Engineering Failure Analysis 18 (2011) 2126–2136

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Morphological study of silver corrosion in highly aggressive sulfur environments

Daniel Minzari *, Morten S. Jellesen, Per Møller, Rajan Ambat

Department of Mechanical Engineering, Technical University of Denmark, DK 2800 Kgs. Lyngby, Denmark

ARTICLE INFO

Article history:
Received 15 May 2011
Received in revised form 27 June 2011
Accepted 1 July 2011
Available online 28 July 2011

Keywords:
Coating failures
Corrosion
Electronic-device failures
Failure analysis

ABSTRACT

A silicone coated power module, having silver conducting lines, showed severe corrosion, after prolonged use as part of an electronic device in a pig farm environment, where sulfur containing corrosive gasses are known to exist in high amounts. Permeation of sulfur gasses and humidity through the silicone coating to the interface has resulted in three corrosion types namely: uniform corrosion, conductive anodic filament type of Ag2S growth, and silver migration with subsequent formation of sulfur compounds. Detailed morphological investigation of new and corroded power modules was carried out, and possible theoretical explanation for various corrosion mechanisms has been attempted.

1. Introduction

The use of electronic devices is continuously growing, as new markets are opened, price is reduced and device sophistication is increased. During the past decade, electronic devices have become a consumer item that is expected to be used anywhere in our everyday life, rather than a luxury item that is well taken care of and stored in a secure place.

Industries are receiving the benefits of the modern functionalities that electronic devices provides, and in the farming industries as an example, electronic devices are used for monitoring the food consumption of live-stock, monitoring air quality and temperature, regulation of ventilation, etc. However, the aggressive environment that often exists at industrial sites introduces reliability challenges to the manufacturers of the electronic components and to the materials usage. In the farming industries alone, the corrosive gases that the electronic device is exposed to will vary according to the animals held, the number of animals, on the ventilation, and even on the type of food that the animals are fed [1]. Apart from the corrosive gasses, geographical factors such as temperature and humidity will also influence the corrosion reliability of the electronic device.

Pig farms are known to produce large quantities of odors and aerial pollutants [1–9]. Particulate matter consisting of swine skin cells, feces, feed, bacteria, and fungi [9], and the presence of a wide variety of organic and inorganic gases including corrosive gases such as ammonia, sulfur dioxide, and hydrogen sulfide [6], and organic compounds such as amines and mercaptans could have a severe impact on the reliability of electronic devices. However, the use of electronics in pig farming and in general in the farming sector is increasing; therefore environmental reliability is a big concern. Though this paper takes focuses on a market failure from a pigs farm environment, silver sulfide corrosion has been reported in a number of

Abbreviations: HTF, Hybrid Thick Film; SHE, standard hydrogen electrode; SEM, scanning electron microscope; FEG-SEM, field emission gun scanning electron microscope; FIB, focused ion beam; CAF, conductive anodic filament; IC, integrated circuit.

* Corresponding author. Present address: IPU Technology Development, DK 2800 Kgs. Lyngby, Denmark. Tel.: +45 4525 4825; fax: +45 4593 6213.
E-mail address: dami@ipu.dk (D. Minzari).

1350-6307/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engfailanal.2011.07.003