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A Reliability Analysis of Metallized Film Capacitors Used for EMI Filtering

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Abstract

Because of their high voltage capability and open circuit failure mode, metallized film capacitors are used to reduce electromagnetic interference (EMI) in electric power mains. This paper provides an in-depth examination of metallized film capacitors used for EMI filtering, as well as their failure modes and mechanisms. Corrosion of the metallized film due to moisture ingress into the package is one of the major failure mechanisms discussed. Standards for metallized film capacitor safety, quality, and reliability are also discussed. The paper concludes with recommendations for film capacitor selection, qualification, and accelerated life testing to ensure long-term reliability.

Keywords: Capacitor • Interference • Metallized • Electromagnetic

Introduction

Capacitors are non-conductive electrical components that store charge on electrodes separated by a dielectric material. These electrodes are thin layers of metal that are insulated by sheets of polymer or paper and co-wound into a tight roll in the case of film capacitors, though vertically stacked configurations are also available. On each end of the roll, a terminal connection is made before it is packaged into a metal or plastic housing [1].

Film capacitors were among the first types of capacitors invented, appearing in 1876. These early capacitors were used in early radio applications and made of wax-impregnated dielectric paper and metal foils. Mansbridge developed a metallized paper film capacitor 24 years later, which improved the technology. This was the first film capacitor to demonstrate metallized films' advantageous ability to self-heal following localised dielectric breakdown (to be discussed later). Film capacitors advanced further in the 1950s, when polymers such as polyethylene terephthalate and polypropylene were used in place of paper [2].

Metal thin coatings have been deposited on polymer films. The wound films are packaged into a capacitor. These capacitors have metallized layers that are 100 nm thick. Both films are wrapped around a hollow mandrel. A metal stoppage is sprayed on to each end of the winding. The stoppage connects the metallization's of the film to the package terminals. Each film has one distinct edge. This is a film edge that does not have metallization printed on it, so that each film connects with only one side of stoppage, effectively isolating the two films and creating a capacitive structure [3].

The ability of metallized film capacitors to self-heal ensures that their electrical characteristics remain stable over long periods of time, making them appealing candidates for industrial applications such as filters in power converters. Some of these industrial applications have life expectancies of more than 20 years, which is several times longer than the life expectancy of typical consumer applications. Industrial applications are typically run at mains voltage levels or higher (> 240 VAC). As a result, not only is dependability important, but so is safety. Metallized film capacitors typically fail in an open circuit mode, which is preferable to other capacitor technologies such as film/foil, which fail in a short circuit mode, increasing the risk of fires in high-power applications [4].

Metalized film capacitors are increasingly being used in low-power capacitive power supplies, where they are connected in series with the application. In traditional applications where capacitors are placed across lines, they are simply used as filters, and the actual capacitance can vary significantly with little or no effect on the application.

Literature Review

Very low dielectric losses, high insulation resistance, low dielectric absorption, and high dielectric strength are all characteristics of PP film. Because the dissipation factor of PP varies only slightly with temperature and frequency, it is an appealing choice for power electronics applications. Furthermore, the film has high moisture resistance and long-term stability. Its dielectric constant has a negative temperature coefficient. PP capacitors are commonly used in high-frequency AC and pulse applications. In addition, they are used in switch mode power supplies. The main issue with PP films is that their maximum operating temperature is only 105 °C, making thermal management critical when used in power electronics.

In the fabrication of metallized film capacitors, two types of metallization are used. The first step is to deposit metallization onto the polymer film. Aluminium, zinc, or a combination of the two is commonly used. Because the thickness of the deposited metallization is frequently in the tens of nanometres range, the sheet resistivity of the metallization contributes significantly to the capacitor's equivalent series resistance (ESR). Because aluminium has a lower resistivity than zinc, thinner layers can be used for a given ESR. Thin metallization's are critical for the capacitor's self-healing. The "schoopage" is the name given to the second type of metallization [5].

Moisture within the package can cause reliability issues like corrosion. Water can carry chlorine, bromine, antimony, and other free ions associated with the epoxy, including the flame retardants in the housing, when it diffuses through the plastic housing that surrounds the capacitor winding. These ions have the potential to improve the corrosion process and rates. If a plastic housing is used, it is critical to test the capacitor in worst-case humidity conditions with and without power to ensure that parameter drift caused by moisture and corrosion is within acceptable limits [6].

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Discussion

Metal cans are frequently impregnated with a dielectric fluid, such as castor oil, to reduce air pockets in the film winding. A small portion of the can is left empty to allow for minor thermal expansion of the capacitor during normal operation. However, if there is significant heating due to dielectric breakdown, gas generation occurs, increasing the pressure in the can and putting stress on the lead attachments. When the lead attachments are stressed, they fail via open circuit, which is a safe failure mode for high-voltage and high-power applications.

When a capacitor fails to conduct current into or out of its plates, it is said to be in the open circuit failure mode. Open circuit failure is advantageous for capacitors used in high power and high voltage applications because it allows for the part to fail safely, as opposed to short circuit mode, which can generate a lot of heat and cause fires. The detachment of the leads from the sprayed metallization is one of the mechanisms associated with open circuit failure. Internal heat causes solder joint failure, which is another cause of open circuit failure. Many of these failure mechanisms are caused by poor manufacturing quality or design, which can increase the application's stress level [7].

Conclusion

Discharge within the capacitor, whether dielectric breakdown or partial/corona discharge, causes a capacitance drop as the metallization vaporises, reducing the available active plate metallization. While this is advantageous in that the capacitor does not form an internal short circuit, the self-healing mechanism reduces capacitance over time. Impurities in the polymer films, the amount of air within the capacitor, the applied voltage to the capacitor, localised factors enhancing the electric field, and the temperature and humidity of the operating environment are the factors that drive the discharge. These factors must be kept to a minimum for long-term dependability. Electrochemical corrosion of metallized film capacitors is becoming more of a concern due to the use of moisture-permeable plastic housings and encapsulants. Moisture diffuses into the capacitor winding and reacts with oxygen and the metallization, oxidising the metallization and reducing the available active plate metallization. Understanding the moisture permeability of a capacitor is critical for understanding how quickly.

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Conflict of Interest

There are no conflicts of interest by author.

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