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Effect of Applied Load in the Nanoindentation of Gold Ball Bonds

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We have analyzed the effects of nanoindentation at applied loads of 10 mN and 20 mN on the micromechanical properties of gold (Au) ball bonds with and without cracks. The depth profile and the plastic zone size for each indentation were determined to identify the substrate effect and its relationship with the observed micromechanical properties. The substrate effect occurred for indentations at 20 mN applied load, but did not occur near cracks for either 10 mN or 20 mN loads. Because of the substrate effect and the presence of cracks, the average hardness or yield strength decreased for indentations on Au ball bonds. Therefore, to minimize the substrate effect, an applied load of 10 mN is best for characterizing Au ball bonds.

Key words: Nanoindentation, Au ball bond, bonding ability, applied load, substrate effect

INTRODUCTION

Because of its technological maturity and cost effectiveness, wire bonding is still the most preferred interconnection technique for electronics packaging despite the introduction of other methods such as flip-chip attachment and tape-automated bonding.[1–5] To decrease the form factor in shrinking electronics packages, the bond pad pitch and the ball bond size need to become ever smaller. Consequently, this will introduce measurement challenges in evaluating the bondability and reliability of ball bonds.

Conventional tests for evaluating the quality of ball bonds such as wire pulling and ball shearing have also become problematic.[2,4–11] Sundaraman et al.[6] found that stresses induced in the silicon substrate under the bond pad are sensitive to the angle of the wire pull; the lowest stresses are produced by pulls normal to the bond pad surface. The stress distribution is also affected by the angle of the pull, where higher angles produce higher stress values. The elongation of the wire also affects wire pull tests.[7,8] Wires with a larger percentage elongation have larger bond pull strengths because of the increase in the final loop height at wire breakage. The bond pull strength is also a function of the wire loop geometry.[8] It has been observed that, when the difference in height between the first and second bonds decreases, the bond pull strength decreases. Harman[2] found that the position of the hook and the pull angle have a significant effect on the wire pull results, owing to the different distribution of forces on the wire bond. The bond pad also has a tendency to peel off when the position of the hook is moved close to the wedge bond.[2,7] In addition, the variability of the results for wire pulls increases and the average value of the bond pull force becomes lower, when the hook is placed near the wedge bond.[2] The pull strength of the wire bond also depends on the character of the bond. During the wire pull test the ball bond remains untested because the weak area is located at the wire and not

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