and processing section to be used, the target cross section of the sample was polished using sandpaper. The sample was attached to the jig using carbon tape or epoxy and was attached to the holder.

During the tests, each specimen was machined for 3 hours using a XILKRAD V2 ion miller. The XILKRAD V2 ion miller is the recently developed by the KEMCTI. (Acceleration voltage 0~7kV, beam diameter 0.5mm, argon gas, vacuum degree $7*10^{-4}$ Torr, milling speed 300um/h).

After attaching to the holder, set the final machining height. Using a jig and the microscope screen in Fig. 2, align the processing point of the sample to the center, and set the height to be less than 100um above the mask. At this time, if the height of the sample is higher than 100um above the mask, the suggested milling speed may not be met.

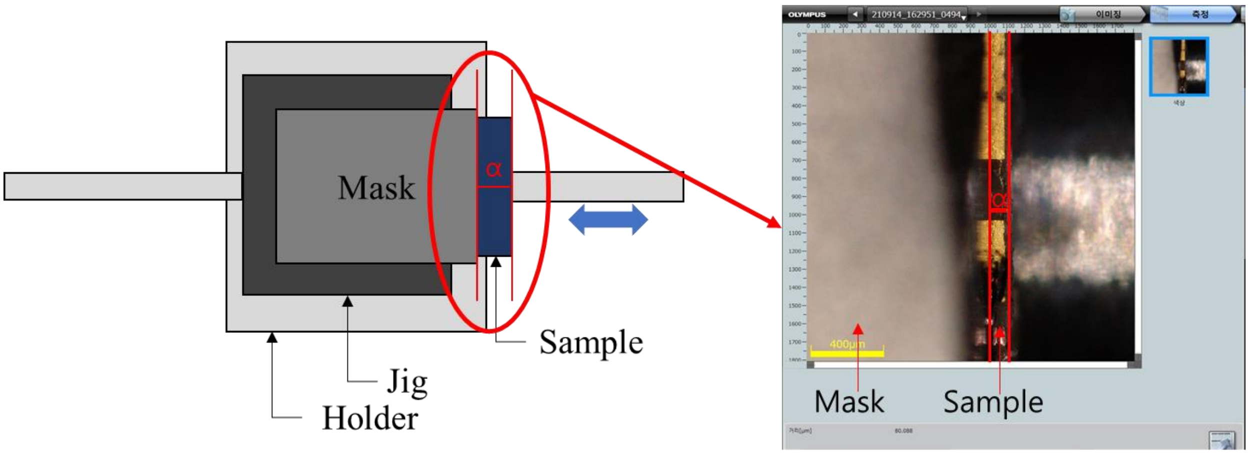


Fig. 2: 150x Microscope sample height setting

The inside of the chamber after sample preparation is shown in Fig.3. The sample is positioned between the holder and the mask, and the sample is protruded from the mask by α.

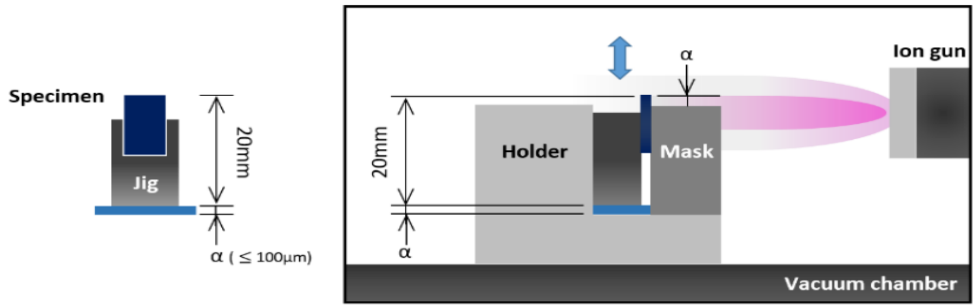


Fig. 3: Schematic diagram in the Chamber

Fig. 4 shows a schematic diagram of the principle of the ion milling process. The plasma ion source generates ions, and the flow of ions from the source becomes an ion beam and collides with the sample to create a cross section of the sample through the sputtering process. In general, ions or atoms of an inert gas such as Ar accelerated to create an ion beam [5]. Acceleration energy and current are important parameters that determine the sputtering yield of the ion source [5]. In Fig. 4, the ion source is inside the vacuum chamber and the staple stage is used to install the specimen. The stage rotates within a specified angle to smooth the machining surface.

