Effect of Tape Liftoff Tool Settings and Plasma Conditions on Metal Peeling from Polyimide Surfaces

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Keywords: Tape liftoff, Polyimide, Oxygen plasma

Abstract

In this paper we report the effect of peeling angle and roller pressure on metal damage during tape liftoff process. Using automated inspection, we find that proper peeling angle is required to significantly reduce metal damage. DOE data also shows that an optimized roller pressure is crucial for a damage free process. In addition, this paper also reports the role oxygen plasma can play to improve metal adhesion to the polyimide surfaces. This weak adhesion has been studied extensively in many fields including the semiconductor industry. Our data shows that oxygen plasma can modify the polyimide surface and improve metal adhesion to such a degree that results from tape liftoff are comparable to the solvent liftoff process. The mechanism of adhesion enhancement is also proposed in this paper.

INTRODUCTION

There is considerable and increasing interest in the tape liftoff process because tape liftoff provides multiple advantages: (1) significantly improves metal reclaim, (2) reduces solvent liftoff equipment PM frequency and time, (3) improves liftoff rework rate, (4) shortens solvent liftoff process time, and (5) opens an avenue to use inexpensive solvent liftoff equipment. However, the disadvantages of tape liftoff is also sometimes very evident: (1) physical damage to the electrical circuits, especially narrow and long metal lines landing on surfaces with weak adhesion, like polyimide structures, (2) tedious tape evaluations to find the optimum tape for our specific application and (3) tape adhesive residues. Tape residue can become a very nagging issue for the process engineer. Overcoming and resolving these issues are critical in developing a robust tape liftoff process.

This paper will report on our methodology in selecting the critical process parameters and successful use of oxygen plasma to reduce metal damage during the tape liftoff process.

EXPERIMENT

All the experiments were conducted on Takatori tape liftoff equipment. The tape used in the experiments was obtained from LINTEC. The oxygen plasma process used to treat the polyimide surface was conducted in a Matrix Asher.

The photolithography and metal deposition process remained unchanged. The post tape lift NMP solvent strip process is a shorter version of the regular production liftoff recipe. The wafers were inspected 100% using automated optical inspection (AOI) equipment. Care should be taken in setting up the AOI inspection to ensure it will detect all the residue and metal damage.

RESULT

Fig.1 shows roller peeling direction with respect to the die orientation. Repeated tests show that when the roller peeling orientation is in the (a) direction, the metal wires have no damage as can be seen in the AOI yield chart shown in Fig. 2. However when roller peeling orientation switches to the (b) direction, some metal wires in the electrical circuit peel and break from the polyimide surfaces as seen in Fig.3. Fig. 2b shows the wafer yield map, with the defects identified by the AOI inspection.

