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Enhancement of Direct Cu Bonding via Pulsed Flash Light

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Abstract

Cu-to-Cu direct bonding is one of the key technologies for 3D (three-dimensional) chip stacking. An innovative pre-treatment to enhance Cu-to-Cu bonding through the exposure of Xenon flash is proposed in this study. Several flash pulses can significantly improve the bonding strength. It can be ascribed to the rapid heating/cooling cycles and thus induced compressive residual stresses which enhance the diffusion of copper atoms and thus direct bonding.

1. Introduction

In order to allow conductance between stacked ICs, jointing by metallic connections is necessary [1-4]. Cu-to-Cu bonding is ideal to form required interconnections because copper possesses many advantages, *e.g.*, excellent electrical conductivity, low cost and high electromigration resistance. Conventional Cu-to-Cu direct bonding has to be performed at high temperatures (~400°C) under high vacuum (~10^{-3} Torr) [5], and a post annealing is necessary to strengthen the joints[6]. Strategies to improve Cu-Cu direct bonding have been proposed. However, strict processing requirements, *e.g.*, annealing process [7], reactive vapor [8], specific copper electroplating parameters or excess coating (intermediate layer or surfactants) [9,10], limit industrial application.

A recent report presented the enhancement of Cu-Cu bonding by the control of surface physical characteristics through air plasma bombardment [11]. To extend the concept, this study adopted Xenon flash pulses to adjust the residual stresses on the faying surface of copper. The influence and mechanisms will be studied and discussed.

2. Results and Discussion

Fig. 1 schematically illustrates the sudden expansion/contraction on the Cu surface with the exposure of pulsed flash light. This may result in compressive stresses which is able to accelerate the diffusion of copper atoms and thus bonding to two faying faces. This concept can be verified by the surface roughness and subsurface hardness of Cu films given in Figs. 2(a) and (b). Subjected to thermal compression at 250°C under 10 MPa for 5 min, Fig. 3(a) illustrates the shear strength of joints bonded between two Cu filmss exposed with different flash pulses prior to bonding. It can be distinguished that 10 flash pulses can reach 30 MPa, which is 64.5% higher than those without flash light exposure. Fig. 3(b) indicates that original Cu surface possessed tensile residual stress. Pulsed flash light exposure contributes to a suppressed tensile stresses and thus increased diffusion coefficient (D/D_o) [12]. The estimated self-diffusivity is about 1.6 times higher than the un-exposed samples. The cross-sectioned microstructure of the 10-pulse exposure joint reveals a firm bonding between two Cu films (Fig. 4).

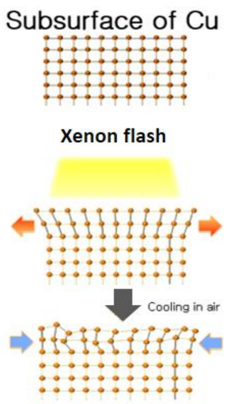
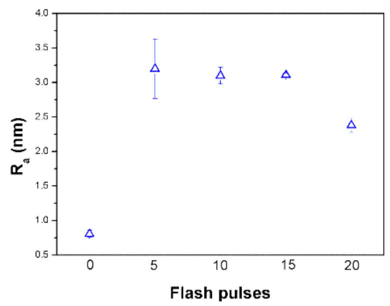
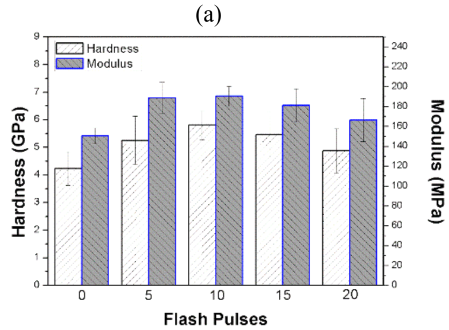


Fig. 1 illustration of the copper surface change subjected to pulsed flash light

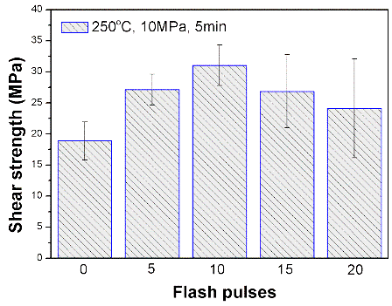


(a)

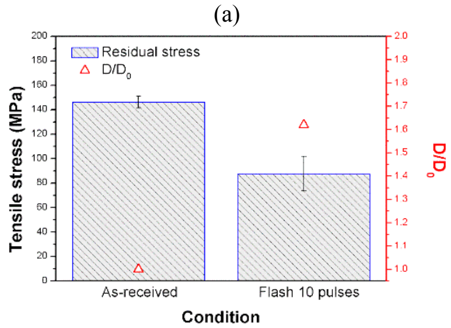


(b)

Fig. 2 The effect of flash pulses on surface properties of Cu films: (a) surface roughness, and (b) subsurface hardness (10 nm underneath the surface).



(a)



(b)

Fig. 3 Effect of flash pulses on (a) Shear strength of direct Cu joints, and (b) residual stresses

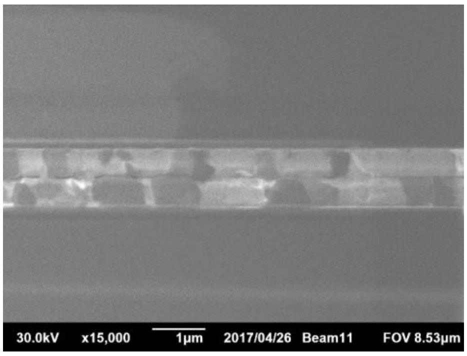


Fig. 4 Bonded interface subjected to thermal compression at 250°C under 10MPa for 5min

Conclusions

Xenon flash exposure which contributes to compressive stress component and thus reduced tensile stress gives rise to an increase in D/D_o. No observable oxidation allow subsequent bonding without using excess deoxidation treatment. The proposed method is efficient and effective to enhance direct Cu bonding.

Acknowledgements

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