Cross Sectional Analysis of IC Devices Using Polishing Techniques and SEM Imaging

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Abstract-- The purpose of the project was to develop a universal procedure for obtaining a cross section of various IC devices, use a Scanning Electron Microscope (SEM) to document these devices, and identify different layers and try to obtain dimensions for the devices. The technique was developed using a mechanical polishing procedure followed by a chemical mechanical polishing step, and worked as expected, producing very good images of the cross section of various film stacks and devices. Wide ranges of devices were analyzed to test the robustness of the process. Film stacks could be measured in both thickness and composition (with the proper equipment), and very clear high magnification images of devices were obtained.

1. GOALS

The main goal of the project was to develop a universal procedure for obtaining a cross section of various IC devices at RIT. Secondary to this, the cross-sectioned devices were then to be imaged using a Scanning Electron Microscope (SEM) and compositional and dimensional information were then to be obtained.

2. BACKGROUND

The need for a process to obtain good cross-sectioned images at RIT is apparent in that all of the equipment to make and test IC devices is present, but a method of looking at the internal structure was not. The only method used previously was that of scribing and cleaving, which is not accurate and is problematic when there are multiple films present. Therefore, based on previous work at Dominion Semiconductor (a wholly owned subsidiary of Toshiba manufacturing DRAM and Flash memory) in the Failure Analysis laboratory, the tripod polishing method used there was decided on. This decision was made based on the availability of the equipment and relatively low expense (to RIT) of developing such a process. As previously work had been done in this area with Dominion Semiconductor, an idea of the equipment and process was already in place.

3. EQUIPMENT

Various equipment was needed to accomplish the aforementioned goals. Some equipment was already available at RIT and some needed purchasing in order to provide a process. South Bay Technology, Inc. was contacted as they had a tripod polishing setup on the market that would suit RIT's needs.

A. Polishing Wheel

The equipment and process outlined by South Bay Technology required a variable speed polishing wheel with a glass plate as the polishing surface for mounting lapping films. The wheel also required a water supply and drain as the polishing done was of a wet nature. A variable speed polishing wheel with water supply and drain was available at RIT and a compatible glass plate was ordered from South Bay Technology. This was then custom mounted to the polishing station

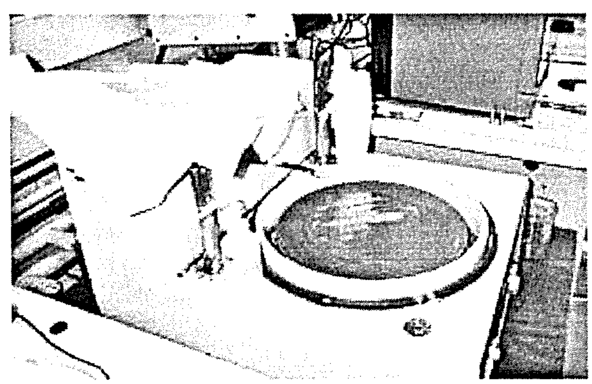

Figure 1: Polishing wheel fitted with glass plate polishing surface.

B. Lapping Films

A set of diamond impregnated lapping films compatible with the glass plate polishing surface was also obtained from South Bay Technology. These were in six different film sizes starting with 30 micron and going down to .5 micron. These will be discussed further when the process is outlined.

C. Tripod Polisher

The samples to be cross-sectioned needed to be mounted in a tripod which would sit on the lapping films as the wheel rotated. This was also ordered from South Bay Technology and is outlined below.

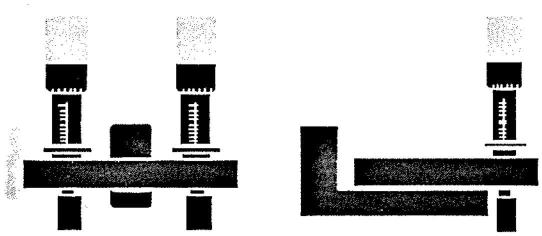

Figure 2: Figures obtained from South Bay Technology literature showing side and back views of the tripod. Sample mounts on the left most point facing down from the side view, and in the center facing down from the back view.

The tripod polisher has sample mounting such that the sample can be removed directly from the apparatus and placed in a SEM for examination. The back feet have integral micrometers for adjustment during polishing to ensure that the sample is polished coplanar to the target area.

D. Microscope

A microscope is needed to adjust the sample in the tripod while polishing to ensure co planarity with the target area. It is also used in sample mounting to get the sample roughly straight on the mounting stub. The microscope must have enough room to fit the complete tripod on end under the objective. This was available at RIT.

E. Colloidal Silica and Compatible Polishing Pad

For the final polishing step (outlined in the procedure), a colloidal silica .05-micron slurry is needed along with a compatible polishing pad. This was present at RIT in the CMP department.

