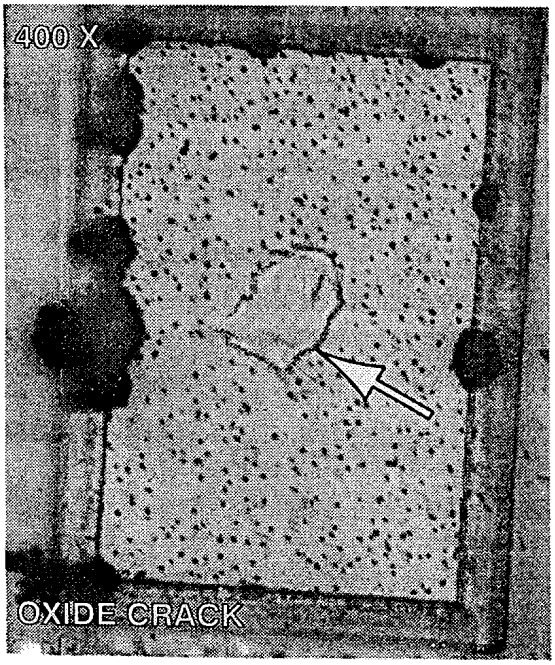
Tech Process Bulletin: Oxide Cracks

DEFINITION

Oxide cracks are very shallow chips that are broken from the thin oxide layer during wirebonding. The oxide resides between the bond pad metallization and the Silicon base. Oxide cracks are long term reliability defects that can only be detected by microscopic examination (200X) after etching the device to remove the wire bond and the bond pad. They differ from craters in depth (craters reach down into the Silicon base) and severity. An oxide crack photographed with an optical microscope at 400X follows. The crack is approximately 25 microns in diameter.



WHEN THEY OCCUR

Oxide cracks occur only in specific metallizations. A paper by T. Koch, HP shows that they occur in Al–Si bond pads without barrier metal. In this alloy system the Silicon is not soluble in the Aluminum matrix. During wafer processing the Silicon precipitates as nodules that bond to the underlying oxide layer. Wirebonding breaks the brittle Silicon nodule from the oxide, initiating a crack. The use of barrier layers, such as Titanium/ Tungsten (Ti/W), eliminates crack formation by stopping the bonding of the nodules to the oxide.[1]

WHY THEY ARE A RELIABILITY PROBLEM

Oxide cracks result in long term reliability failures, they can cause device failures out beyond the 20 year life expectancy. They are detected during thermal aging and cycling. During the life of a device metal migration occurs. Migration of gold from the ball bond, through the oxide crack, and into the Silicon chip will cause a failure. Oxide cracks do not represent as great a problem for Aluminum wedge bonded devices.

CUTTING WIRES, WIRE STRESS

Residual stress in the wire during etching can have a significant effect on the formation of oxide cracks. This is especially true in low loop packages where the wires have a higher stress level than normal loop height packages. During etch the aluminum bond pad under the gold ball is etched preferentially. This undercuts the ball and reduces the cross section between the ball and the oxide

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layer. As the cross section is reduced the residual stress increases. Eventually it can become large enough to initiate a crack. During long term aging the cross section under the bond remains intact. Residual stress does not increase as it does during etching. By cutting the wires at second bond before etching the residual stress effect is reduced. We are still able to detect oxide cracks attributable to bonding but eliminate those due to residual stress on the small cross section during etch.

The following experiment was designed to show the effect of cutting the wires at second bond before etching the device. Each combination of ultrasonic power and force was replicated, with the wires from some devices cut before etching and the wires from others not cut before etching. The experiment was run fully randomized with inspection for oxide cracks blinded (the inspector did not know the previous history of the device) to remove bias from the experiment. The most significant response was whether the wires were cut prior to etching. Devices that were not cut had an average of 25 more oxide cracks than devices where the wires were cut. Ultrasonic power and bond force had insignificant effects.

