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Degradation of moulding compounds during highly accelerated stress tests – A simple approach to study adhesion by performing button shear tests

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ABSTRACT

High temperature storage can degrade moulding compounds for chip encapsulation to such an extent that the adhesion to surfaces like copper (lead frames) or polyimide (chip coating) decreases drastically causing delamination. Also during normal operation of electronic components heat is generated locally (bond wire or chip surface) degrading the moulding compound and reducing the adhesion which in extreme cases can destroy the metallisation or the bond wires.

1. Introduction

The adhesion between different materials on different interfaces is the base of high package reliability. The most important interfaces are moulding compound – chip surface and moulding compound – lead frame. The properties of these interfaces are influenced by various materials and process parameters for chip surface and bond pad conditioning.

Standard tests as thermal cycling do not aim at quantifying adhesion but predict, in the case of adhesion loss, delamination.

An evaluation method based on a suitable test vehicle which enables the study of decoupled influence parameters for adhesion is missing. To characterise the adhesion characteristics of these interfaces a shear-test method of moulding compound buttons on different base materials was developed. The moulding compound buttons ($2 \times 2\,mm^2$) are applied on base material stripes with a dimension of $100 \times 20\,mm^2$ (e.g. from copper or silicon). The test setup and the typical test vehicles are shown in Fig. 1.

The authors are aware that different setups for moulded buttons have already been proposed. Durix [1] used triangle shaped buttons for shear tests to observe stable interface crack propagation. Also cylindrical samples (tapered) are proposed to investigate adhesive strength [2].

The MMC (Mixed Mode Chisel) [3] method used for investigating the silicon-moulding compound interface allows determination of the adhesion of mode I (tension) and mode II (shear). A well prepared initial interface crack is necessary to obtain reproducible results.

In our investigation it turned out that shearing $2 \times 2\,mm^2$ buttons no pre-crack is needed and also stable crack propagation is observed. The main advantage of the selected geometry is the observability of the crack by mean of a uniDAC (universal deformation analysis by correlation).

The aim was to have a simple setup and to have the possibility to mould buttons on different surfaces also in order to study process influences. Adhesion of moulding compounds on polyimides was of major interest because for power electronics it is often used as a buffer material between chip and moulding compound allowing higher displacement without breaking the interface.

Shear test results are expected to be highly dependent on the surface properties as shown in Fig. 2. Rough well wetted surfaces should have the best adhesion. Voids in the interface (surface–moulding compound) should lead to low adhesion.

Performing shear tests with a constant shear speed (standard) of 250 μm/s force–displacement curve can be recorded.

In Fig. 3 typical force–displacement plots are shown to investigate combinations of moulding button–copper lead frames or polyimide on silicon.

Plotting the measured maximum shear force for different material combinations is shown in Fig. 4. Moulding buttons have been assembled on copper surfaces, copper surfaces with adhesion promoter and nickel surfaces. Apart from the nickel surface (all selected moulding compounds C, D, E, F and G do not show very high adhesion) the assumption that an adhesion promoter helps in any case is not true. For moulding compound B pure copper surface gives much better adhesion than with the adhesion promoter. Moulding compounds D and E show the expected adhesion benefit with an adhesion promoter.

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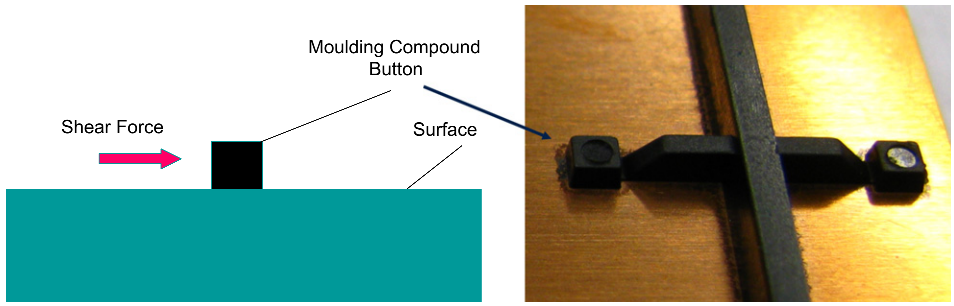

Fig. 1. Experimental setup for enabling shear tests. The shear results are highly adhesion dependent.

