Microelectronics Reliability xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Microelectronics Reliability

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

Reliability analysis of UHF RFID tags under long-term mechanical cycling

Kamil Janeczek

7R Logistic Kraków Kokotów Sp. z o.o., Ludwinowska 7, 30-331 Krakow, Poland

ARTICLE INFO

Article history:
Received 13 December 2016
Received in revised form 14 June 2017
Accepted 14 June 2017
Available online xxxx

Keywords:
RFID
RFID tags
Mechanical cycling
Long-term bending

ABSTRACT

Radio Frequency Identification is becoming more and more popular although unit price of RFID tags is still higher than price of barcodes. Further decrease in cost of using RFID techniques can be possible to achieve by recycling of tags. However, their multiple use causes that RFID tags are placed repeatedly on a surface of identified object and then, peeled off. Thus, tags have to withstand even long-term mechanical exposure in order to guarantee reliable work in a long period of time. In this paper, reliability of UHF tags under long-term mechanical cycling is reported. Two different RFID tags were used to perform investigations which revealed that mechanical properties of tested RFID tags are mostly dependent on their stackup, i.e. additional top and internal foil or paper layers may introduce significant growth of mechanical durability of the tested RFID tag samples.

1. Introduction

In the recent years, Radio Frequency Identification (RFID) has become more and more frequently used automatic identification technique which has found application in various areas, such as logistics, warehouse management, retail, automotive and healthcare [1–6]. In relation to the most popular identification method with using barcodes RFID does not require maintaining line-of-sight to establish connection between tag and reader, RFID tags can be invulnerable to dust, moisture, high pressure, high temperature depending on their design and their read range can be higher than a few meters, even in case of their passive versions [7].

Irrespectively of an application area RFID tags may be subjected to mechanical exposure e.g. during their use on flexible substrates or utilization of RFID wristbands in hospitals. Therefore, it is necessary to examine how temporary and long-term mechanical stresses affect their properties.

Mechanical properties of thin aluminium films which are currently mostly used in production of RFID tags have been reported in [8] where different material thickness and specimen size were considered. It was shown that peak stress was proportional to specimen area whereas it exhibited opposite behaviour to crack length. Other studies [9] reported that mechanical properties of aluminium foil depend mostly on its structure and condition of its surface.

Reliability analysis of passive RFID tags consisted of an aluminium antenna on thin flexible polyethylene terephthalate (PET) foil was demonstrated in [10]. The tags were subjected to a combination of environmental stresses, including bending cycles. It was noticed that the bending testing made before the humidity cycles did not notably influence performance of the samples after the humidity cycling. Further, it was found that delamination between aluminium wiring and PET substrate took place when the test samples were exposed to bending and humidity cycles. However, the results presented in [11] exhibited that delamination in the tags can be avoided by selection of proper material for their fabrication.

It has been also reported that mechanical durability of RFID tags [12–15] are strongly influenced by mechanical properties of chip's joints. These joints are often formed with using isotropic or anisotropic conductive adhesives [16–20]. In case of the first type of adhesives it is usually necessary to encapsulate RFID chips to enhance their high durability [21–23], but special attention needs to be paid to material selection because choice of improper coating materials may result in damage of tags, e.g. in ripping off the chip from their fixture pads to an antenna due to a higher adhesion strength between the chip and the coating compared to the chip and its fixture pads [24]. Other solution described in literature [25] suggested that mechanical properties of RFID tags may be boosted by using thinned-down silicon chips which are thin and flexible differently than their rigid silicon equivalents.

Taking into account that to the best Author's knowledge there is no comprehensive studies reporting mechanical properties of RFID tags produced with conventional techniques the aim of this paper is to present reliability analysis of these tags subjected to long-term bending cycling in which their properties during mechanical cycling were assessed by resistance measurement and analysis of their surface after the tests.

2. Experimental

2.1. Sample preparation

In the described study, commercial paper face RFID tags, Rafltac (RDB) and Smartrac (SDB) DogBone (Fig. 1), were used as test samples.

E-mail address: kamil.janeczek@7rlogistic.pl.

http://dx.doi.org/10.1016/j.microrel.2017.06.024
0026-2714/

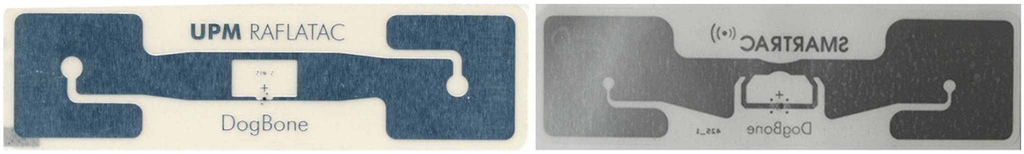

Fig. 1. Shape of RFID tags used in the study: RDB (left), SDB (right).

