International Journal Of Electrical, Electronics And Data Communication, ISSN: 2320-2084 Volume-5, Issue-9, Sep.-2017
http://iraj.in

INVESTIGATION OF ELECTRICAL CHARACTERISTICS OF FLEXIBLE PET/ITO SUBSTRATES FOR WHOLE-FOLDING TEST

[1]BOR-JIUNN WEN, [2]TING-YU TSENG, [3]PIN-HSUAN HUNG

[1,2,3]Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, Keelung 20224, Taiwan
E-mail: [1]jiunner@mail.ntou.edu.tw

Abstract- For display industry flexible displays are high current interests for a variety of information product applications. This study presents an electrical characterization of flexible polyethylene terephthalate/indium tin oxide (PET/ITO) substrates for whole-folding test by using an automatic sliding-folding testing system (ASFTS). To quantize folding conditions, ASFTS for folding function is utilized to control radii of curvature of the flexible substrates, whole-folding times, and velocities. As a result, the new technique successfully measures electrical characteristics of flexible PET/ITO substrates up to 120,000 whole-folding times with a folding radius of 25 mm. The electrical characteristics post-test were then compared to the pre-test findings. Based on the comparative analysis, it could be seen that resistance varied by approximately 300 Ω. These results provide a reference for flexible electronic product researchers and manufacturers, to improve flexible electronic devices in the future.

Keywords- Polyethylene Terephthalate/Indium Tin Oxide, Whole-Folding Test, Automatic Sliding-Folding Testing System.

I. INTRODUCTION

Flexible displays are characterized as being lightweight, thin, flexible, and impact resistant. Their unique feature is that optical properties will not be degraded by bending. With the rapid development in flexible electronics [1-6], testing of flexible displays under different deformation geometries will play an important role in research and production. As of now, many flexibility test platforms are available, however, local radial bending can only be performed in a set position on certain systems, or the bend angle is too limited due to the mechanism being restrictive in setup, leading to a poor bending effect. With regard to the collapsing radius device [7], is a vice-like design in which the flexible sample is arched and fixed. Its moveable side can move to bend the flexible sample. With the change of the distance Lp between sliding rails, various radii of curvature can be obtained. The relation between the curvature radius and the distance between the sliding rail is $r=Lp/2$. This design allows for easily obtained results. However, its disadvantage is that an initial radius of curvature has to be set and the clamping process could easily damage the sample. In addition, the scope of bend is not large enough to provide accurate results. With X–Y–θ bending system [8], one end of the flexible sample is fixed while the other end is bent to reach the required bending position and tangential direction, which is determined by the curvature radius. The advantage of using the bend angle to determine flexibility is that the range of flexibility is increased, whilst the disadvantage is that it is not easy to design a practical measurement mechanism, and complicated optical and electric measurements have to be performed. In the flexible-characteristics inspection system (FCIS) design [9,10], a vertical jaw is used to clamp the test sample, and a rear jaw allows the applied bending force to be opposite to the clamping force. The orbital motion formed by both jaws eliminates the influence of gravity and generates conditions for pure flexibility testing, or creates a rigid surface for a rigid sample, to allow for repeated flexibility testing. However, this design is not applicable to foldability testing (the sample has to be bent with both ends parallel to each other). In addition, in the above designs only a section of a sample can be tested, so they are not suitable for flexibility or foldability testing on an entire sample. Therefore, this paper designed and established an automatic sliding-folding testing system (ASFTS), which not only allows for the adjustment of the folding and bending radius, but also automates the folding and bending process on the entirety of the sample. The whole-folding test is realized because of two actions: folding, and then sliding the folded position. This method contributes to obtaining complete testing data of the entire sample. The paper also investigated and analyzed the changes in electric characteristics of the sample because of the foldability test.

