Microelectronic Engineering 113 (2014) 123–129

Contents lists available at ScienceDirect

Microelectronic Engineering

journal homepage: www.elsevier.com/locate/mee

Reflow processes in micro-bumps studied by synchrotron X-ray projection nanotomography

J. Bertheau [a,b,*], P. Bleuet [b,1], F. Hodaj [c,2], P. Cloetens [d,3], N. Martin [a,b,1], J. Charbonnier [b,4], N. Hotellier [a,5]

[a] ST Microelectronics, Crolles, France
[b] CEA, LETI, Minatec Campus, 38054 Grenoble, France
[c] SIMAP, Grenobe INP-UJF, Grenoble, France
[d] European Synchrotron Radiation Facility, Grenoble, France

ARTICLE INFO

Article history:
Received 3 May 2013
Accepted 19 July 2013
Available online 8 August 2013

Keywords:
Micro-bumps
Nanotomography
SnAgCu solder
Interfacial reaction
Intermetallics

ABSTRACT

In microelectronics, the trend to lower the device dimensions forces to adapt the characterization tools. Here, we report a 3D characterization study of SnAgCu alloys in micro-bumps (μ-bumps) used for flip chip packaging, with bumps diameters as small as 25 μm. Such a study of thick, bulk samples requires penetrating radiation and consequently hard X-rays provided by synchrotron radiation have been used in a specific tomographic scheme. The intermetallics compounds (IMCs) growing at the copper/SnAgCu alloy interface are revealed at different reflow conditions by using holography coupled to X-ray projection nanotomography. This characterization method for such a system as μ-bumps allows here to render and measure the volume of IMC depending of the heat treatment conditions. At the same time, the influence of the bump size on the μ-bumps microstructure was studied by using copper pillars of different diameter.

© 2013 Published by Elsevier B.V.

1. Introduction

To face the growing industrial demand of downscaling electronic devices, die to die or die to wafer interconnects (3D integration) are now considered as majors alternatives integration strategies and still need to further decrease in size. In this framework, molten interconnects based on micro-bumps of 25 μm diameter become now widely used in electronic packaging [1,2]. This integration process consists in an assembly of interconnection extremities through eutectic bonding of a tin-based solder joint (Fig. 1).

For stability purpose, the copper and SnAgCu solder alloy stacking undergo a bumping process before this flip chip achievement. The bumping process is achieved through a specific heat treatment (or reflow process). During this first reflow step, interfacial intermetallic compounds (IMCs) grow at the copper/Sn-3.5 wt%Ag-0.7 wt%Cu (SAC 357) alloy interface [3,4] leading to the formation of reaction layers. Given the rapid growth kinetics of the reaction layer formed during the reflow process, these compounds can be detrimental to the interconnection reliability properties. Moreover, it has been proved that the first reflow has drastic impact on the whole IMC morphology evolution during the following potential thermal constrains [5]. Thus the conditions of this first reflow and the induced IMC's morphology are decisive for the whole interconnection reliability.

The manufacturing of these interconnects is so challenging that nano-characterization techniques must be used to control the bumps all along manufacturing process.

Current morphological nanocharacterization tools usually used include optical microscopy [1,2], Scanning Electron Microscope (SEM) coupled with Energy Dispersive X-ray (EDX) spectroscopy [3,4], Electron Backscattered Diffraction (EBSD) [6,7] and Transmission Electron Microscopy (TEM) [8,9]. However, these techniques are not relevant for copper pillars because they are either destructive, too local, or they are only surface-sensitive techniques. Moreover, these techniques do not allow 3D information of the solder bulk or the interfacial system.

μ-Bumps for flip chip packaging are made of high Z materials, among which one can find Ni, Sn, Ag and Cu. Recovering the 3D inner distribution of interconnects is then possible only by using a radiation having a sufficient penetration depth: electrons cannot be used because their mean-free path reaches a micrometer at best. On the other hand, hard X-rays have an attenuation

* Corresponding author at: CEA, LETI, Minatec Campus, 38054 Grenoble, France. Tel.: +33 (0) 4 38 78 07 76.

E-mail addresses: Julien.Bertheau@cea.fr (J. Bertheau), Pierre.bleuet@cea.fr (P. Bleuet), fiqiri.hodaj@simap.grenoble-inp.fr (F. Hodaj), cloetens@esrf.eu (P. Cloetens), Nicolas.martin@cea.fr (N. Martin), Jean.charbonnier@cea.fr (J. Charbonnier), Nicolas.hotellier@st.com (N. Hotellier).

[1] Tel.: +33 (0) 4 38 78 08 98 64.
[2] Tel.: +33 (0) 4 76 82 65 15.
[3] Tel.: +33 (0) 4 76 88 26 50.
[4] Tel.: +33 (0) 4 38 78 59 56.
[5] Tel.: +33 (0) 4 38 92 36 23.

0167-9317/$ - see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.mee.2013.07.013

Fig. 1. Micro-bump at initial state – after SAC deposition (a); after bumping reflow (b); after assembly performed by eutectic bonding (c).

