Journal of ELECTRONIC MATERIALS, Vol. 42, No. 12, 2013
DOI: 10.1007/s11664-013-2711-z

Optimized Cu-Sn Wafer-Level Bonding Using Intermetallic Phase Characterization

THI-THUY LUU,[1,2] ANI DUAN,[1] KNUT E. AASMUNDTVEIT,[1] and NILS HOIVIK[1]

1.—IMST-HiVe, Department of Micro and Nano Systems Technology, Vestfold University College, Raveien 197, Borre, Norway. 2.—e-mail: thi.luu@hive.no

The objective of this study is to optimize the Cu/Sn solid–liquid interdiffusion process for wafer-level bonding applications. To optimize the temperature profile of the bonding process, the formation of intermetallic compounds (IMCs) which takes place during the bonding process needs to be well understood and characterized. In this study, a simulation model for the development of IMCs and the unreacted remaining Sn thickness as a function of the bonding temperature profile was developed. With this accurate simulation model, we are able to predict the parameters which are critical for bonding process optimization. The initial characterization focuses on a kinetics model of the Cu_3Sn thickness growth and the amount of Sn thickness that reacts with Cu to form IMCs. As-plated Cu/Sn samples were annealed using different temperatures (150°C to 300°C) and durations (0 min to 320 min). The kinetics model is then extracted from the measured thickness of IMCs of the annealed samples.

Key words: Intermetallic formation, SLID bonding, Cu/Sn bonding, Pb-free solder

INTRODUCTION

Cu/Sn solid–liquid interdiffusion (SLID) wafer-level bonding is an attractive assembly technique for microelectromechanical systems (MEMS) encapsulation and interconnection due to its low cost, high temperature stability, high bond strength, and hermeticity.[1,2] This bonding technique has been demonstrated for MEMS encapsulation, high-density interconnection, and simultaneous MEMS encapsulation and interconnection,[3–5] but an optimized bonding process taking into account the aspects of wafer-level bonding has not yet been established. A typical bonding temperature profile and development of intermetallic compounds (IMCs) during the bonding process are described in Fig. 1.

As any SLID bonding technique, Cu/Sn SLID bonding is based on rapid formation of IMCs between two metal components: one low-melting component (Sn) and one high-melting component (Cu). The bonding is typically carried out at moderate temperatures between 250°C and 300°C,[3,6] which is above the melting point of Sn. When the Sn melts, the IMCs solidify isothermally. For correctly designed layer thicknesses, the resulting bond-line will only consist of Cu and the intermetallic phases (Cu_6Sn_5 and Cu_3Sn), with melting temperatures of 415°C and 676°C, respectively. The overall goal of the wafer-level bonding process is to achieve a $Cu/Cu_3Sn/Cu$ final bond-line, which is thermodynamically stable.

An important aspect of Cu/Sn SLID wafer-level bonding is the formation of Cu_6Sn_5, the geometry of which has been shown to influence void formation in the bond-line. Voids would impact the bond strength and subsequently the hermeticity and overall reliability. The formation of Cu_6Sn_5 has been observed at room temperature.[7,8] During a wafer-level bonding process where the temperature is increased following a defined profile, the Cu_6Sn_5 grains will grow. If Cu_6Sn_5 reaches the Sn surface while the temperature is still below the melting point of Sn, the Cu_6Sn_5 grains will act as spacers, and voids will later form.[7,9]

(Received January 10, 2013; accepted July 23, 2013; published online August 30, 2013)