Variable bond strength in low temperature directly bonded wafers

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***Abstract*—Using an improved Maszara test we have shown that post anneal bond strength of both radical activated wafers and plasma activated wafers varies by up to 50% across the entire wafer surface. We have shown that this is independent of the wafer pre-treatment, µm scale surface geometry and any discontinuities visible in the post anneal infra-red transmission image.**

I. Introduction And Background

VARIATION in final bond strengths of plasma activated wafers has long been tacitly acknowledged in wafer bonding literature[1]. We have been working to parameterize the AML[b] radical activated bonding device, or RAD ring[2]. However we initially found significant variation in bond strengths for identically processed bonded wafer pairs. Utilizing an optimized Maszara test[3] we were able to map the bond strength of a bonded wafer pair in 2 dimensions in order to determine the spatial extent and amplitude of any variation.

We were particularly interested as to what process parameters controlled this phenomenon and whether it was purely an artifact of the RAD ring or was also present in the more common plasma activation process.

Our test samples were 100 mm diameter, single crystal [1,0,0] native oxide silicon wafers. Pre activation they were prepared using Pirahna solution and de-ionised water to remove particle contamination and present a clean and uniform native oxide. The plasma activated wafers were treated using an oxygen ICP while the radical activated wafers were treated using AML's RAD ring. Wafers were contacted using the AML bonding unit tooling and annealed for 2 hours at 200°c

II. Results

Figures 1. and *2.* are illustrative of the bond strength maps obtained using our methodology and represent some two our most uniform samples.

We compared maps such as these with post anneal infra-red transmission images and maps of the wafer geometry in order to attempt to explain the variations. We also conducted a number of other studies comparing differing methods of mechanical contact and post activation conditions such as the atmospheric pressure and composition prior to contact.

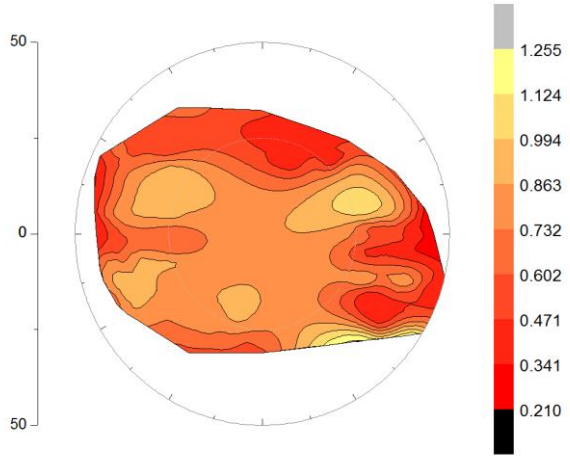

Fig. 1. Post anneal bond strength map of a RAD activated wafer. The wafers were activated for 4 minutes in an oxygen environment. The bond strength would be reported as approximately 0.8 ± 0.4 Jm^{-2}. The circular outline represents the edge of the wafer.

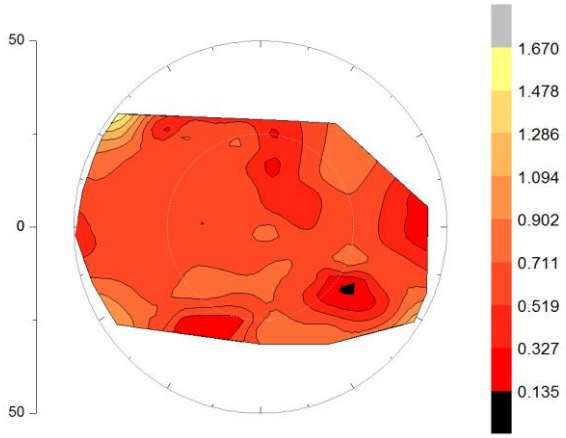

Fig. 2. Post anneal bond strength of a plasma activated wafer. The wafers were activated for 30 s in an oxygen environment. The bond strength would be reported as approximately 0.6 ± 0.2 Jm^{-2}.

We have found that both plasma and radical activated wafers exhibit significant bond strength variation across their interfaces. We have not found any correlation between pre-treatment, post treatment or activation process and the spatial extent and amplitude of the bond variability. This strongly indicates that wafer surface geometry is the primary source of this effect.

References

[1] M. Petzold et al, (1999), Microelectronics Reliability 39 1103-1108.
[2] T. Rogers et al,. (2008), ECS Transactions, 16 (8) 507-516
[3] V. Masteika et al, (pre-print) *The effect of atmospheric moisture on crack propagation of the interface between directly bonded silicon wafers*.