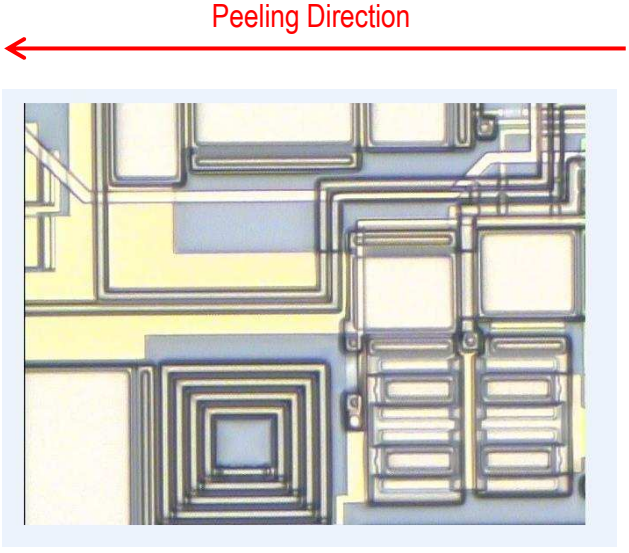


Fig. 1 (a), 0 degree

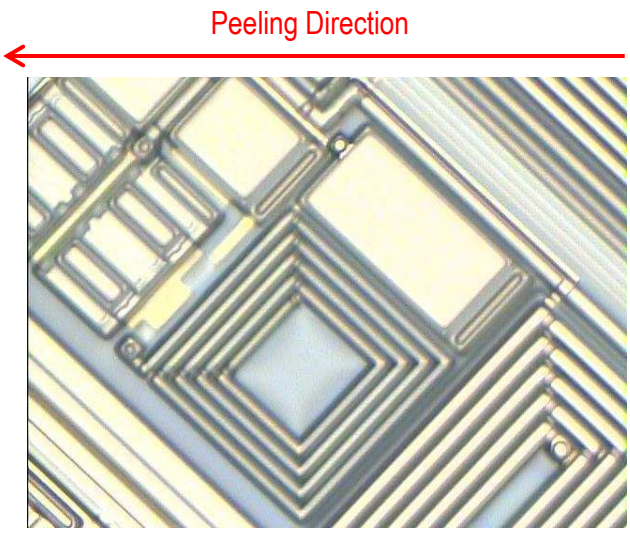


Fig. 1 (b), 45 degree

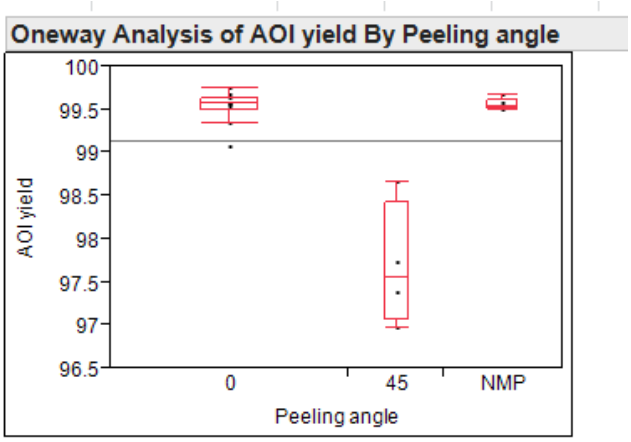


Fig.2a AOI yield for different peeling orientation

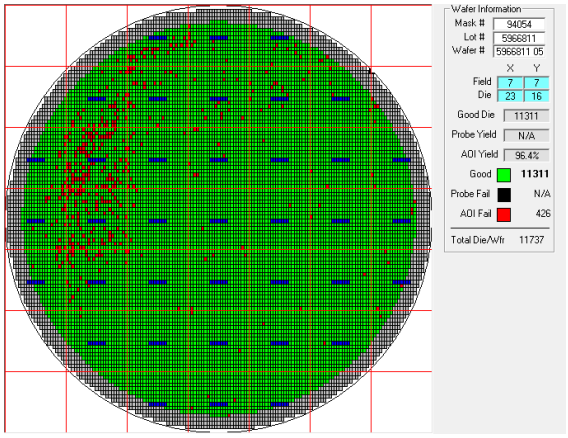


Fig. 2b AOI yield loss due to the metal damage

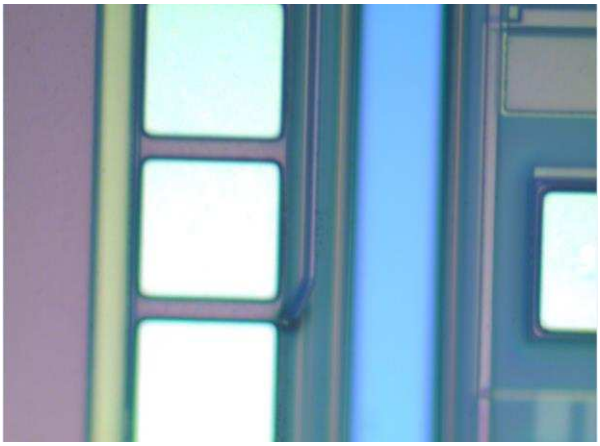


Fig.3 Metal wire is peeling from polyimide surface

During the tape liftoff process, a roller applies pressure to the wafer as the tape is applied. Fig. 4 shows roller pressure effects on AOI yield. As roller pressure changes from 0.07 MPa to 0.12 MPa, AOI yield is seen to decrease. The yield loss has been confirmed with both AOI and microscope manual inspection. These defects are thin metal wire peeling from the polyimide surfaces.