F. Sample Mounting

SEM stubs that mount directly into the tripod polisher were part of the tripod package from South Bay Technology. Mounting the samples required a hotplate and polymer with high boiling point relative to it's melting point (also supplied with the tripod kit) which was melted on the stub in preparation for the sample.

4. PROCESS

The process used to polish the samples was based on the recommendations of South Bay Technology and past experience at Dominion Semiconductor. Application of the process to the equipment available at RIT was done by experimenting with polishing speeds with the various lapping films to where a manageable and comfortable polishing rate was achieved without causing damage to the films or sample. This was done as a trial by error as it had more to do with equipment preferences than anything else.

First, the sample was mounted on the supplied SEM stub by placing the stub on a hotplate at 120 degrees Celsius. Some of the aforementioned polymer glue was then placed on the stub. A sample approximately one centimeter by 5 millimeters was then placed on the stub and positioned so that the target area was hanging off the edge of the stub by approximately 3 millimeters. The sample is then immediately placed under a microscope and, while the glue is still hot, straightened to the edge of the stub as best as possible. Once this is done, the stub is allowed to cool for a minute or two and then mounted in the tripod.

Once mounted in the tripod, the micrometers on the back feet of the tripod must be adjusted to the same height as the target area on the sample. This is to assure that the cross-section occurs at a right angle to the top surface of the sample.

Next, the first lapping film must be mounted on the polishing wheel. This is done by first wetting the glass wheel and then placing the film down on top of the glass. The water must then be pushed out from under the film by using a rubber or plastic spatula. The film will then stick to the wheel held by suction.

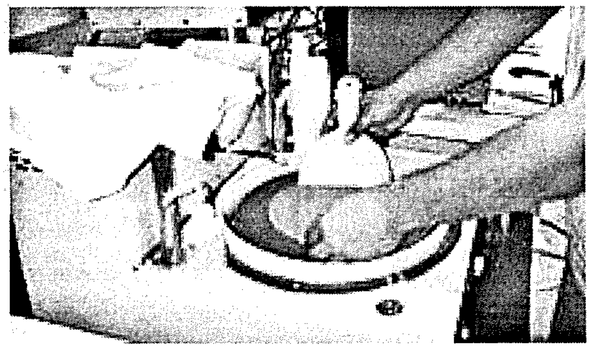

Figure 3: Mounting of the lapping film using wet adhesion.

The tripod is then placed on the rotating wheel back feet first. The sample end of the tripod is slowly placed in contact with the wheel and no pressure is applied. The only pressure is that to hold the tripod in place on the wheel. The tripod should be placed with the sample facing the direction of rotation.

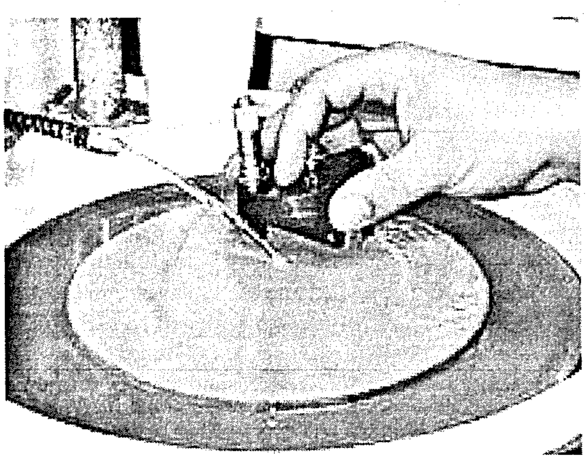

Figure 4: Bringing the sample into contact with the wheel.

A paper towel should be placed over the trail of polishing debris so that the sample is not scratched and the film does not get clogged or burnt.

The speed of the polishing wheel depends on the film used and also the operator. The polishing rate must be kept at a manageable level so that the target area is not overshot or undershot. Table 1 shows the procedure best able to control the polishing rate using the available equipment.

Table 1: Shows process obtained for given equipment.

Film	Speed	Comments
30 μm	130rpm	Uniform scratches on entire surface. Inspect under microscope and adjust micrometers parallel to plane of Interest.
15μm	100rpm	30 mm scratches completely removed. Polish until plane of interest is ~ 300 mm away. Inspect under microscope to ensure the polishing plane is parallel to the plane of interest.
6μm	70rpm	15 mm scratches completely removed. Polish until plane of interest is ~ 100 mm away. Inspect under microscope to ensure the polishing plane is parallel to the plane of interest.
3μm	50rpm	6 mm scratches completely removed. Polishing plane should be parallel to the plane of interest, make final adjustments.
1μm	30rpm	3 mm scratches completely removed. Plane of polish should be parallel with the plane of interest.
.5μm	15-20rpm	1 mm scratches completely removed. Polish until plane of polish is just outside the plane of interest. Inspect under inverted microscope to locate the area of interest.
.05μm Colloidal Silica	30rpm	Use Polishing cloth. Polish for 30 seconds to a minute in the opposite orientation. Clean immediately with Q-tips. Rinse cloth.

