# Optimization of Metal Adhesion for GaAs Backside Wafer Processing

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**Keywords: metal, adhesion, backside processing**

**Abstract**

**Through use of analytical techniques and process monitors, we have studied metal adhesion to the wafer backside following through-substrate via processing. It was discovered that metal adhesion could be controlled by GaAs surface preparation with wet chemistry, RF pre-metal deposition sputter etch, and target crystallinity due to sputter power. Our results are based on Auger electron spectroscopy, optical reflectometry, atomic force microscopy, x-ray pole figures, and a test we developed to evaluate practical work of adhesion.**

## INTRODUCTION

In GaAs through-wafer via processing, metal is required to be deposited on the backside of thinned wafers [1]. A full thickness GaAs wafer is thinned using a combination of grind polishing and wet etch thinning. The wafer then receives backside via processing followed by backside metal deposition. The metal deposition is accomplished by physical vapor deposition (PVD) sputtering. Subsequent processing through saw and tape transfer stress the adhesion of the backside metal to the substrate. The primary failure mode of the process is peeling backside metal. Though the process is not as complicated as most frontside metallization schemes, it still needed to be studied and understood to maintain its robustness and manufacturability. Since backside metallization occurs near the end of processing, much has already been invested in manufacturing costs at this point. This makes elimination of backside adhesion failures crucial, and motivated work to understand, measure, and control its process effects. Through the use of measurements, metal adhesion could be optimized and proper process controls put in place to eliminate backmetal adhesion failures.

This paper includes a discussion of three primary processes related to backside metallization that were investigated and the analytical techniques and process parameters that were used to study their effects. The processes covered are: wet chemistry surface preparation, RF sputter-etch prior to metal deposition, and target crystallinity due to sputter power. In our discussion of each parameter, analytical techniques as well as the process controls are covered.

## WET CHEMISTRY PRE-CLEAN EXPERIMENTS

The first process investigated was the wet chemistry pre-clean. This process cleans the GaAs surface and creates its necessary roughness prior to metal deposition. Atomic force microscopy (AFM) revealed that the wet processing method and chemical concentration altered the GaAs surface roughness (Table 1).

**Table 1** AFM results for various pre-clean applications.

| RPM | Pre-clean Application | Zmax (nm) | RMS (nm) |
|---|---|---|---|
| 150 | Pumped | 74.7 | 8.6 |
| 150 | Aspirated | 246.1 | 32.93 |
| 50 | Concentrated | 213.9 | 24.52 |
| 50 | 1:1 dilution | 60.1 | 7.31 |

Scanning electron microscope (SEM) cross-sections revealed that concentrated pre-clean chemistry roughened to the extent of creating voids in the GaAs surface (Fig. 1) and supports AFM results.

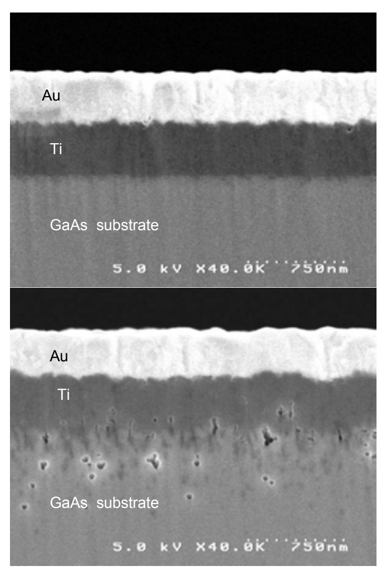



Figure 1: SEM cross-sections of 1:1 dilute (top) vs. concentrated chemistry (bottom). Note voiding at Ti-to-GaAs interface for the concentrated sample.

To correlate these results to a measure of adhesion, a test was developed (Fig. 2) to compare adhesion values between different parameters. This process is a relative measure of the practical work of adhesion, and provided our factory with a quantitative adhesion rating. Ratings range from 1 to 10, where a 10 rating would be equivalent to, virtually, no peeling and a 1 complete delamination. In our manufacturing environment this test proved to be useful, as experimental results were quickly attainable.

