Surface Patterning of Photocurable Resin Using
Micro-Moses Effect

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This paper is a review of our recent work on a micro-manipulation of the shape of a
liquid surface by means of modulated magnetic fields[1]. A microscopic field
modulation is achieved by insertion of a field modulator in a homogeneous magnetic
field. The surface of a feeble magnetic liquid placed on the modulator is modulated
according to the modulation of the field produced over the modulator surface
(micro-Moses effect). Upon solidification of the liquid by means of
photopolymerization, for example, the surface modulation is fixed. In this paper, an
application of this technique to the contact-hole formation on the electrode bumps of IC
(integrated circuit) chips is presented.

Keyword: integrated circuit, contact hole, micro-Moses effect, photo curable
resin, modulated magnetic field

1. Introduction

Recently, considerable attention has been
paid to the magnetic effects on feeble
magnetic materials including paramagnetic
and diamagnetic materials from a viewpoint
not only of basis studies but also of industrial
applications [2]. Under a magnetic field of 10
T or more, feeble magnetic materials (most
organic and inorganic materials belong to this
category) behave like ferromagnetic materials
(iron etc.) that are put close to a permanent
magnet. Moses effect [3,4] is a typical
example. Clear magnetic effects on feeble
magnetic materials can be also observed even
with a permanent magnet if a well-designed
experimental setup is devised [5].

In this report, we present contact-hole
formation of photo-curable resin on the
electric bumps of chips. Due to the demands
of high-density packaging for IC (integrated
circuit), face-to-face connection of two chips
or a direct connection of a chip to a circuit
board is required, whereby insulating
materials (underfill) should fill the space
between bumps in order to protect the bumps
from moisture and stress. In the method we
present here, the insulating resin is precoated
and the resin covering the bumps is removed
using micro-Moses effect [6] to form a hole
on each bump. This is necessary to ensure the
electric contact of bumps when two chips are
connected face-to-face.

2. Experimental

2.1. Materials

A test element group (TEG) with Au/NiP bumps
was heat-treated at 450°C for 1h to convert the NiP
to be ferromagnetic. A UV curable epoxy (resin
precursor) of viscosity of 5 mPa s was coated on a
thus-treated TEG, which was then subjected to a
magnetic field of 0.5 T whose direction is
perpendicular to the TEG surface. The UV curable
epoxy covering the bumps was repelled from over the bumps due to micro-Moses effect to form a hole on each bump. Because the magnetic flux density is stronger over the bumps, the epoxy covering bumps receive a force that repels the epoxy from over the bumps. Then, the coated precursor was subjected to a UV (365nm) irradiation (6000mJ/cm²) for precuring. Another TEG was prepared by the same procedure. These two TEGs were then connected by the ultrasonic junction process.

3. Results and Discussion

A schematic diagram of the removal of the resin precursor from the surface of bumps is shown in Figure 1. When the magnetic field is applied vertically, the magnetic flux is concentrated over the Au/NiP bumps because the bumps were thermally treated to be ferromagnetic. As a result, the magnetic flux density becomes higher on the bumps. Then, resin precursor, which is diamagnetic, is repelled from the bump surface to form a hole.

Figure 1. Schematic diagram showing the removal of the resin precursor by micro-Moses effect. Initially the resin precursor covers the electric bumps (left). Upon application of a vertical magnetic field, the resin is repelled and removed from the surface of the bumps (right).

The height to which the resin precursor is removed is expressed by the following equation:

$$\eta = -\chi(B_1^2 - B_0^2)/(2\mu_0 \rho \gamma)$$  (1)

where $\chi(<0)$ is the magnetic susceptibility of the resin precursor, $\mu_0$ is the magnetic permeability of vacuum, and $B_1$ and $B_0$ are the magnetic flux densities on the bump and the remaining region, respectively. Using typical values of $\chi = -10^4$, $B_1 = 0.5$ T, $B_0 = 0.4$ T, and $\rho = 10^3$ kg/m³, we obtain that $h$ is ca. 4μm. This value is much larger than the thickness (ca. 0.5μm) of the resin covering the bumps.

Wettability of the resin with respect to the bump surface is an important factor [7]. If the wettability is very good, a remaining amount of the resin could stick on the surface even the most amount of the resin is removed by micro-Moses effect.

Figure 2 shows the depth profile of holes formed on the bumps. The hole depth is ca. 0.4μm.

Figure 2. Experimental result for the depth profile of the holes formed on the bumps corresponding to Fig. 1.

4. Conclusion

It was demonstrated that micro-Moses effect is a useful means to manipulate the liquid surface microscopically. Removal of resin precursor from the electric bumps of IC chips has been successfully carried out using micro-Moses effect. The technique used here might be useful in general to manipulate a liquid surface microscopically.

References