Design and fabrication of cyclic bending test apparatus for flexible printed electronics

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ABSTRACT – This paper presents the design and fabrication of a customized cyclic bending test apparatus for flexible printed electronic (FPE) applications. In general, FPE is made from flexible substrate and attached with electrically conductive polymer composites paste using printing method to form the board circuitry. Cyclic bending test is one the method applied to determine the reliability of FPE, by applying continuous cycle of bending loads to the samples at varying number of bending cycles and varying bending speed. The developed cyclic bending test apparatus consists of a DC electric motor, sample holder, and slider-crank linkages. The electrical input can be supplied either using a battery or from source measurement unit (source meter). The resistivity value of the circuit before and after subjected to cyclic bending load were measured either using Four-Point probe apparatus or digital multimeter. The outcome of the project was a simple, portable, low cost and workable cyclic bending apparatus for FPE reliability laboratory scale studies.

1. INTRODUCTION

Flexible printed electronics (FPE) is one of the fastest growing areas currently for electronic product applications [1]. The flexibility performance enabled designers to explore more advanced applications such as wearable electronics devices, flexible displays and foldable transmission antennas [2]. To establish the use of FPE, one of the major hurdles is to characterize the reliability of the components, especially under repeated mechanical load such as subjected to bending force. Reliability test results can provide valuable results as indication of the product long term functionality in actual operation conditions.

In this paper, a new design of customized cyclic bending test apparatus for FPE reliability testing was developed. Cyclic bending test was simulated by applying continuous cycle of bending loads to the samples at varying number of bending cycles and varying bending speed using the apparatus. The development process involved product design, prototype fabrication and functionality test.

2. RESEARCH METHODOLOGY

The overall test rig development process involved several steps which are development of product design specifications (PDS), benchmarking on existing product on the market, developing conceptual designs, developing final design, materials and component selection, prototype fabrication and functional test. Due to article page limitation, only several stages of the test rig development process are described in this paper.

2.1 Product Design Specifications

The first stage involved development of PDS (or also known as design rules or design requirements) for the intended product. Based on Pugh Total Design method, there are 33 PDS elements which are involved in any product design process, and designers need to choose suitable elements related to the aim of the project. Definition of the PDS is crucial because it served as the primary guideline to designers in formulation the solution to meet the customer expectation. Based on brainstorming process, the final PDS main requirements formulated for the cyclic bending test apparatus is summarized are performance, weight, ergonomics, cost, as well manufacturability, assembly and maintenance

2.2 Benchmarking

After finalizing the PDS for the design, benchmarking on available cyclic bending test apparatus on the market was made. Based on literature review, there are two (2) reported similar cyclic bending test equipment made by University of Oulu, Finland and Advanced Packaging and Thin Film Lab, Korea Advanced Institute of Science and Technology (KAIST), South Korea as shown in Figure 2.1 and Figure 2.2, respectively. The test equipment as shown in Figure 1 utilized rotary motion to drive the cyclic bending mechanism, while test equipment as shown in Figure 2 used linear motor to perform similar function.

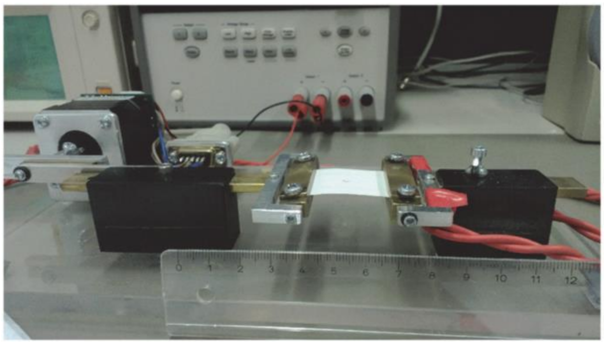

Figure 2.1 Cyclic bending test apparatus for FPE made by University of Oulu, Finland [3]

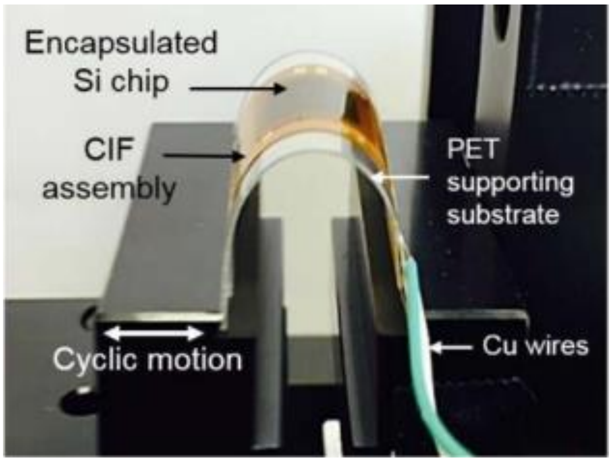

Figure 2.2 Cyclic bending test apparatus for flexible electronic packaging by KAIST, South Korea [4]

3. RESULTS AND DISCUSSION

3.1 Final Design and Fabricated Test Apparatus

Figure 3.1 shows the final design of the cyclic bending test apparatus developed based on the PDS requirements. In overall, the apparatus design comprised of five (5) major components, which are the sample holder, DC motor, motor mounting, apparatus base and the cyclic linkage mechanism. The cyclic linkage concept selected was based on the in-line slider-crank mechanism, which provide simple and reliability bending movement to the samples, using low number of components. The linkage mechanism was custom-designed to meet the function requirement and produced via 3D printing method based on acrylonitrile butadiene styrene (ABS) material for high durability.

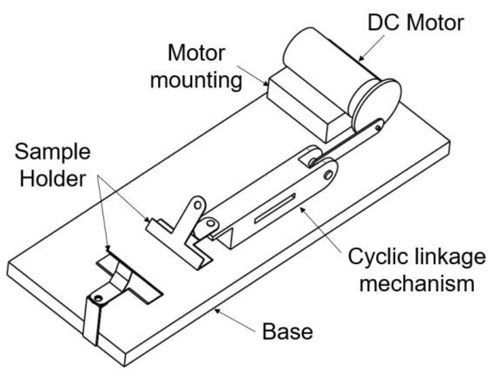

Figure 3.1 3D CAD model of cyclic bending test apparatus

Figure 3.2 shows the fabricated prototype of the cyclic bending test apparatus. Paper clips was selected to be used to hold the samples which provide quick and easy handling as well as lower cost. Soft-board was also selected as the base material for the apparatus which is lightweight, rigid and can be easily be mounted to by other components using screw joints. The DC motor input was fixed at 11V and bending speed of 100 cycles per minutes. The electrical input can be supplied either using a battery or from source measurement unit (source meter). Meanwhile, the resistivity value of the circuit before and after subjected to cyclic bending load can be measured either using Four-Point probe apparatus or digital multimeter.

Figure 3.2 Fabricated cyclic bending test apparatus

4. SUMMARY

Several conclusions from the project are listed as below: -

i) A cyclic bending test apparatus was developed based on the PDS requirements
ii) The customized cyclic bending test apparatus was proven workable and offer additional advantages such as design simplicity, portability and low cost which is very suitable for FPE reliability laboratory scale studies.

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