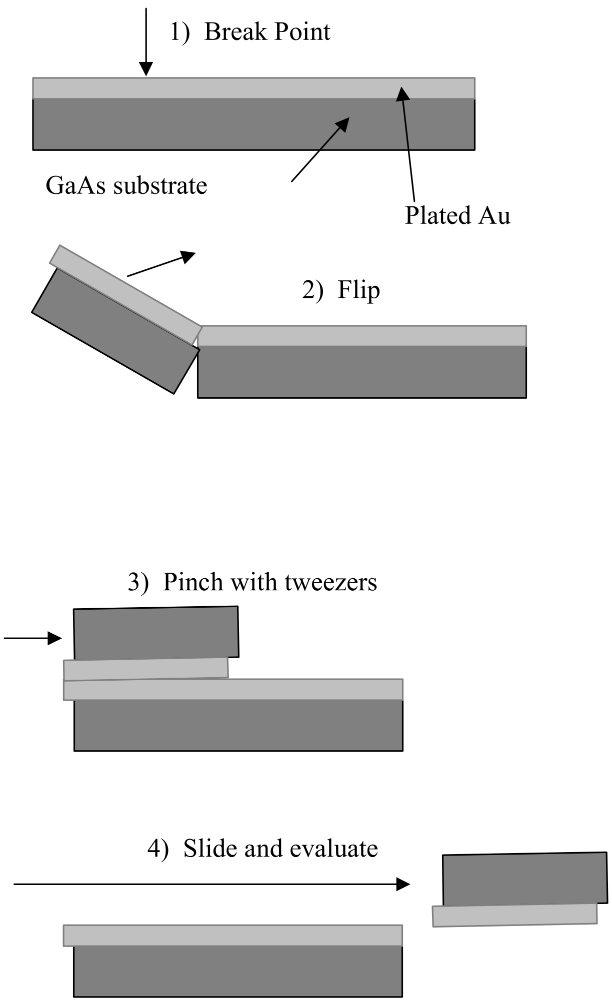
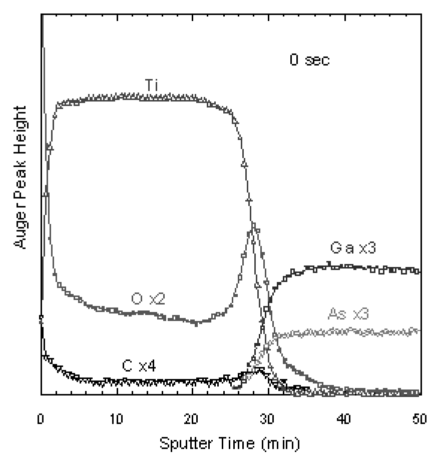



Figure 2: Break and slide method developed for adhesion evaluation.

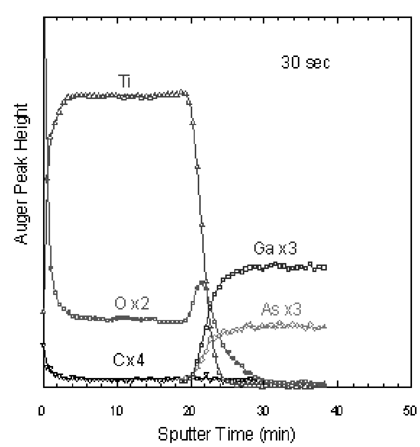
Voiding at the GaAs interface correlated to lower adhesion values than samples without voiding. We categorized this type failure mechanism as GaAs-GaAs (fractures occur within GaAs). Based on this information, an inline process control was instituted to monitor surface roughness following wet chemistry pre-clean. Reflectometry measurements of the surface were added to determine if the pre-clean had produced the desired roughness. Low reflectivity values indicated potential GaAs surface voiding, while high reflectivity would indicate insufficient roughness. Insufficient roughness resulted in lower adhesion values, as the fracture toughness of the Ti-GaAs interface is decreased.

RF SPUTTER ETCH EXPERIMENTS

The second process studied was the *in situ* RF sputter-etch that occurs prior to metal deposition. Sputter etches are designed to remove surface contaminants prior to metal deposition and have the added benefit of doing so under vacuum. Etch time was evaluated from zero to 180 seconds. During the course of this work, Auger electron spectroscopy (AES) was used to determine the RF etch influence on the metal-to-GaAs interface. The AES depth profiles revealed that samples with no RF etch had an intense oxygen peak at the interface while increasing RF etch time correlated to decreased oxygen signals (Fig. 3). Adhesion testing also found correlation between RF etch time and oxygen intensity at the Ti-GaAs interface, as decreasing RF etch time improved adhesion. This variety of failure was not GaAs-GaAs, as with the wet pre-clean, but failed at the Ti-GaAs interface, which validated AES results.