Power	Force	Wires Cut Before Etch	Wires Not Cut Before Etch	Shear Strength
65	60	1	47	49.1
	75	2	18	52.69
	90	0	11	56.51
85	60	0	16	62.48
	75	1	36	65.86
	90	4	22	72.69
105	60	2	13	67.02
	75	0	52	63.83
	90	0	20	63.94
MEAN (%)		**1.1 (0.5)**	**26.1 (12.3)**	

PROCESS PARAMETERS

The paper by Koch and our experiments at K&S have shown that although bond parameters play a role in the formation of oxide cracks their effect is small compared to the effect of barrier metal layers or metallization . The conclusion by HP was to fix the problem with a Ti / W barrier metal layer. The experiments conducted at K&S concluded that higher bond force, lower ultrasonic power and higher loop heights all had positive results on oxide cracks. We expect that a higher bond temperature, because it will allow lower ultrasonic power for equivalent ball shear strength will also be beneficial.

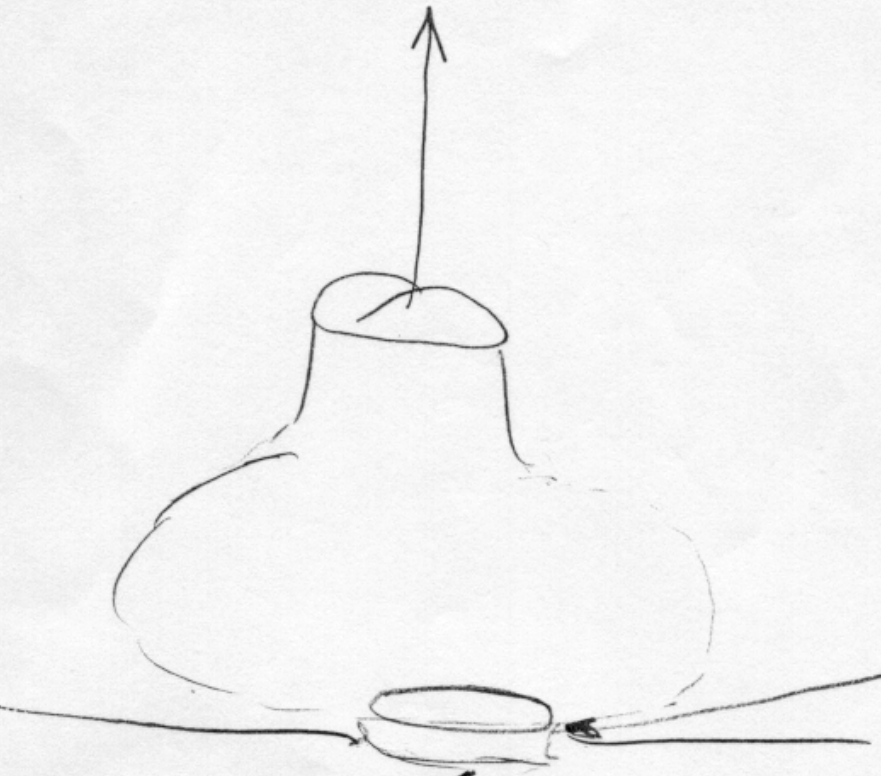
A low aspect ratio for the bonded ball will also have a beneficial effect on oxide cracks. "Pancake" or "Nailhead" balls, with a large deformation cross section prior to initiation of ultrasonic power will have fewer oxide cracks than high, lightly deformed balls.

CONCLUSIONS

- The best way to resolve the problem requires the wafer fab to change the metallization.
- **IT IS MANDATORY TO CUT THE WIRES AT SECOND BOND BEFORE ETCH.**
- Bond parameters have a small effect. Lower ultrasonic power will have less cracks.
- A large, deformed ball cross section, prior to turning on ultrasonics will have less cracks.

[1] T. Koch, et. al. "A Bond Failure Mechanism", 1968 IEEE/IRPS, June 86, pg. 55–60

Residual Stress in Wire



ACID EATS AWAY CROSS SECTION of BOND FASTER than it EATS the ball.

High STRESS from SMALL CROSS SECTION CAUSES high Number of SMALLER OXIDE CRACKS.