THE EFFECTS OF IN-SITU FORMIC ACID TREATMENT ON OXIDE REDUCTION FOR COPPER WAFER BONDING

Nooshin Saeidi[1], Tony Rogers[2], Anna Draisey[2], Rhodri Davies[2], Declan Casey[3], Cindy Colinge[3], Andreas Demosthenous[1], Nick Donaldson[1]

[1]University College London, UK
[2]Applied Micro-engineering Limited
[3]Tyndall National Institute, Cork, Ireland

Abstract
One of the issues associated with metal bonding for interconnect applications is the requirement for oxide free surfaces which would provide a good electrical connection and eliminate the need for the application of high pressures to crush the surface oxide. In this paper, we report copper-copper direct bonding of wafers that were exposed to an in-situ saturated vapour pressure of formic acid vapour and present the results of investigation on the influence of in-situ formic acid vapour on oxide reduction at the bond interface.

Introduction

Three dimensional (3D) integration that allows for stacking and packaging of separately fabricated wafers is a promising solution to realize high density devices with enhanced performance. Metal bonding is a key process for 3D integration as it offers both wafer stacking (mechanical bond) and vertical interconnects (electrical bond). Since copper has lower electrical resistivity than aluminum, it is an attractive choice for interconnect materials. Consequently copper wafer bonding is a promising candidate for realization of vertical interconnects and 3D integration. However, the removal of surface oxide which is essential for a reliable electrical contact remains a challenge. Wet chemical cleaning steps that are usually performed on wafers prior to bonding reduce the surface oxide to some extent but in-situ treatment of wafers is a preferred solution for oxide reduction as the controlled conditions (e.g. vacuum ambient) of the bonding chamber would prevent oxide regrow. Formic acid has been reported to be an effective reducing agent for copper oxide [1-2]. In this work formic acid vapor purge prior to bonding was used as in-situ treatment for blanket copper wafer bonding and the result was compared to non in-situ treated copper wafer bonding.

Experimental

Blanket copper wafers were prepared by coating 4” silicon(100) wafers with 20nm of titanium as an adhesion layer followed by 200nm of copper. Prior to bonding the wafers were wet cleaned in H2O:HCl (1:1) for 30 seconds and rinsed in DI water. The bond recipe consists of three phase:

1. The wafers were heated to 300ºC in vacuum ambient (10^{-4} mBar) and then formic acid vapour was introduced to the bonder chamber for 15 minutes.
2. The wafers were contacted and the chamber was pumped down to the vacuum level again.
3. The bond temperature was increased to 450ºC and then 15kN of force was applied for 15 minutes.

Similar recipe was performed on another pair of blanket copper wafers without in-situ treatment to investigate the influence of formic acid on oxide reduction.

Results and Discussions

Figures 1 and 2 show the SAM images of the bonded pairs. As shown, the bond force (15 kN) was not sufficient to achieve a good bond when no in-situ oxide reduction process is employed. Figure 3 and 4 more clearly show that formic acid treatment reduced oxide at the bond interface.

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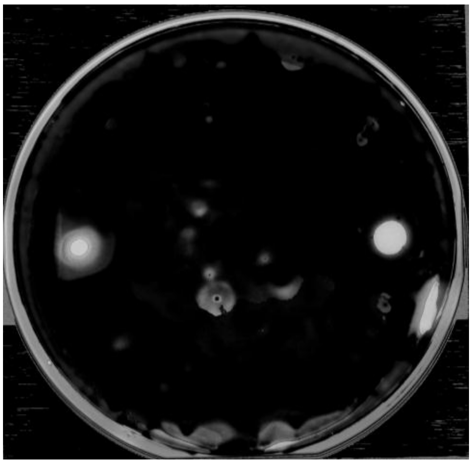

Figure 1: SAM image of formic acid treated wafer pair

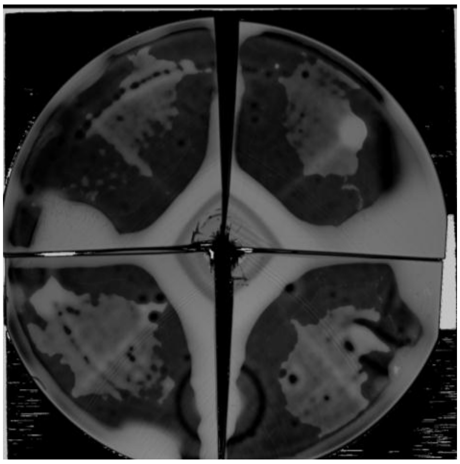

Figure 2: SAM image of wafer pair that only received wet cleaning

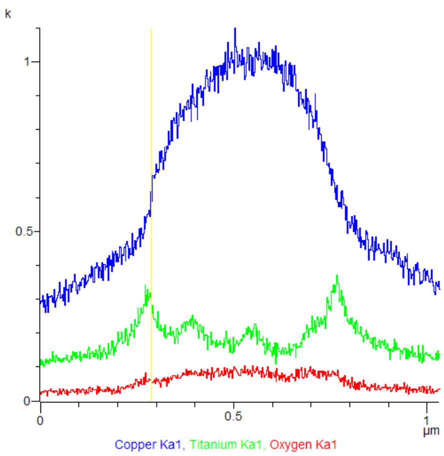

Figure 3: EDX spectra of bond interface for formic acid treated wafer pair

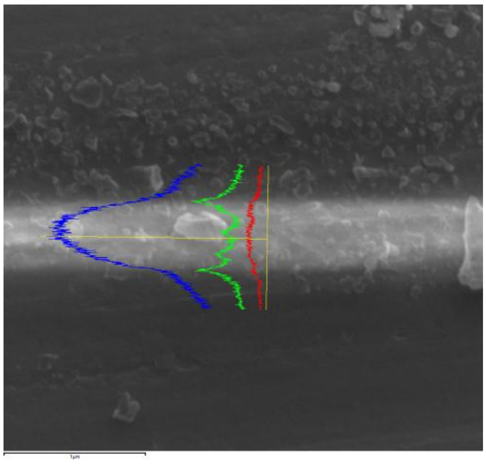

Figure 4: SEM image of bond interface for formic acid treated wafer pair

Conclusions

In situ treatment of blanket copper wafers with formic acid vapour was found to be an effective way to perform copper-copper bond for electrical contact applications. Further work is needed to improve the bond yield and formic acid purge process.

References

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