II. AUTOMATIC SLIDING-FOLDING TESTING SYSTEM

The testing mechanism designs referenced above emphasize the bending of a single side and were not capable of bending or folding the entire sample. Therefore, this paper designed and established an ASFTS, consists of two actions: a primary fold, and a mobile fold of the folded position. ASFTS was designed with a screw-type mechanism, which uses a screw to control the back and forth movement of the jaw. The benefits of using a screw mechanism is that folding of the entire sample can be realized by just moving back and forth to force the flexible sample to move when folded. When the sample is moved, its folding position is also changed; and, as a result, the folding of the entire sample can be realized by moving the sample in a linear manner. As shown in Fig.1, the flexible substrate is placed on a clamping rod; next, the bolts are screwed but not tightened; all four diagonal bolts on the other clamping rods are then screwed on in this manner, after which, all bolts are tightened. Next, the baffle is locked, and the other clamping rod is adjusted to a horizontal position for assembly, after which, the baffle is installed and locked; the clamping board is then mounted on the screw, which is tightened until the flexible sample unfolds completely. Finally, the initial position is input in the program, and the number of folds is set, to ensure the sample fully unfolds after each individual fold is complete. The flexible sample can be tested once above steps are complete. After the program is started, the motor drives the screw upwards; both the jaw located at the upper end of the screw and the clamping rod at the fixed end of the base, start to approach so that the distance between the clamping rods is reduced. When this occurs, the flexible substrate is compressed between the clamping rods and forced to slowly arch, as shown in Fig 2. The distance between the baffles on the clamping rods is the folding radius of the sample. As shown in Fig 3, the screw continues to move past the fixed jaw; after which, the sample is slowly pulled open until fully unfolded, to complete a single fold. The motor then rotates in reverse to make the clamping rod platform move backwards, folding the sample back to its original position, thus completing a test cycle. Fig. 4 represents graphic models demonstrating how ASFTS completes a whole-folding cycle with a 25 mm folding curvature. Fig 5 shows the graphic model of the testing device performing a test.

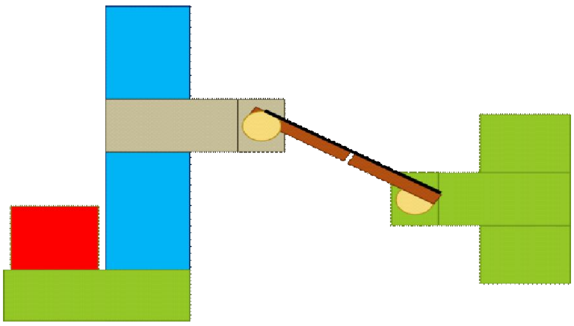


Fig.1. Top view of flat initial condition of ASFTS.

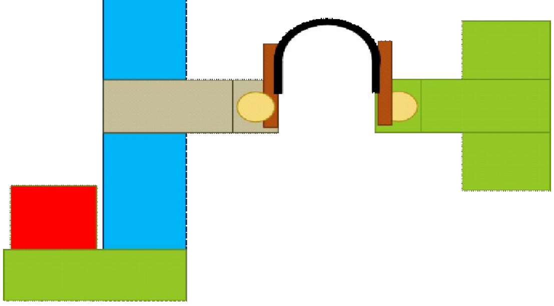
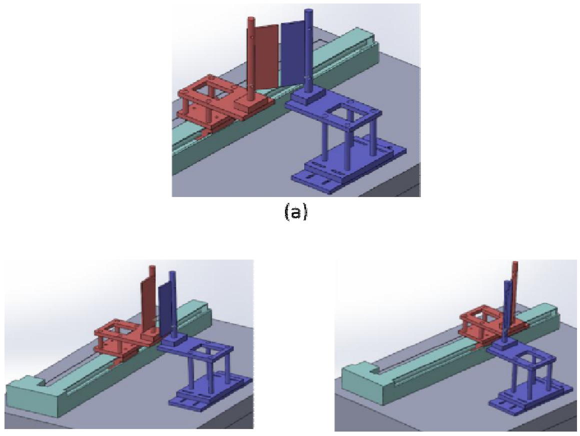


Fig. 2. Top view of upside arch condition of ASFTS for whole-folding test.

Fig. 3. Top view of downside arch condition of ASFTS for whole-folding test.



