Microelectronics Reliability 54 (2014) 327–330

Contents lists available at ScienceDirect

Microelectronics Reliability

journal homepage: www.elsevier.com/locate/microrel

Research Note

Endurance behavior of conductive yarns

Hans de Vries *, Kunigunde H. Cherenack

Philips Research, Eindhoven, The Netherlands

ARTICLE INFO

Article history:
Received 2 May 2013
Received in revised form 13 August 2013
Accepted 26 August 2013
Available online 26 September 2013

ABSTRACT

Various companies are industrializing 'photonic' textiles for medical and architectural applications. Here we report reliability testing of photonic textiles based on woven textiles with integrated copper-based conductive yarns used to drive attached LEDs. These textiles were subjected to cyclic mechanical stress tests and the cycle life was analyzed in terms of fatigue. Results show that failure is due to wire fractures at the transition from the rigid component to the compliant textile. The results are in good agreement with Cu-fatigue data from literature. This shows that it is possible to estimate the lifetime of electronic textiles under use conditions by the mechanical fatigue of the conducting yarn material properties.

1. Introduction

In the past years interest in the integration of electronics in textiles has grown [1], especially to generate comfortable wearable products. A specific application is light therapy in which case light-emitting diodes (LEDs) and other components are mounted on textile substrates. Electrical conductors are woven into the textile or laminated between textile sheets and the LEDs are connected by conducting adhesive or placed on rigid or flexible substrates and soldered to the conducting yarns. Such textiles are called 'photonic' textiles.

Since such applications are explicitly meant to be worn, they will be subjected to various additional stress loads apart from the usual environmental stress. These additional stress loads in the applications are typically bending, folding, and pulling. This makes the study to the endurance properties of such structures a topic of its own [2].

This paper reports the results of a study to investigate long-term mechanical robustness of woven photonic textiles exposed to cyclic bending. The level of the applied stress load has been varied in order to arrive at a model description of the failure mechanism that enables the estimation of photonic textile lifetimes once the operational conditions are known.

2. Fabrication and test set-up

An overview of the technologies is given in [1]. Test samples were made as shown in Fig. 1. The textile area is $85 \times 100\ mm^2$, with conductive yarns woven into it parallel to the warp direction. Further characteristics of the textile are: dtex = 76 (mass in grams per 10,000 m yarn) and 33 picks/cm (number of yarns per cm in weft direction). Sections of conducting yarn lie on top of the textile (in so-called "floats") to enable device attachment. A staggered row of LEDs is mounted with isotropic conducting adhesive (Henkel 3103 WLV) onto the floats in the textile, and reinforced with a globtop encapsulation (visible in the figure).

The conductive yarn is Elektrisola litze wire [3] that consists of 20 silver plated copper filaments with a diameter of 40 μm, each wrapped with a twist of approximately 240/m. The non-conducting yarns are made of polyester.

The samples were subjected to a cyclic test load as described elsewhere [2]. The textile is held straight by springs and is loaded into specially designed clamps with cavities that can be positioned over the LEDs (see Fig. 2). These clamps can then be used to bent the textile from a neutral (unbent) position downwards to a maximum displacement of 86 mm and back at about 40 cycles per minute without exerting any force on the LEDs (see Fig. 3).

In the tests reported here only one row of LEDs is placed between the clamps and for the analysis only these four components are considered. This test set-up was designed to exert a force at the interconnect points between the LED and the conducting yarn (bold arrows in Fig. 3). During cyclic bending, LEDs are driven at a forward voltage of 4 V. The current through the LEDs is monitored to detect failures in the conductive path, defined as the moment when the current becomes irregular, as shown in Fig. 4.

In this way samples were tested to failure for displacements of 59, 77 and 86 mm. For each setting two samples were used. An additional sample was tested at 35 mm but this test was terminated after 1,538,000 cycles without observing any electrical failure.

After each test, failure analysis was carried out by means of X-ray microscopy and cross sectioning of the transition zones where the LED is attached to the conducting yarn. This was done to reveal the failure mode.

* Corresponding author. Tel.: +31 6 3163 7529.
E-mail address: j.w.c.de.vries@philips.com (H. de Vries).

0026-2714/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.microrel.2013.08.014

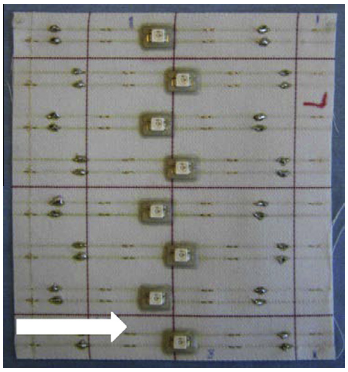

Fig. 1. Test sample with staggered row of LEDs. The globtop is visible as the brownish ring around the LEDs. The white arrow indicates the warp-direction.