Milling conditions using the ion source are 7*10-4 Torr. Ar gas 1sccm (Stand Cubic Centimeter per Minute) is introduced into the vacuum chamber. Milling is performed with an acceleration voltage of 7 kV and a plasma current of 2.6 mA, and the measurement current of the sample stage is 240-260 μA [6].

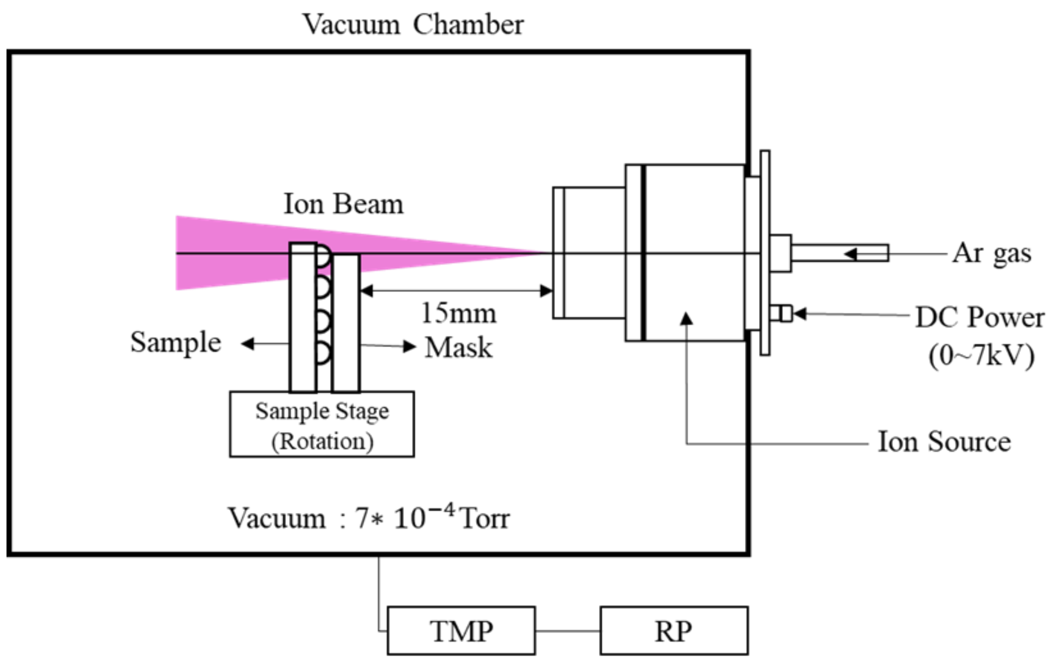


Fig. 4: Schematic diagram of Ion Milling

As shown in Fig. 5, if there is a protruding part on the sample surface due to solder balls on flip chip bonding and it is not flat, there is a space on the flat surface on the mask and the solder balls of sample. This space may cause the beam diffusion. The experimental sample is a pcb and the protrusion height is 6 µm. The setting of test samples was explained in Fig. 1. Three tests by changing the location of test sample were performed as explained in Fig. 1.