(a)

(b) (c)

Fig. 4. Three steps of (a), (b), and (c) in order within one whole-folding cycle by using ASFTS to obtain 25 mm folding curvature.

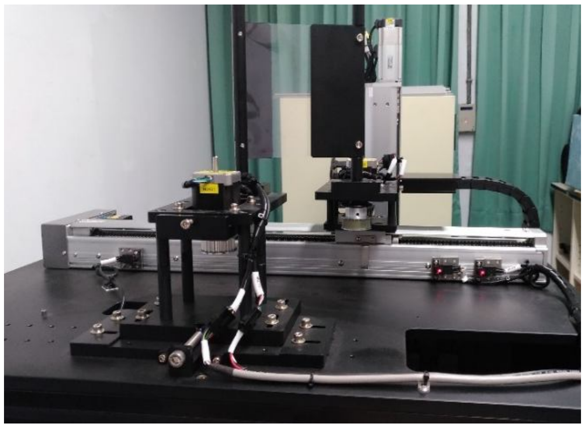


Fig. 5. Photo of ASFTS for whole-folding test.

ASFTS presented in this paper adopted a screw-type control mechanism. LabVIEW software was used to design a human-machine interface and a program to work with a servo control system for the sliding-folding of the samples. The servo control system primarily consisted of a 4-axis servo movement control card and three servo controllers. LabVIEW was also used to design a control panel interface based on an imported Dynamic Link Library, so that the motion control card can be used to control the actions of the device. The automatic control computer interface is shown in Fig. 6.

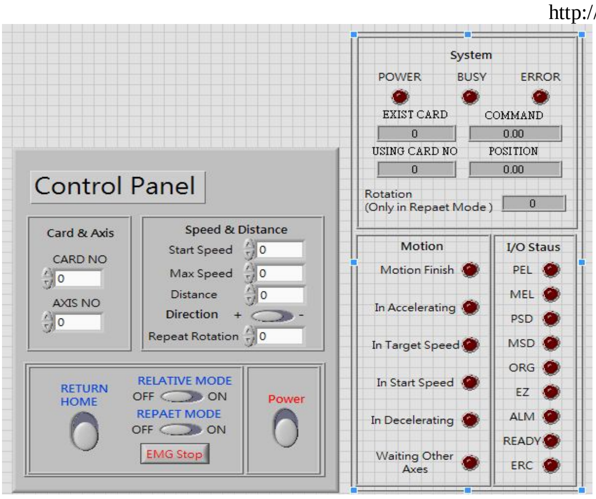


Fig. 6. Automatic control computer interface of ASFTS.

III. EXPERIMENTAL RESULTS

The size of the flexible PET/ITO sample used in this paper was 127 mm x 148 mm. A laser was used to cut out fine lines with a line width of 203 µm, as well as the 15 mm x 40 mm rectangular panel with electrodes, as shown in Fig 7, so that a multimeter can be used to measure the electrical properties. Fig 8 shows the graphic model of the testing of the substrate. As shown in the test results in Fig 9, substrate resistance varied after folding. The measured resistance before folding was 42.9 kΩ. A single folding cycle consisted of the screw-type platform folding the sample 2 times, and then returning to its original position. After folding 1000 times with a folding radius of 25 mm, resistance clearly increased to 43.1 kΩ, however, showed little variation after that. After folding approximately 50,000 times, resistance again increased to 43.2 kΩ, after which, resistance maintained stable until the end of the test (the resistance showed no obvious changes when folded approximately 120,000 times). As indicated by the test results, resistance increased around 200 Ω after folding 1,000 times, indicating that major damage as a result of folding occurred. Once the sample was folded 50,000 times, further minor damage was incurred. By the end of test,