The size of both tags is 97 × 27 mm and their thickness was about 270 μm and 330 μm, respectively. In order to measure resistance of an antenna layer during mechanical cycling side parts or the whole surface (depending on a test) of the RFID tags were treated with chemicals using a procedure as follows:

- removing a top paper surface of RFID tags with using Schweizer's reagent exhibiting ability to dissolve cellulose,
- washing a sample in acetone in order to remove residues of paper and adhesive layers,
- dissolving of an adhesive layer between protective foil and antenna layer with using acetone,
- mechanical removal of the protective foil by its slow tearing off,
- washing the antenna layer with acetone to remove residues of adhesive.

Example image of a sample with bare side parts prepared for resistance measurement is presented in Fig. 2. The same procedure was used for the samples after cyclic bending in order to make possible to observe damage in antenna layers.

2.2. Methods

Electrical resistance of the prepared samples was measured with a four-point-method described in [26–27]. Cyclic bending test was carried out in room temperature on a test stand comprises a ripper in the form of a linear module with toothed belt, digital multimeter and computer with software for data acquisition. For all the samples following parameters of cycling bending were used: speed of movable table – 50 mm/s, movement range of table relative to a fixed handle – from 18 mm to 52 mm, duration – up to 193,500 cycles (450 bending cycles per hour), bending radius – 11 mm. The used minimum bending radius was smaller than the proposed one in [28–29] (50–75 mm) because it was assumed in this study to determine reliability of RFID tags under extreme mechanical cycling. The assumed bending conditions are similar to the ones mentioned in [30] (minimum bending radius 18 mm). Changes in antenna layers after the cycling bending test were examined by microscope analysis. For each tests at least 3 specimens (every type) were utilized.

Fig. 2. A sample with bare side parts prepared for resistance measurement.

3. Results and discussion

In the first step, influence of top paper and adhesive layers on electrical properties of RFID tags was investigated with using RDB samples. Changes in resistance of RFID tag samples without and with the top layers are presented in Fig. 3. It was revealed that the bare sample (tag without the top paper and adhesive layers) was completely damaged after about 13,950 bending cycles whereas the paper face RFID tag was destroyed after about 31,500 cycles. Both types of samples lost electrical continuity of their antenna circuits what was confirmed during microscope analysis. As it is presented in Fig. 4 (the photos were made after removal of top layers after bending cycles) the top layers caused that the antenna layer was sustained and did not fall off from a substrate. In effect cracks created in the samples during cyclic bending did not result in fast complete damage of the paper face sample.

In the next stage of the study, it was examined how design of RFID tags influences their mechanical properties. Changes in electrical properties of their antenna during cyclic bending are depicted in Fig. 5 where it was noticed huge difference between mechanical durability of the RBD and SDB samples. The second one exhibited much lower resistance increase after over 193,500 bending cycles than the first one which was completely damaged after about 31,500 cycles. Further, it was revealed that resistance value of the SDB antenna showed rapid growth two twice, after about 45,000 cycles and then after about 166,500 cycles. Such a behaviour may be probably attributed to forming of considerable

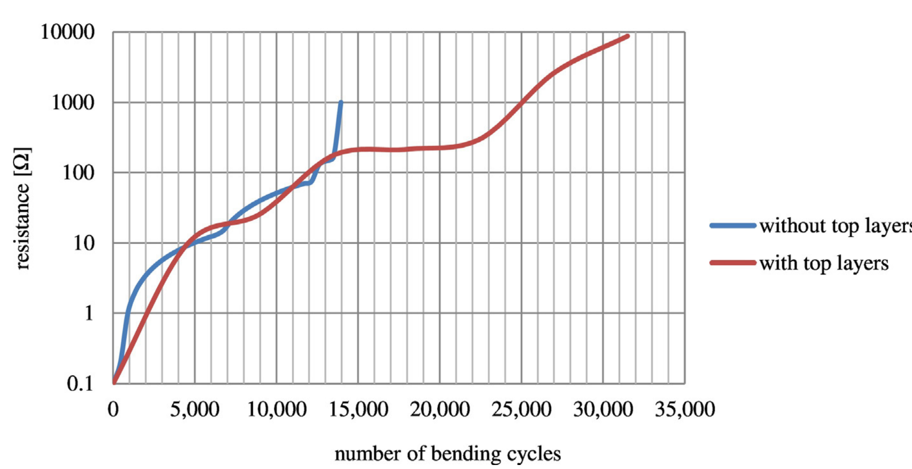

Fig. 3. Resistance changes for the samples with (paper face tag) and without (bare tag) top layers during cyclic bending.

Please cite this article as: K. Janeczek, Reliability analysis of UHF RFID tags under long-term mechanical cycling, Microelectronics Reliability (2017), http://dx.doi.org/10.1016/j.microrel.2017.06.024