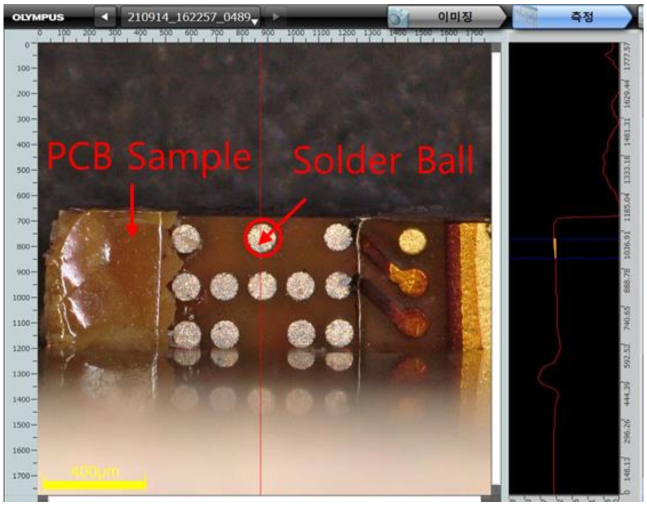


Fig. 5: Optical microscope image of sample

Fig. 7 shows how the sample is usually attached to a jig and sample with jig is attached as test 1 in Fig. 1. The beam of the ion mirror starts processing from the front side of the sample. Since the surface that touches the mask is not flat, the sample surface is damaged by the beam as shown in Fig. 8. It has the advantages of simple sample preparation and short processing time.

Fig. 8 shows the sample with the sample processing surface attached to the jig in the opposite direction as test 2 in Fig. 1. The beam of the ion mirror starts processing from the back side of the sample. Start processing from the back side of the sample. As shown in Fig. 9, there is no damage to the surface of the sample to be measured. However, it takes a long time to process because the entire thickness of the sample has to be processed.

Fig. 6 shows the moulding operation on the sample. After moulding, use a cutter to cut according to the sample size. After that, prepare the sample as in the sample preparation as test 3 in Fig. 1.

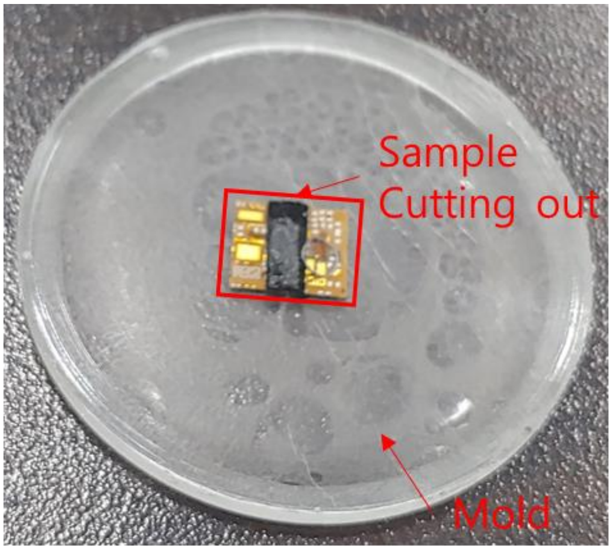
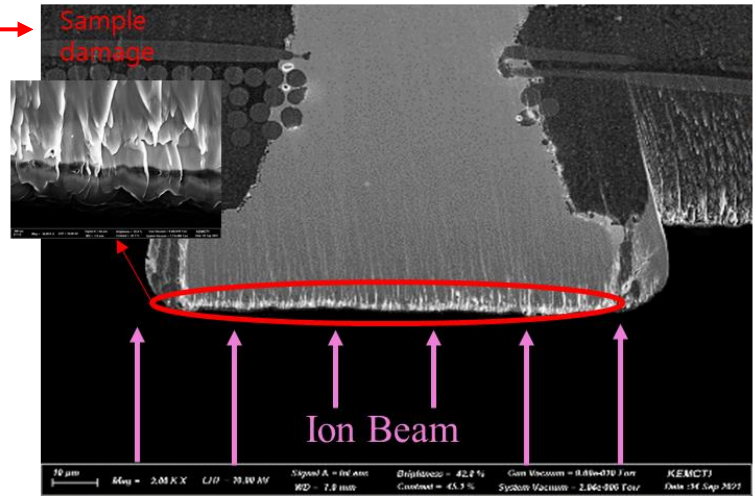
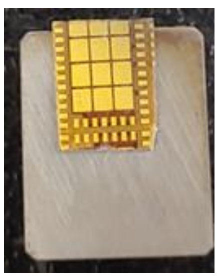
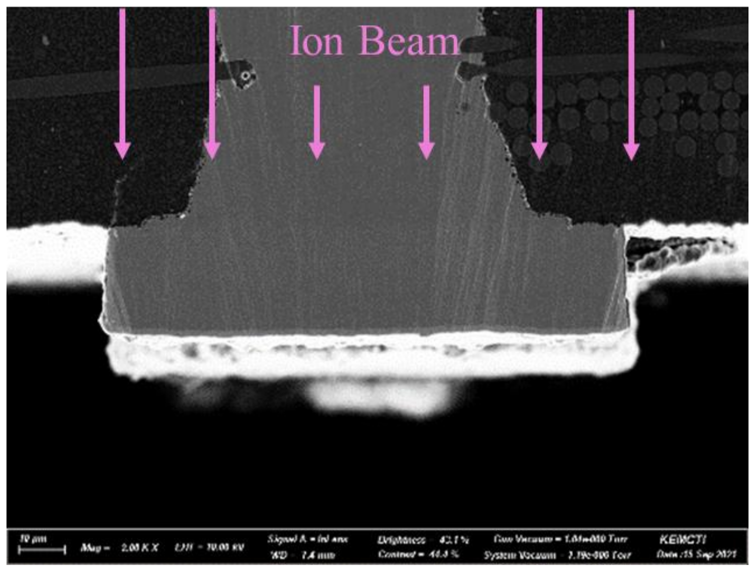
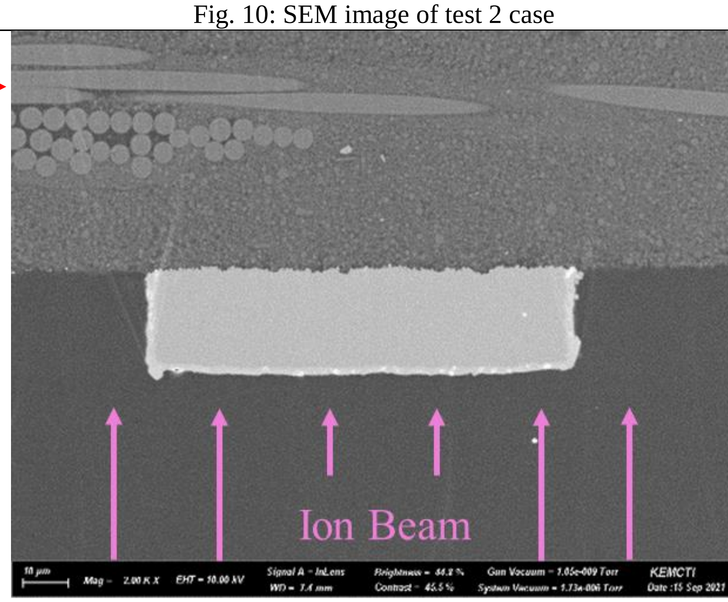


