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The Effect of Sn Orientation on Intermetallic Compound Growth in Idealized Sn-Cu-Ag Interconnects

CHRIS KINNEY,[1,3] XIORANNY LINARES,[1] KYU-OH LEE,[2] and J.W. MORRIS JR.[1]

1.—Department of Materials Science and Engineering, University of California, Berkeley, CA 94720, USA. 2.—Intel Corporation, Chandler, AZ 85226, USA. 3.—e-mail: kinney@berkeley.edu

The work reported here explores the influence of crystal orientation on the growth of the interfacial intermetallic layer during electromigration in Cu||Sn||Cu solder joints. The samples were thin, planar Sn-Ag-Cu (SAC) solder layers between Cu bars subject to a uniaxial current. Electron backscatter diffraction (EBSD) was used to characterize the microstructure before and after testing. The most useful representation of the EBSD data identifies the Sn grain orientation by the angle between the Sn *c*-axis and the current direction. The tested samples included single-crystal joints with *c*-axis nearly parallel to the current ("green" samples) and with *c*-axis perpendicular to the current ("red" samples). At current density of 10^4 A/cm^2 (steady-state temperature of ~150°C), an intermetallic layer grew at an observable rate in the "green" samples, but not in the "red" ones. A current density of 1.15×10^4 A/cm^2 (temperature ~160°C) led to measurable intermetallic growth in both samples. The growth fronts were nearly planar and the growth rates constant (after an initial incubation period); the growth rates in the "green" samples were about 10× those in the "red" samples. The Cu concentrations were constant within the joints, showing that the intermetallic growth is dominated by the electromigration flux. The measured growth rates and literature values for the diffusion of Cu in Sn were used to extract values for the effective charge, z^*, that governs the electromigration of Cu. The calculated value of z^* is significantly larger for current perpendicular to the *c*-axis than along it.

Key words: Solder, electromigration, orientation, EBSD, effective charge

INTRODUCTION

The emergence of Sn-rich and SAC solders as leading candidates to replace leaded solders has led to a considerable body of work on their microstructure and properties. Much of this work has focused on the electromigration behavior of these solders; electromigration is a directional diffusion phenomenon caused by an imposed current.[1–5] The imposed current creates a net migration of ions, including copper, due to an "electron wind," and can accelerate the growth of various intermetallic compounds, most notably Cu_6Sn_5.[6,7] The driving force of electromigration, the effective charge or z^*, is a dimensionless measure of the electrostatic and electron wind forces on an ion, of which the latter is dominant.[8–10] Sn, which accounts for the bulk of the interconnect, has a tetragonal structure; therefore some of the properties of β-Sn differ depending on the orientation of the [001] *c*-axis,[11–13] including the diffusivity of Cu.[9,14,15] As solder interconnects are made smaller, they are more likely to be composed of a single grain of Sn. Given anisotropy, if the single-crystalline Sn has an unfavorable orientation, electromigration damage may occur at an accelerated rate, leading to premature failure. This study was undertaken to examine the electromigration behavior of single-crystalline Sn in planar Cu||Sn||Cu interconnects to explore the effect of

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