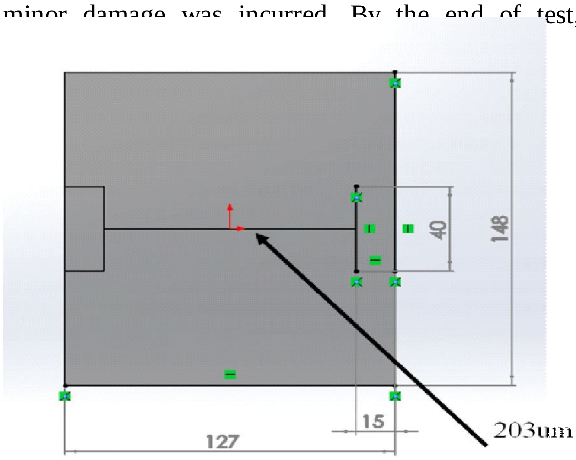


Fig. 7. Schematic diagram of a 203-µm-wide line pattern on the PET/ITO sample.

Fig. 8. Photo of a 203-µm-wide line pattern on the PET/ITO sample.

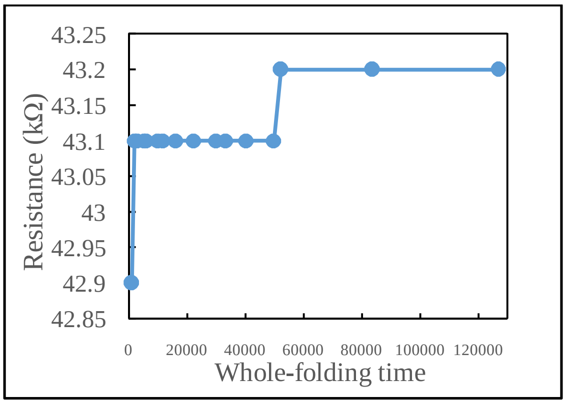


Fig. 9. Electrical-resistance measurement of flexible 203-µm-wide line pattern on the PET/ITO sample up to 120,000 whole-folding times with a folding radius of 25 mm.

CONCLUSIONS

This study deals with flexible PET/ITO substrates up to 120,000 whole-folding times with a folding radius of 25 mm by using an ASFTS. The electrical characteristics post-test were then compared to the pre-test findings. Based on the comparative analysis, it could be seen that resistance varied by approximately 300 Ω. These results provide a reference for researchers and manufacturers specializing in flexible electronic devices to assist in the making of better flexible electronic products. In addition, it is expected that ASFTS can also be adapted to evaluate the performance of whole-foldable devices under controlled environmental conditions.

ACKNOWLEDGMENTS

The authors wish to thank National Science Council of Taiwan for financial supports (grant numbers: 105-2221-E-019-029).

REFERENCES

[1] Y.-L. Chen, H.-C. Hsieh, W.-T. Wu, B.-J. Wen, W.-Y. Chang, and D.-C. Su: Displays 31 (2010) 191.

[2] P.-C. Wang, J.-Y. Yu, and K.-H. Li: Mater. Chem. Phys. 130 (2011) 1346.
[3] P.-C. Wang, C.-I. Chao, W.-K. Lin, and S.-Y. Hung: J. Chin. Inst. Eng. 35 (2012) 595.
[4] P.-C. Wang, L.-H. Liu, D.A. Mengistie, K.-H. Li, B.-J. Wen, T.-S. Liu, and C.-W. Chu: Displays, 34 (2013) 301.
[5] J. Ma and L. Xuan: Displays, 34 (2013) 293.
[6] C.-M. Gee, C.-C. Tseng, F.-Y. Wu, H.-P. Chang, L.-J. Li, Y.-P. Hsieh, C.-T. Lin, and J.-C. Chen: Displays 34 (2013) 315.
[7] J. Lewis, S. Grego, B. Chalamala, E. Vick, and D. Temple: Appl. Phys. Lett. 85 (2004) 3450.
[8] J. Lewis, S. Grego, E. Vick, B. Chalamala, and D. Temple: Mater. Res. Soc. Symp. Proc. 814 (2004) 14.
[9] B.J. Wen and T. S. Liu: Displays 32 (2011) 296.
[10] B.J. Wen and T.S. Liu: Control Eng. Pract. 21 (2013) 593.

★★★