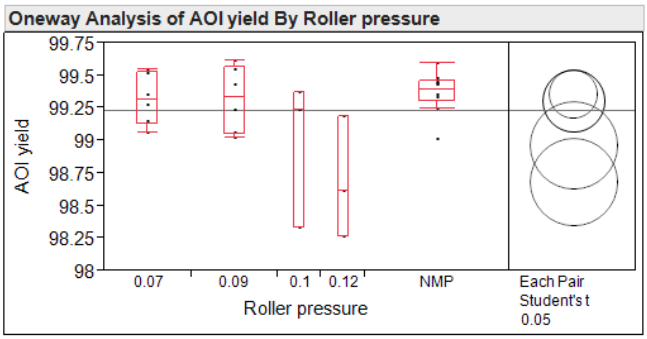


Fig.4 Roller pressure effects on AOI yield

However, when oxygen plasma was used to treat and modify the polyimide surfaces, even with the 45 degree peeling angle and higher roller pressure of 0.12 MPa, comparable AOI yield to the standard NMP solvent liftoff was still achieved as shown in Fig 5. The same experiments repeated on other products with different masks also showed consistently good yield.

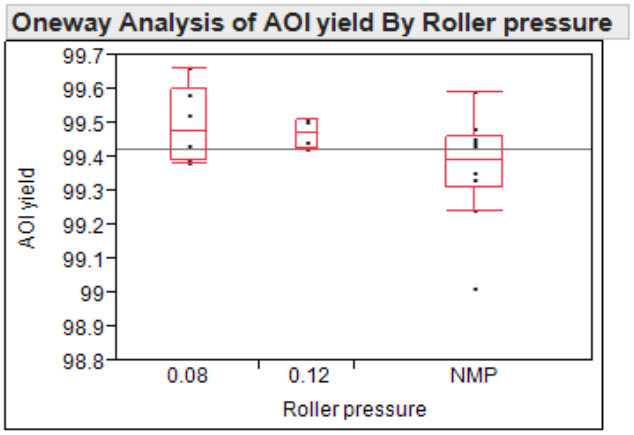
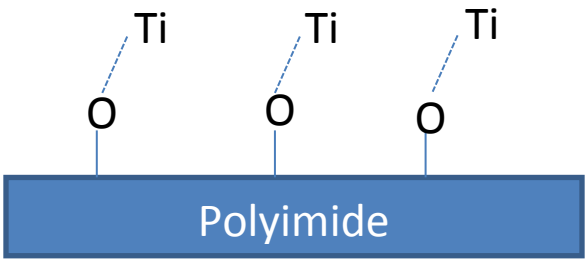


Fig.5 Oxygen plasma improves tape liftoff AOI yield. In this figure, tape liftoff wafers were treated with oxygen plasma

The metal deposited on top of polyimide surfaces starts with the first layer of about 300 angstrom of Titanium (Ti). Based on the experiment results and other reports, a mechanism to enhance adhesion of metal on polyimide surfaces is proposed in the schematic below:



When oxygen plasma is used to treat polyimide surfaces, the inherent oxidization creates many oxygen atoms on the polyimide surfaces. These oxygen atoms behave as active adsorption sites to adsorb Ti atom during the metal deposition process, forming a strongly bonded monolayer. The pseudo chemical bond (O-Ti) formed during the metal deposition process is believed to be responsible for enhancing the metal adhesion [(1)]. Surface roughness created by the oxygen plasma treatment is a secondary factor to further improve the adhesion [(2)].

CONCLUSIONS

This work shows that the process parameter settings for tape liftoff process are very important to develop a robust process. The process parameters should be optimized with a variety of DOE experiments. In addition liftoff wafers with different masks should be studied to ensure the process is compatible with different layouts and geometries. The ultimate aim is to minimize metal damage and tape adhesive residue. If the optimization is done correctly, the AOI yield matching solvent liftoff process can be achieved. The DOE experiments also show that oxygen plasma treatment can significantly enhance the adhesion of metal on the polyimide surfaces. This adhesion enhancement can effectively minimize metal damage during tape liftoff process and raise wafer yield.

REFERENCES

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ACRONYMS

AOI: Automated Optical Inspection