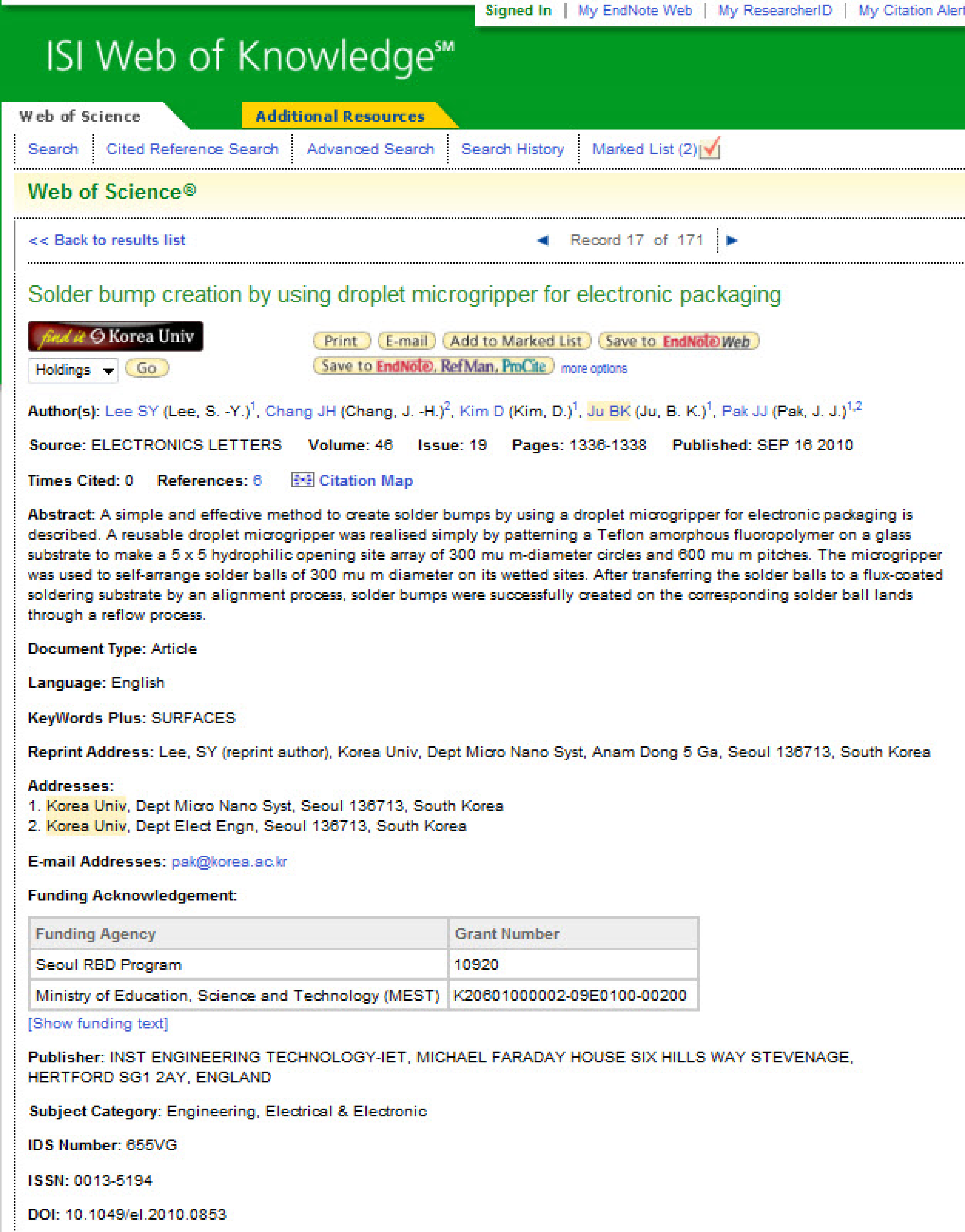

Solder bump creation by using droplet microgripper for electronic packaging

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Source: ELECTRONICS LETTERS **Volume:** 46 **Issue:** 19 **Pages:** 1336-1338 **Published:** SEP 16 2010

Times Cited: 0 **References:** 6 Citation Map

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Document Type: Article

Language: English

KeyWords Plus: SURFACES

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Funding Acknowledgement:

Funding Agency	Grant Number
Seoul RBD Program	10920
Ministry of Education, Science and Technology (MEST)	K20601000002-09E0100-00200

[Show funding text]

Publisher: INST ENGINEERING TECHNOLOGY-IET, MICHAEL FARADAY HOUSE SIX HILLS WAY STEVENAGE, HERTFORD SG1 2AY, ENGLAND

Subject Category: Engineering, Electrical & Electronic

IDS Number: 655VG

ISSN: 0013-5194

DOI: 10.1049/el.2010.0853

Solder bump creation by using droplet microgripper for electronic packaging

S.-Y. Lee, J.-H. Chang, D. Kim, B.K. Ju and J.J. Pak

A simple and effective method to create solder bumps by using a droplet microgripper for electronic packaging is described. A reusable droplet microgripper was realised simply by patterning a Teflon amorphous fluoropolymer on a glass substrate to make a 5 × 5 hydrophilic opening site array of 300 µm-diameter circles and 600 µm pitches. The microgripper was used to self-arrange solder balls of 300 µm diameter on its wetted sites. After transferring the solder balls to a flux-coated soldering substrate by an alignment process, solder bumps were successfully created on the corresponding solder ball lands through a reflow process.