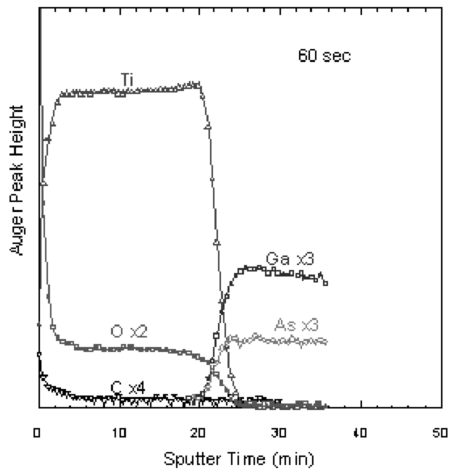



a: 0 seconds RF etch

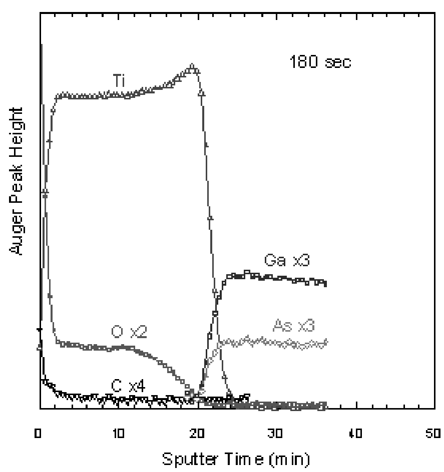



b: 30 seconds RF etch




c: 60 seconds RF etch




d: 180 seconds RF etch

Figure 3: In a through d (above) AES profiles through Ti into GaAs. Note decreasing oxygen signals at metal-GaAs interface as RF etch time is increased.

The RF etch effect was proven through use of test wafers produced at different levels of RF etch time prior to metal deposition. An interaction also was observed from tests involving RF etch and reflectivity from the wet chemistry pre-clean. With reflectivity low (but not so low to indicate GaAs voiding), the RF etch did not have a substantial influence on adhesion (Fig. 4). However, as reflectivity was increased, influence from the RF etch became significant. The RF etch was found to further increase surface reflectivity, thereby, again, reducing the interfacial fracture toughness. This result provided evidence that the RF etch should be minimized (or eliminated) to improve wet surface preparation latitude. Our findings also provided data necessary to establish upper limits for reflectivity measurements.