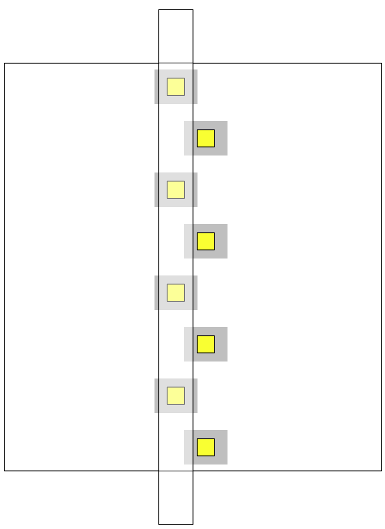

Fig. 2. Schematic showing clamp placed over the LEDs.

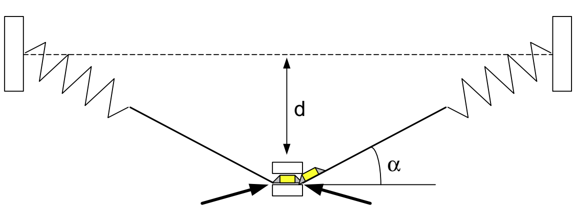

Fig. 3. Schematic of the test showing the position of the clamp over the LEDs, the springs to hold textile straight, displacement (d) and the bending angle α. The bold arrows point to the transition zones.

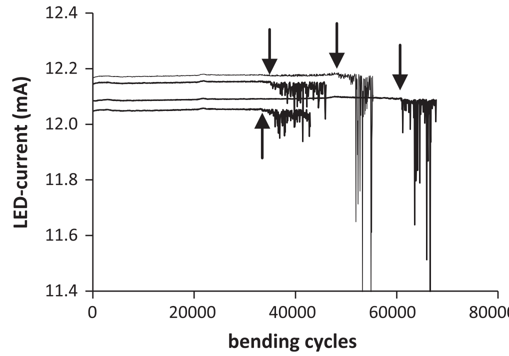

Fig. 4. Current measurement during cyclic bending. Failure moments are indicated by the arrows. The ample displacement is 77 mm.

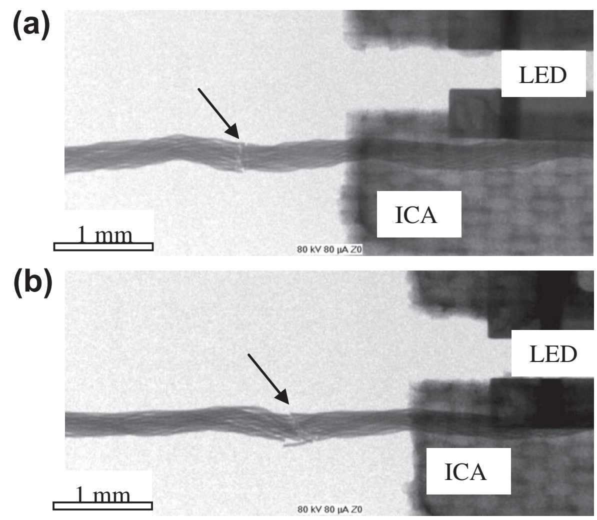

Fig. 5. X-ray pictures of samples tested at (a) 59 mm and (b) 35 mm displacement. Conducting wires are broken outside of the LED contact pad and ICA (see arrows).

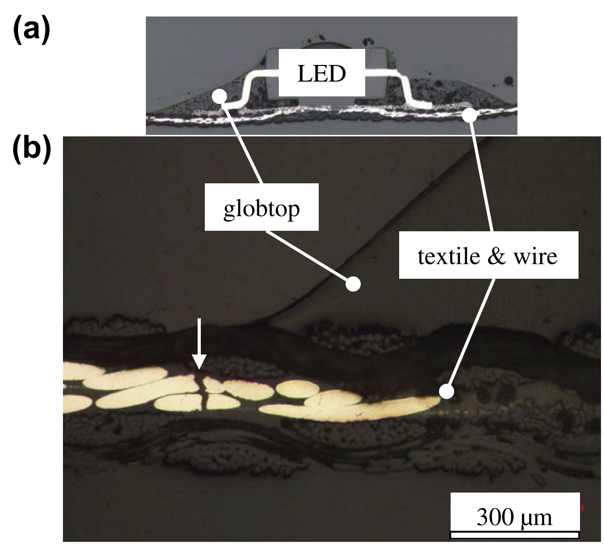

Fig. 6. (a) Cross section of the complete assembled product with a textile substrate, a LED and globtop. (b) Cross section of sample tested at 86 mm displacement. The broken wire is visible at the edge of the globtop (see arrow).

3. Results and discussion

In Figs. 5 and 6 representative pictures of samples after testing are shown. The X-ray pictures show that the conducting wires are broken in the transition zone between the rigid globtop and the compliant textile (see the arrows pointing to cracks in the conducting yarn). These cracks are visible in all tested samples, even for the sample where cyclic testing was terminated since no electrical failure was detected after more than 1.5 million cycles. Fig. 6a shows a cross section of a complete LED attached to a conductive yarn.

Apparently, cyclic bending causes the conducting wires to break at the edge of the rigid globtop and the soft compliant textile. Each bending cycle causes the wire to bend at that transition point. Each subsequent cycle results in an accumulation of deformation (ε) until failure occurs.