Introduction: Solder bump creation is a key technical element in flip chip packaging to interconnect semiconductor devices, such as IC chips and microelectromechanical systems, to external circuitry with solder bumps on the chip pads. Among several solder bumping methods, solder ball placement has been widely used because of its good reliability, alloy flexibility, bump height uniformity, and extendability to 300 mm wafers [1, 2]. However, the conventional method has required vacuum suction tools with an arrangement plate for solder ball placement. We recently reported a simple method of self-arranging solder balls by using the surface wettability difference between a hydrophobic passivation layer and hydrophilic solder ball lands [3]. However, it is not yet applicable to the current packaging industry, because it requires the use of a hydrophobic material as the passivation layer or selective hydrophobic surface treatment except on the solder ball lands. This Letter presents a modified method of solder ball placement by using a droplet microgripper for self-arrangement of solder balls. This microgripper is cheap and simple to fabricate and it also allows arranging solder balls on soldering substrates repeatedly for mass production without the vacuum suction tools that are required in the conventional method.

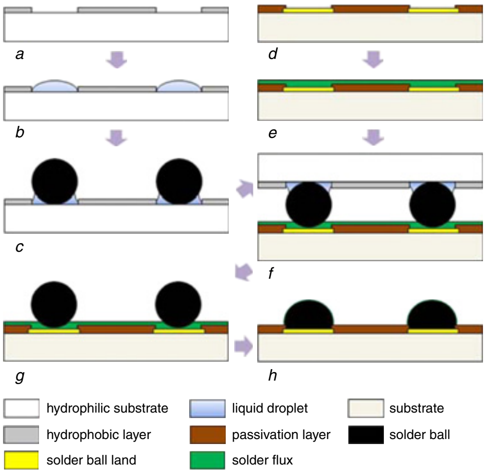

Fig. 1 *Schematic process steps for solder bump creation by using droplet microgripper*

a Patterning of hydrophobic layer on hydrophilic substrate
b Formation of liquid droplets on hydrophilic opening sites
c Self-arrangement of solder balls by droplets
d Soldering substrate
e Flux coating on surface
f Alignment of microgripper and soldering substrate
g Release of the microgripper
h Reflow

Design of experiments: Fig. 1 shows schematic process steps for solder bump creation by using a droplet microgripper. The droplet microgripper can be realised simply by patterning a hydrophobic layer on a hydrophilic substrate (Fig. 1*a*). A liquid droplet is held on each hydrophilic opening site by the attractive force between the solid and the liquid after the substrate is dipped into a liquid bath (Fig. 1*b*). Then, each droplet can catch and hold an encountered solder ball (Fig. 1*c*). After flux coating on a soldering substrate (Figs. 1*d* and *e*), the droplet microgripper, which is holding the solder balls, is aligned and approached to the soldering substrate (Fig. 1*f*). When the solder balls held by the droplet microgripper contact the flux of the soldering substrate, the solder balls are transferred to the soldering substrate because the adhesive force of the flux is stronger than the liquid droplet (Fig. 1*g*). Finally, solder bumps are created on the solder ball lands after a reflow process (Fig. 1*h*).

Surface wettability is a key parameter to make this droplet microgripper work properly. The work of adhesion (W_{SL}) for the solid–liquid interface depends on the liquid surface tension (γ_L) and the contact angle (θ_C) as given by the following Young-Dupré equation [4]:

$$W_{SL} = \gamma_L(1 + \cos\theta_C)$$

For the droplet microgripper, glass and Teflon are suitable for making the hydrophilic substrate and the hydrophobic layer, respectively. For the liquid droplet, water is good because of its high surface tension of 72.8 $\mathrm{mJ/m^2}$ [5]. The measured water contact angles on the glass and Teflon surfaces were 40° and 116°, respectively [3, 6]. From these water contact angles, the work of adhesion values for the glass–water and the Teflon–water interfaces can be obtained as 129 and 40.9 $\mathrm{mJ/m^2}$, respectively. This means that the attractive force at the glass–water interface is 3.2-times higher than that at the Teflon–water interface.