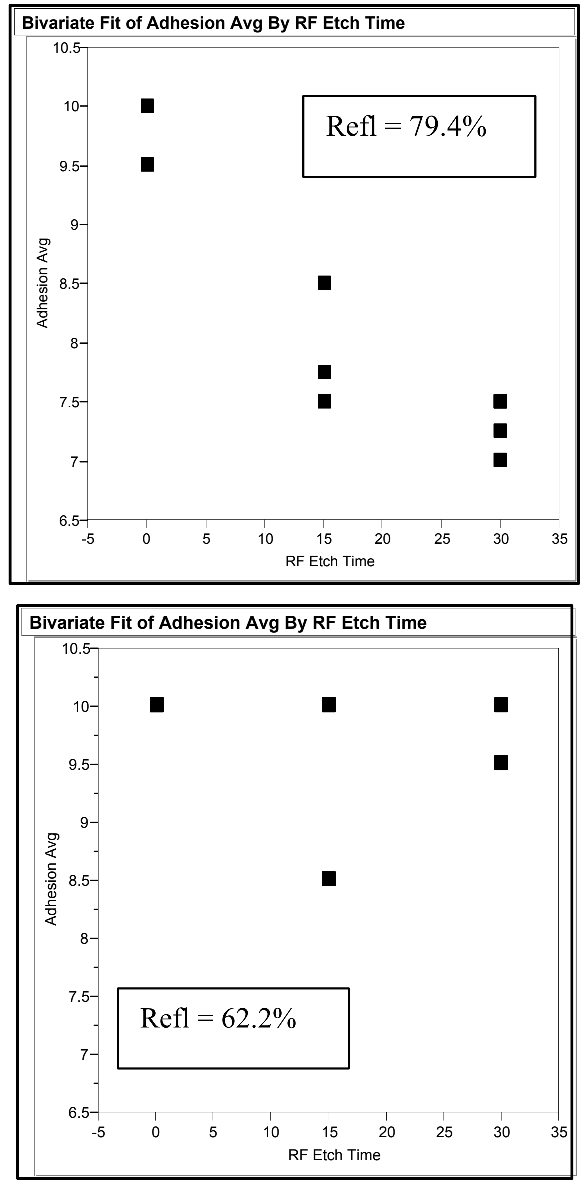



Figure 4: RF etch-GaAs surface reflectivity interaction. Note that for a sample with high reflectivity (top), correlation exists with RF etch time and for a surface with low reflectivity (bottom) no correlation exists.

## TITANIUM TARGET GRAIN SIZE

The final effect studied was the metal deposition process. A titanium target associated with spectacular adhesion failures had large grains in a small area compared with the normal, small grain structure (Fig. 5). This target was associated with weak metal adhesion [2]. X-ray pole figure analysis determined that films sputtered from the large-grained area had strong orientation of the (1 0 –1 0), (0 0 2) and (0 0 0 4) planes compared to a random orientation from the small-grained target films.

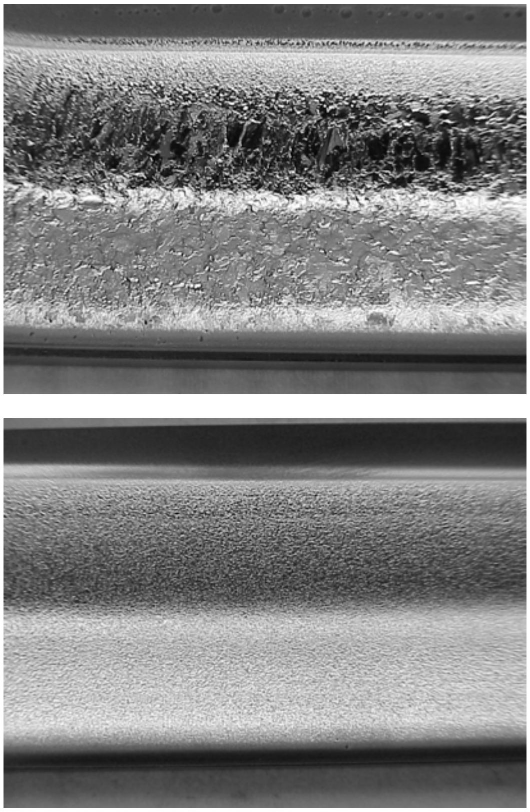


Figure 5: SEM images of large (top) and small (bottom) grain titanium targets.

## CONCLUSIONS

In conclusion, the use of analytical techniques and process monitors enabled us to elucidate the key components associated with backside Ti-GaAs adhesion. We demonstrated that adhesion could be controlled by GaAs surface preparation, RF pre-metal deposition sputter-etch, and Ti target crystallinity. Additionally, by developing a method to rank adhesion within our factory (albeit relative), we were able to attain rapid results from our experiments.


## ACKNOWLEDGEMENTS

The authors would like to thank members of the backmetal improvement team: Keith Thuemler, Jason Wright, Lup Yee, Helmut Francz, and Karen Lenaburg. We also thank Ben Myers, and the PMCL staff for their efforts and devotion toward our backmetal adhesion studies. Special thanks to Joe Vella and Alex Volinsky of PMCL for their discussions and advice on adhesion theory. Finally, we thank CS-1's technicians.


## REFERENCES


[1] Henry Hendriks et al., *Challenges of Rapidly Scaling up Backside Processing of GaAs Wafers*, 2001 GaAs MANTECH Technical Digest, p. 181-184

[2] Shalish and Yoram Shapira, J. Vac. Sci. Technol. B 17(1) Jan/Feb 1999


## ACRONYMS

AES: Auger Electron Spectroscopy
AFM: Atomic Force Microscopy
XRD: X-ray Diffraction
SEM: Scanning Electron Microscope
PVD: physical vapor deposition
RF: Radio Frequency