Microelectronics Reliability xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Microelectronics Reliability

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

Charging–discharging characteristics of a wound aluminum polymer capacitor

U.H. Jeong [a], J.P. Hyung [b], Y.G. Yoon [c], M.J. Ko [b], S.G. Ha [d], D.H. Lee [e], H.W. Lim [b], J.S. Jang [a,*]

[a] Department of Industrial Engineering, Graduate School of Ajou University, Suwon, Republic of Korea
[b] Reliability Assessment Center, Korea Testing Certification, Gunpo, Republic of Korea
[c] Medical Device Center, Korea Testing Certification, Gunpo, Republic of Korea
[d] Technical Research Center, ENESOL Co., LTD, Yongin, Republic of Korea
[e] Reliability Test Team, LG Display Co., LTD, Gumi, Republic of Korea

ARTICLE INFO

Article history:
Received 3 July 2016
Accepted 8 July 2016
Available online xxxx

Keywords:
Polymer
Power device
Degradation
PEDOT:PSS
Shrinkage
Charging-discharging

ABSTRACT

This study characterized aluminum polymer capacitors, especially when they are charging and discharging. Tests were conducted under various conditions. The following environments were considered: three high-temperature conditions, two high temperature/high humidity conditions, and room temperature. Various operating conditions were also considered, such as charging–discharging, operating, and storage. The test results showed that the capacitance of the wound polymer aluminum capacitor degraded with charging–discharging at low temperature. At lower temperatures, this characteristic accelerated but was mitigated with a dry electrolyte. The degraded capacitances partially recovered when the capacitors were stored at a high temperature. These characteristics were not observed for a conventional liquid aluminum capacitor. This unreported special characteristic of polymer aluminum capacitors should be considered when designing systems such as power electronics. Polymer capacitors are known for their high reliability, especially at high temperatures. At low temperatures, however, the charging–discharging characteristic should be carefully considered. This paper reports on this characteristic of polymer capacitors for consideration by industries.

1. Introduction

Since the development of polymer aluminum capacitors with organic materials [1], their application has increased due to their high reliability, low impedance, thermal stability, and long life. Conventional liquid electrolyte aluminum capacitors have many disadvantages, including high impedance, thermal instability, and liquid electrolyte leakage, because they use a low-conductivity (10^{-2}–10^{-3} S/cm) and thermally unstable liquid electrolyte [2]. Table 1 presents types of electrolytic capacitors and their characteristics.

In 1994, Kudoh et al. [3] studied the thermal stability of polymer electrolytic capacitors and showed that a hermetically sealed aluminum polymer capacitor has excellent stability and can function without any deterioration after 3600 h even at 150 °C. Even if a polymer aluminum capacitor has high reliability, international standards like IEC 60384–26 basically use the same approach as that for conventional liquid electrolyte aluminum capacitors [4]. AEC Q200, which is a standard for the harsh automotive environment, also applies the same requirements as for liquid electrolytic capacitors [5].

Electrolytic capacitors can be used in many domains, such as avionics, automotive, and industrial. Such components are required for most power supplies and have one of the highest failure rates [6]. Compared to conventional liquid electrolytic capacitors, the polymer aluminum capacitor is known for high reliability at high temperatures, but this should be verified for other environments or applications. This paper presents the failure mechanism and special characteristics of polymer electrolytic capacitors.

1.1. Aluminum electrolytic capacitor

Fig. 1 shows the structure of an aluminum electrolytic capacitor, which has an etched aluminum anode foil, aluminum oxide layer as a dielectric, electrolyte, and cathode foil. In a polymer aluminum electrolytic capacitor, the electrolyte is a polymer, not a liquid.

The capacitance can be calculated as follows:

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d} \quad (1)$$

where C is the capacitance, A is the area of two plates, ε_r is the relative static permittivity between two plates, ε_0 is the electric constant (8.854×10^{-12} F/m), and d is the separation between the plates.

Aluminum electrolytic capacitors can yield a high capacitance despite their relatively small size because of the increased area A with the etched anode foil. Aluminum electrolytic capacitors are affected and degraded by the operating environment, especially with regard to the voltage, frequency, and temperature. If an electrolytic capacitor is

* Corresponding author.
E-mail address: jsjang@ajou.ac.kr (J.S. Jang).

http://dx.doi.org/10.1016/j.microrel.2016.07.078
0026-2714/© 2016 Published by Elsevier Ltd.

Table 1
Types of electrolytes and their characteristics.

Types of electrolytes	Working voltage [V]	Characteristics
Conventional	~450	Inexpensive unit capacitance, high temperature/frequency dependency.
Polymer	~100	Low ESR, high reliability
Tantalum	~50	Expensive, compact, low temperature dependency, high reliability

degraded, the capacitance decreases. This increases ripples in the output stage and can make a system or sub-system fail [7].