Experimental results: To make the droplet microgripper, 3.3 µm-thick positive photoresist (AZ1512, Clariant) was spin-coated on a glass substrate at 500 rpm for 30 s and patterned to make a 5 × 5 array of 300 µm-diameter circles with 600 µm pitches. 0.6 wt% Teflon AF (amorphous fluoropolymer, 601S2-100-6, DuPont) diluted in a fully-fluorinated solvent (FC-40, 3M) was spin-coated on the patterned surface at 1000 rpm for 30 s and baked at 165°C for 2 min. The resulting Teflon thickness was about 30 nm. After removing the photoresist by lift-off process in acetone and rinsing with methanol and deionised water consecutively, the droplet microgripper was completed with hydrophilic glass opening sites. The fabricated microgripper was dipped into a water bath to form a water droplet on each glass opening site. Fig. 2*a* shows an optical image of 0.1 M methylene blue droplets held on the transparent droplet microgripper, in which methylene blue was used just to aid visualisation. The microgripper was tilted at about 10°, and 300 µm diameter solder balls (Sn3.0Ag0.5Cu, Duksan Hi-Metal) were rolled down from the upper side of the microgripper. Then, the solder balls were self-arranged successfully, resulting in a 5 × 5 solder ball array with 600 µm pitches corresponding to the opening sites on the microgripper (Fig. 2*b*).

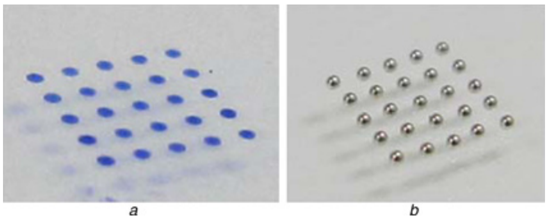

Fig. 2 *Optical images of fabricated droplet microgripper*

a 0.1 M methylene blue droplets formed on hydrophilic glass opening sites
b Self-arranged solder balls by water droplets

To make the soldering substrate, 50 nm Ti as an adhesion layer and 200 nm Au were deposited on a silicon substrate. Polyimide (Durimide 7510, Fujifilm), which is a negative photoresist, was spin-coated at 5000 rpm for 30 s and patterned as the passivation layer with opening Au solder ball lands. At this time, the same photo-mask for the positive photoresist was used again, and hence the polyimide pattern was the same as the hydrophobic layer on the microgripper. Liquid rosin flux (BF-505, Bukwang Chemical) was coated on the surface of the fabricated soldering substrate.

To transfer solder balls, the flux-coated substrate was aligned with the microgripper containing solder balls by using an optical microscope system. After attaching and removing the microgripper, the solder balls were successfully transferred to the soldering substrate (Fig. 3*a*). It was concluded that this microgripper is reusable more than 10 times because the solder ball placement was performed 10 times successfully with one of these microgrippers. The gap between the droplet microgripper and the flux-coated substrate may be as high as the solder ball diameter and this distance would prevent the flux from contaminating the microgripper. It also seems that the transferred water with the solder balls evaporates quickly without any residue. Finally, the solder balls were reflowed on a hot plate, in which the temperature was maintained above the solder alloy melting point of 217°C for 1 min with a peak of 245°C, and they were successfully changed to solder bumps on the Au solder ball lands (Fig. 3*b*).

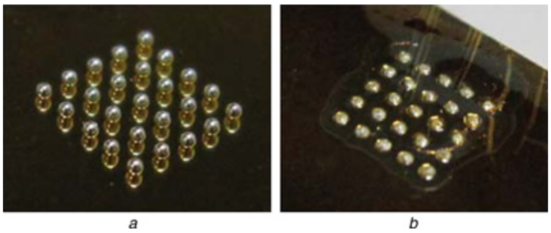

Fig. 3 *Optical images*

a Transferred solder balls from droplet microgripper to soldering substrate
b Created solder bumps on substrate after reflow process

Conclusions: A simple and effective method to create solder bumps is described. The droplet microgripper was fabricated simply by patterning Teflon as the hydrophobic layer on the hydrophilic glass substrate to make a 5 × 5 array of 300 μm-diameter circles with 600 μm pitches. Each solder ball of 300 μm diameter was successfully caught and held on a hydrophilic opening site of this microgripper by the self-arrangement method. These solder balls were transferred to the flux-coated soldering substrate simply by making the solder balls to contact with this substrate, owing to the adhesive force difference. After the reflow process, a 5 × 5 solder bump array was successfully created on the solder ball lands. This method of creating solder bumps by using a droplet microgripper may be applicable to the current electronic packaging industry in a more efficient way.

Acknowledgments: This work was supported by Seoul R&BD Program (No. 10920) and by the National Research Foundation of Korea (NRF) through a grant provided by the Ministry of Education, Science and Technology (MEST) in 2009 (No. K20601000002-09E0100-00200). S.-Y. Lee and J.-H. Chang are co-first authors, and contributed equally to this work.

30 March 2010
doi: 10.1049/el.2010.0853
One or more of the Figures in this Letter are available in colour online.

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