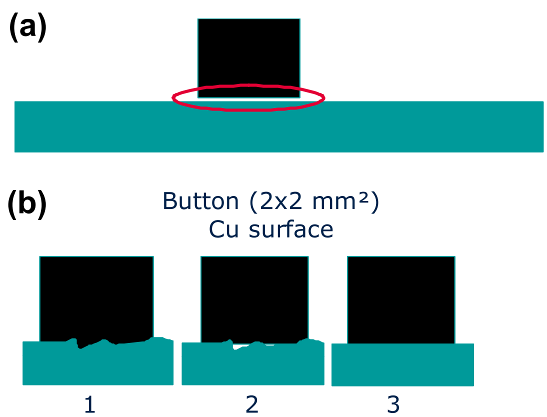

Fig. 2. Surface topology influences the adhesion (a). (b) Different surfaces, rough (1), rough with interface voids (2) and smooth (3) are shown.

We have to conclude that tests have to be performed to find out the best combination of moulding compound and surface concerning adhesion.

2. Simulation and experiments

First High Temperature Storage (HTS) experiments with temperatures up to 250 °C (normally 175 °C is not exceeded because of the decomposition of epoxy resins) on copper stripes with moulding compound MCA showed a degradation of the moulding compound adhesion represented by a reduction of the maximum shear forces.

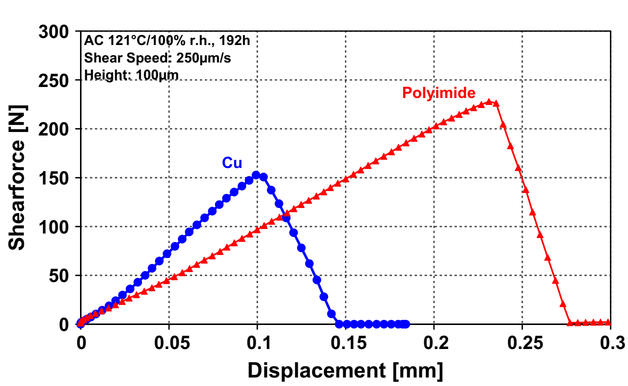

Fig. 3. Force–displacement curves for performed shear tests on copper and polyimide surfaces.

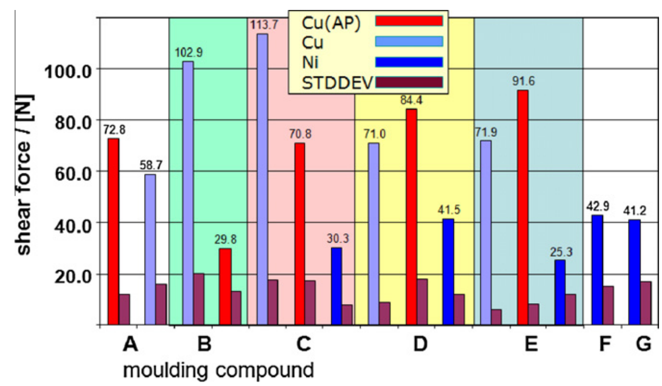

Fig. 4. Shear results with different material combinations (Cu, Ni, Cu with adhesion promoter AP).

Shear tests have been enabled to measure highly reproducible force–displacement curves which can be used to calibrate simulation models using cohesive zone elements in order to describe the adhesion of the selected material combinations.

Generally performing shear tests, two forces have to be taken in consideration:

1. Traction to separate two materials.
2. Shear to displace the moulding compound on the surface.

Performing button shear tests always is a combination of the 2. It is a mixed mode depending on the shear height (Fig. 5).

For the performed tests, shear heights of 100 µm and less were chosen to have $F_s \gg F_t$. FEM simulations confirm this approach.

In Fig. 6 a simple FEM model for the button shear test is built. The stress distribution along the shear path depends on the location and varies between tension and compression. The influence of the shear height is clearly shown in the simulation.

The calculated principal stress S3 is shown in Fig. 7. The dotted line shows the shear path and in Fig. 8 the height dependency is

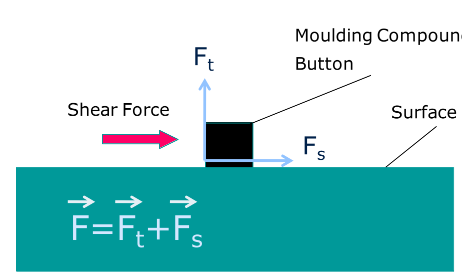

Fig. 5. Mode mixity (tension and shear).