1.2. Degradation mechanisms of the electrolytic capacitor

A conventional aluminum electrolytic capacitor is known to fail through vaporization of the electrolyte. When a capacitor is charging or discharging, it generates heat internally, which vaporizes the electrolyte. This decreases the capacitance and finally causes the capacitor to fail. This mechanism is the basis for most methods testing the lifetime of conventional electrolytic capacitors [7,8].

Other mechanisms include the charging and discharging ion exchange, which leads to electrolyte degradation, or a voltage surge that causes defects in the aluminum oxide layer. Such defects react with the electrolyte and produce gas and high internal pressure, which can cause a catastrophic failure from the popping of a rubber seal [7].

This study combined conventional high temperature test methods and a charging and discharging test to determine the failure of the electrolytic capacitor. Aluminum polymer capacitors were used as samples with a rated voltage of 63, 68 μF, and PEDOT:PSS (poly polystyrene sulfonate) as the electrolyte. Fig. 2 shows a sample.

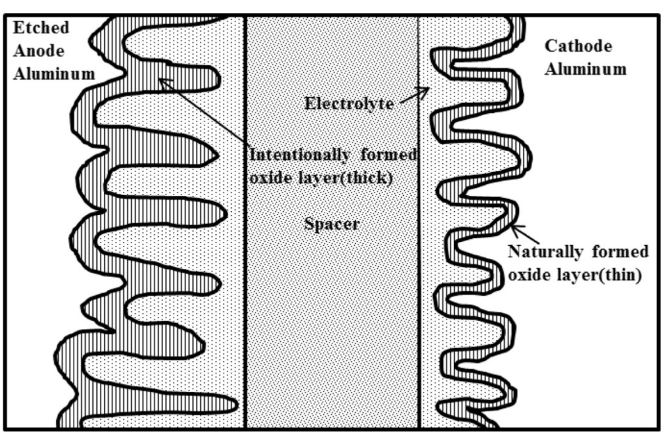

Fig. 1. Structure of an aluminum capacitor.

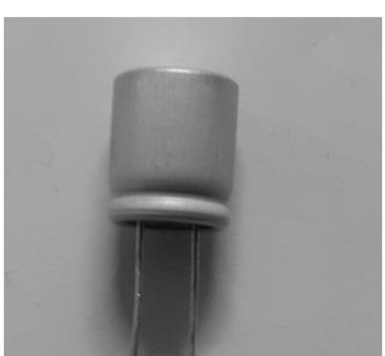

Fig. 2. Tested sample.

Table 2
Test conditions.

Test environment	Test conditions
60 °C/90% RH	30 s charging/30 s discharging 30 s charging/330 s discharging charging No source
85 °C/85% RH	30 s charging/30 s discharging 30 s charging/330 s discharging Charging No source
125 °C	30 s charging/30 s discharging 30 s charging/330 s discharging Charging No source
140 °C	30 s charging/30 s discharging 30 s charging/330 s discharging Charging No source
155 °C	30 s charging/30 s discharging 30 s charging/330 s discharging Storage Operating
Room temperature	5 s charging/5 s discharging 10 s charging/10 s discharging 30 s charging/30 s discharging 30 s charging/330 s discharging

1.3. Test conditions

The test conditions were designed as combinations of high temperature and charging/discharging. This approach is based on the degradation mechanism of electrolytic capacitors, as discussed in Section 1.2. As indicated in Table 2, five samples were tested under all of the conditions. Twenty samples were tested in each environment, and five samples were tested under each condition.

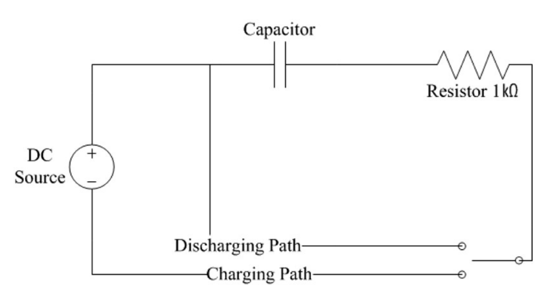

Fig. 3. Test circuit schematic.

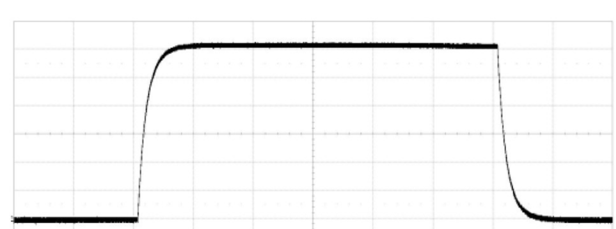

Fig. 4. Measured waveform: 500 ms/div, 10 V/div.

Please cite this article as: U.H. Jeong, et al., Charging–discharging characteristics of a wound aluminum polymer capacitor, Microelectronics Reliability (2016), http://dx.doi.org/10.1016/j.microrel.2016.07.078