Fig 6: Sample moldng

Fig. 11 shows the state of attaching the molded sample to the jig. The beam of the ion mirror starts processing from the front as shown in test 3 in Fig. 1. As shown in the SEM measurement in Fig. 12, there is no damage to the cross section of the sample processed after molding. The machining time is the same as the normal machining time, but the time for the molding operation is added. Therefore, this method is suitable for thick samples or working with multiple samples at once.

Test 1 in Fig. 1	 Fig7: sample attached as test 1	 Fig. 8: SEM image of test 1 case
Test 2 in Fig. 1	 Fig. 9: sample attached as test 2	 Fig. 10: SEM image of test 2 case
Test 3 in Fig. 1	 Fig 11: molded sample attached as test 3	 Fig 12: SEM image of test 3 case

3. Conclusion

In this study, pcb specimens were prepared through ion milling using a wide ion beam. The phenomenon in which damage is applied to the surface of the specimen behind the mask caused by solder balls was solved by various methods of pretreatment of the specimen. Conversely, it was possible to remove the damage on the observation surface by installing molding sample, but the disadvantage was that it takes a long time to process depending on the thickness of the specimen, and the result was that it could not be applied when measuring both surfaces. When the specimen was molded to make the surface flat and then processed, the damage could be minimized, both of which could be measured, and the milling time was also relatively reduced.

Acknowledgements

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The reference section at the end of the paper should be edited based on the following:

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