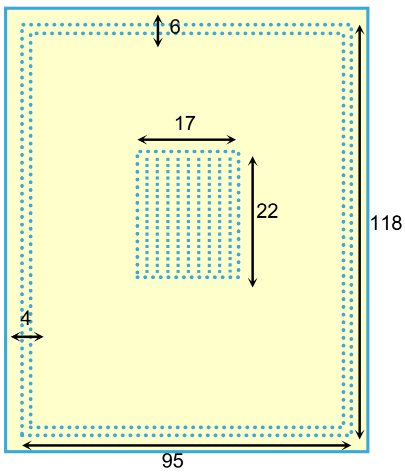

Fig. 2. Design layout schematic of chip with bumps location and account.

length in metals that is sufficient to explore thick samples; making X-ray imaging ideal for the investigation of 3D interconnects. To date, there are however no commercial device that can provide hard X-rays, *i.e.* with energies higher than 20 keV, together with a sub-100 nm resolution in a reasonable scanning time. In this context, it turns out that the only probes able to perform high resolution 3D imaging of µ-bumps are the modern end-stations based on 3rd generation synchrotron radiation sources [10].

In this framework, interconnections will be studied thanks to synchrotron radiation. The following paragraph deals with sample features and sample preparation. Then the X-ray tomography technique is presented and 3D results are shown together with calculated IMC volume. Finally, the role of the heat treatment and the micro-bump size effect on IMC thickness and morphology is presented and discussed.

2. Materials and methods

The design layout on wafer consists in 1090 chips of 4.7 mm × 5.9 mm. Each chip contains 1416 micro-bump and 374 of them are located in a central matrix (Fig. 2). The pitch between micro-bumps is 50 µm (Fig. 3a).

Samples were processed from 200 mm bulk silicon wafers. Pure silicon was heated at 1050 °C in order to form a 500 nm thick SiO_2 layer. A 100 nm Ti layer and a 200 nm Cu seed layer were deposited using Physical Vapor Deposition (PVD). These layers were respectively used as an adhesion layer, and as an initiation layer for following Electro Chemical Deposition (ECD) process. Then, the photo-resist is applied, exposed and developed to create the openings inside subjacent seed layer. The conferred pattern shows in this way an open surface of about 9,1cm^2 per wafer. Afterwards 12 µm or 30 µm of copper is electroplated followed by 10 µm or 25 µm of SnAgCu (SAC 357) alloy. Deposition currents are 180 mA.cm^{-2} for copper and 120 mA.cm^{-2} for SAC alloy. The photolithographic resin is stripped by wet etching before that the Ti/Cu layer is etched through plasma cleaner. Finally, the reflow process is performed in order to get the hemispherical shape of the µ-bump (Fig. 3a and b).

Through this fabrication process, two classes of samples with different diameters (Ø) and heights (h) of deposited materials were actually prepared, as described in the Table 1.

Three specific heat treatments have been applied for each class of sample: (i) 1 reflow process, (ii) 5 reflow process performed in a conveyor furnace and (iii) isothermal holding performed in a 2920 TA Instruments Differential Scanning Calorimetry (DSC) device.

The corresponding temperature–time profiles for each heat treatment are shown in Fig. 4. Note that a great difference exists between the heating and cooling rates used in conveyor furnace and in DSC device (see Table 2).

After the reflow step or DSC treatment, samples are finally micro-splited using SELA MC-600i equipment, so that only one

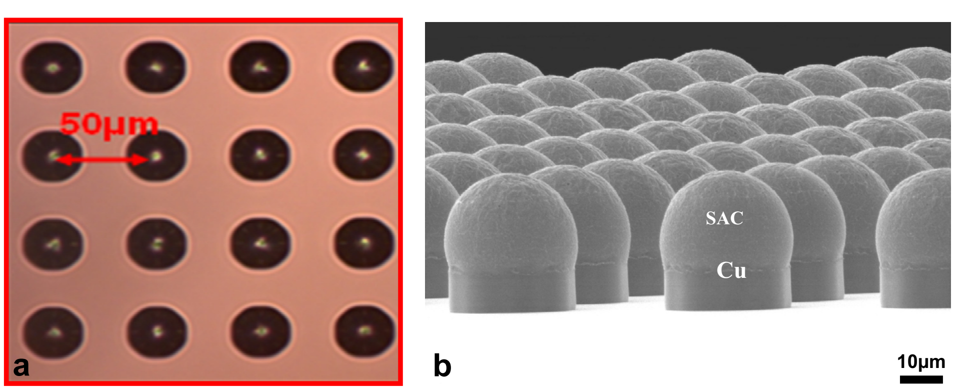

Fig. 3. Optical microscope observation of a micro-bumps matrix (a), micro-bumps SEM inspection (b).

Download English Version:

https://daneshyari.com/en/article/539820

Download Persian Version:

https://daneshyari.com/article/539820

Daneshyari.com