DETERMINATION OF THE STRENGTH OF INTERFACE IN PRINTED CIRCUIT BOARDS (PCBs): PEELING TEST AND ROLE OF PLASTICITY

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1 Introduction

A printed circuit board (PCB) is a multi-layered material, made of dielectric materials and copper. For aerospace applications, the number of copper layers is large (over 10 to 20) and the reliability of the boards must be ensured during decades to make the electronic devices operating (in satellites or other equipments). During the qualification process, aero-mil standard must be fulfilled. For example, the PCB is subjected to thermal cycles in the range [-55°C, +125°C]. It is important to check that the copper traces are not presenting damage and that the interfaces remain safe. In the present talk, we discuss only the interface issue.

The structure of the board design for specific applications can mix various dielectric materials having very different mechanical properties. In the present work, we concentrate on the interface between a woven composite (glass fibers and epoxy resin) and a thin foil of copper.

The present talk will have two distinct parts: an experimental part for the characterization of the behavior of the interfaces and a numerical part. The goal of experiments is to feed numerical simulations with real data measured in laboratory. The ultimate goal of this work is to anticipate problem in advanced design so as to provide accurate predictions which can explain observed failures on specific printed circuits.

2 Experiments

For the experimental part, we have prepared samples which are representative of materials used in the real applications. For that purpose, pre-preg of epoxy glass fibers laminate and copper have been processed according to the industrial standard. Curing of the pre-preg materials at elevated temperature ensures the adhesion of copper. Secondly, strips of copper (10 mm) are etched on the surface of the sample, Figure 1. Note that the bonding of the copper is realized only on 2/3 of the total length of the sample so that the strip can be fixed in the grip of the peeling device, see Fig2. The peel test is carried out at a fixed crosshead velocity and the steady force for the peel force is recorded during the test, Fig3. For a given peel angle, tests have been carried out several times, providing the same stationary peel force, see Fig3. In our configuration, the copper film is thin (thickness 35µm). Three different peel angles (45, 90, 135 degrees) have been considered. It has been shown in this present work that the peel force decreases when peel angle increases as reported in Williams and Kauzlarich [1].

Fig. 1: Sample used for the peel test. The copper film has the following dimensions: 200mm length and 10mm width.

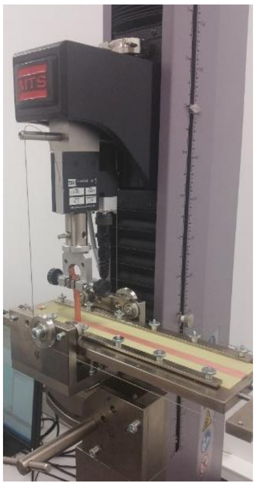

Fig. 2: Experimental peeling device. The film is pulled at constant velocity.

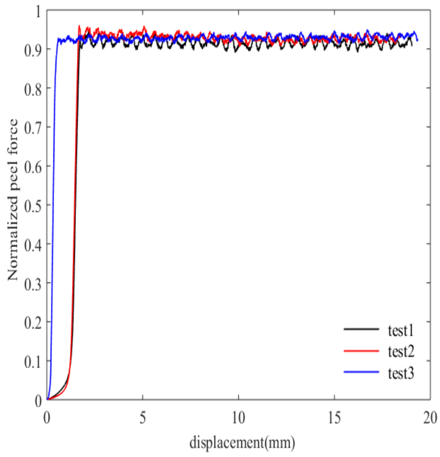

Fig.3: Evolution of the normalized peel force measured during a 90° peel test. After a few millimeters of crosshead displacement, a steady state is established.

3 Modeling

In an attempt to model the peel force evolution with the peel angle, the theory of elastic peeling test has been first adopted [2] and it has been shown, as already mentioned in the literature, that an elastic theory is not able to explain the trend when a thin metallic foil is considered. To understand the role of plasticity of copper during peeling, a numerical model has been developed with the finite element software ABAQUS. From the simulations, we have observed two zones where plasticity is cumulated: a first bending zone at the tip of the interface and a reverse plastic bending latter in the free arm. Those results are consistent with the work of Wei and Hutchinson [3]. Usually, in the literature, the behavior of the metallic thin film is not often known. In our work, the elastic-plastic behavior of copper thin film has been identified based on a uni-axial tensile test. In addition, the elastic behavior of the substrate has been identified in our laboratory. Cohesive elements (traction separation law) have been adopted to model the interface between copper and the substrate. Parameters of the cohesive elements have been estimated to mimic the experimental results. In the present talk, the effect of plasticity in the peel test will be quantified based on the energy balance. In the present configuration, it will be shown that the peel force does not provide a direct measurement of the interface energy. Additional work must be addressed to extract from the peel force, the surface energy.

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