After the 30, 15, and 6 micron polishing steps, the sample needs to be examined under a microscope while still attached to the tripod to ensure the polishing is occurring co planar to the target area. If it is not, the micrometers need to be adjusted to straighten it. If an adjustment is needed, polish on the same film for ~5 seconds so as to not damage the next film. By the time the three micron polish is complete, adjustments should be finalized.

The final film (.5 micron) must be used very carefully as it is easily damaged and the target area can be overshot on the sample. Frequent examination and slow polishing speeds are important for this step.

The final polish is done using a .05 micron colloidal silica slurry on a compatible polishing cloth at 30 rpm. This is done in the opposite direction, with the sample facing away from the direction of rotation, and it's purpose is to remove all scratches left on the surface. It can be done for 30 seconds to one minute. The sample must then be cleaned, usually done by rinsing under water and rubbing with a q-tip that has some soap on it. This is to remove all of the remaining slurry on the sample. It is very important to completely clean the polishing pad when finished as if slurry dries on it, the sample will be scratched when it is used again. Also, the glass plate on the polishing wheel must be kept clean as any dirt on it can scratch the sample or damage the films placed on it.

5. RESULTS

Very high quality images were obtained using the above outlined process. The images taken were done on a LEO Scanning Electron Microscope. At high acceleration voltages, the images obtained were excellent.

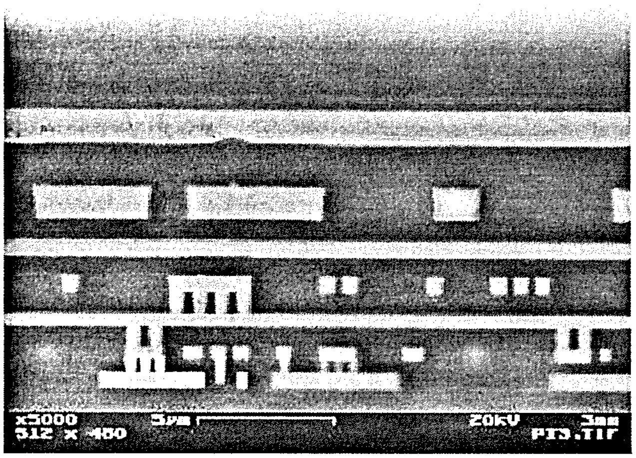

Figure 5: Image of industry chip taken at 20kV, 50000x magnification

The various layers were identifiable and had very good contrast. Scratches were not evident.

For the first round of samples prepared, the final polishing step was not performed as it was thought to be unnecessary. At lower acceleration voltages (~2kV), however, scratches became apparent. This made looking at thin film layers and grains of various layers very difficult. Once the final polishing step was performed, the images were excellent, even at acceleration voltages as low as 1kV.

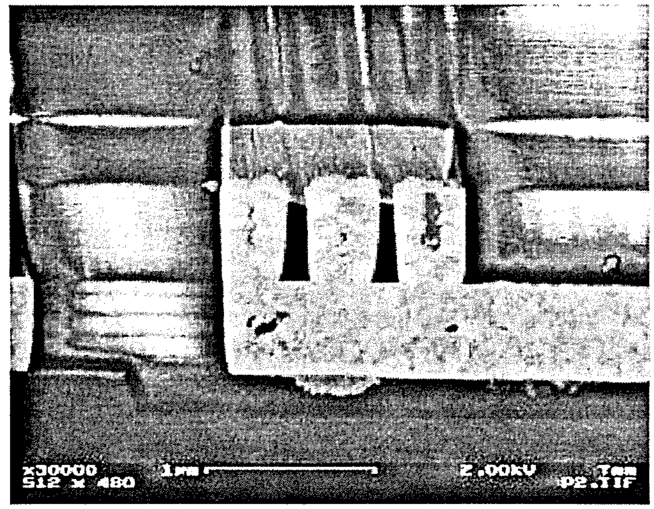

Figure 6: Image of Industry chip taken at 2kV, 80000x magnification. Notice the grain of the tungsten (lighter) layer.

Compositional information and various film thicknesses were also obtained using various methods (EDAX x-ray and computer aided measurements).

6. CONCLUSION

The polishing procedure developed for the equipment available at RIT was very successful, obtaining very high quality SEM images of various structures. This was done at a minimal cost as opposed to other methods, and was more successful than originally anticipated. All of the goals set forth were achieved and RIT is now more capable as a facility, especially in the failure and device analysis areas.

ACKNOWLEDGMENTS

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Peter Terrana, originally from Afton, NY, received B.S in Microelectronic Engineering from Rochester Institute of Technology in 2001. He attained co-op work experience at Dominion Semiconductor. He is currently seeking employment.