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Flip Chip bonding of bare die on a flexible PET substrate with ablated copper.

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Summary:

The use of low-cost materials such as PET, paper, and unpackaged bare dies has become critical for cost-effective mass production, as demand for flexible hybrid electronics has skyrocketed, particularly for internet of things (IoT), electronic skin, and wearable applications. The advantages of this design include the sustainable use of resources, such as low-cost, readily accessible, and biologically degradable raw materials, and their suitability for printed electronics applications has been well researched. Mostly printed silver and sputtered silver has covered this market but has its own shortcomings. Combining this with techniques such as flip chip bonding and subtractive laser ablation provides us with the opportunity of fast fabrication and smaller size which can cater for new applications. In this study, we look at the flip chip bonding bare die to ablated copper on a PET substrate aided with anisotropic conductive paste. Furthermore, we investigate its reliability by performing bending tests.

Keywords: Ultra-thin dies; Hybrid integration; Printed electronics; Anisotropic conductive adhesives, (ACA); Anisotropic conductive paste (ACP); Polyethylene-terephthalate (PET); Chip on flex (COF); flexible electronics; laser ablation

Introduction

The implementation of devices based on low-cost materials such as PET, paper, and unpackaged bare dies has become crucial for economical mass production, as the demand for flexible hybrid electronics has increased extensively, specifically for the internet of things (IoT), electronic skin, and wearables applications [1]. Because standard wire bonding techniques are limited in their ability to accommodate flexible substrates, flip chip bindings are an important bonding technology for integration on them. Flip chip applications on flexible substrates have increased significantly, including Smart Cards, paging devices, disk drives, and LCD driver chips. These products are designed for large volume, low-cost, high-density assembly, compact and thin packaging, and low power consumption applications. [2][3]. In the past flip chip bonding on PET based substrates with printed silver circuitry has shown promising results but investigation on copper-based substrates is really limited. In this work, we bond bare dies to PET substrate with ablated copper circuitry. Moreover, to improve the reliability of the die it was encapsulated by a UV cured epoxy. In this research we investigate the possibility of flip chip bonding bare die to copper coated on PET substrate. The test vehicle consists of an NFC tag which can be used as a readout circuit.

Methods and materials

A 100µm PET substrate, coated with 500 nm of copper via physical vapor deposition, was utilized as the substrate. The circuitry design was created using commercial CAD software. A pulsed UV laser (Explorer One; 355 nm; 50KHz) was employed to ablate the copper surface, effectively removing the copper to achieve the desired electrical pattern. This laser system enables the ablation of relatively large patterns with high precision and resolution.

A die-bonder (Fineplacer, Finetech GmbH) was used to bond the ultra-thin dies to the ACA flip-chip. The system comprises of a heatable die handling tool and a separate heated stage. The bonding settings were calibrated so that the stage and tool temperatures were 135°C. A modest bonding force (30 N) was used to minimize any damage to the thinned dies. Planarization of the surfaces is crucial in this procedure; thus, the picking tool and stage were accurately adjusted using a pressure-sensitive foil, resulting in a perfect planer chip orientation. This is a two-step method that begins with dispensing the ACP and then applies pressure and temperature. ACP provides electrical connections at fine-pitches and gives mechanical stability to the joint by acting as an underfill. A schematic of the final sample is shown in Fig.1 with the red arrow shows the conductive path.

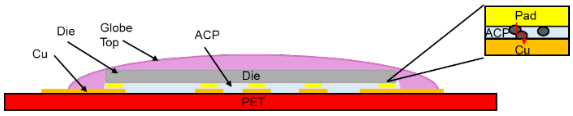

Fig. 1. Bonded sample

The bonded region was eventually covered by glob top dispensing. In the instance of Glob-top, a single component UV curable epoxy glue (OG116-31, Epotec, USA) was dispensed and cured by both UV irradiation and heated to 70°C. After fabrication, the samples were electrically evaluated at bending diameters ranging from 5 to 50 mm with a vernier caliper. The change in voltage was specified as the criteria to identify whether bending had any influence on the die's electrical interconnections. Optical images of the NFC tags can be seen in Fig .2.

Fig. 2. Optical images of NFC tag while bending

Results

After fabrication, the samples were electrically evaluated at bending diameters ranging from 50 to 30 mm with a vernier caliper. 50mm is the length of the sample when not bended. Three NFC tags were used in the experiment to make a quantitative analysis. Three diodes on the die were selected for the test. For the reference, diode voltages were measured on a rigid PCB board. These values are denoted by (x) in Fig 3. As we can see in Figure 3, the voltage increases as the bending diameter decreases.

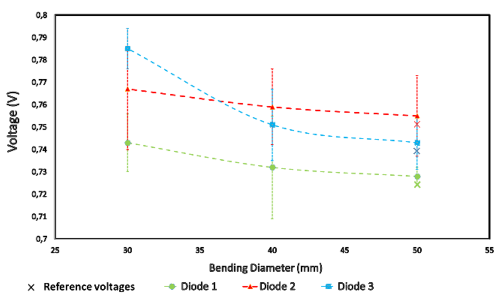

Fig. 3. Electrical characterization of the fabricated samples at different loop diameters.

Till 40mm, all three diodes indicate a little rise ~0.08V. The rise in electrical resistance of the bonded stack during the bending test can be attributed to the loss of contact between the conductive particles in the adhesive and the pads on the substrate or die. We also observe diode 3 shows a significant increase in the voltage ~0.04V bending from 40mm to 30mm compared to ~0.01V when bending from 50mm to 40mm.This can be attributed to the delamination of the chip edge from the substrate. Thus, we may conclude that this flip chip technique can be employed for bonding on flexible substrate fabricated and patterned by laser ablation, which can serve as an alternative to printed silver. This also opens further possibilities if silver cannot meet the application's demands.

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