This PhD project is motivated by the demand for the deeper understanding of the effects of humidity and contamination on corrosion related issues and overall reliability of electronic devices. The information available today is limited and incoherent, thus the directions for the research subtopics were to a significant extent guided by the climatic reliability issues the electronic companies are currently facing. The research in this thesis is focused on the synergistic effects of process related contamination, humidity, potential bias, and PCBA design related aspects, while various tests methods suitable for electrical measurements are attempted and compared with standardized test methods. The focus is also placed on the methods for corrosion prediction on a PCBA layout with the aim of profiling corrosion prone regions or simulating the possible humidity effects on a circuit design assuming parasitic circuit due to water layer formation on the PCBA surface.

The chapters 2-5 review the factors influencing the climatic reliability of electronics namely humidity interaction with materials and ionic contamination on the PCBA surface, common types and sources of ionic contamination in electronics, the test methods and techniques, and failure mechanisms related to climate and contamination. Chapter 6 summarizes the materials and experimental methods employed in this thesis. The results of various investigations are presented as individual research papers as published or in the draft form intended for publication in international journals. Prior to the appended papers, chapter 7 provides a short summary of appended papers with important results and discussion. The results are summarized in 8 papers, presented in chapters 8-15. Papers 1-3 investigate the interaction between ionic contaminants i.e. NaCl, flux residues, WOAs and humidity, and their effects on leakage current, corrosion and electrochemical migration. Paper 4 compares the two types of ionic contamination i.e. NaCl and flux residue in terms of their impact on leakage currents and probability for electrochemical migration, while Paper 5 is focused on the electrochemical migration of tin under pulsed voltage. Paper 6 contains a corrosion study of Au-Al wire bonds and Au-Al intermetallics in iodine environments. Paper 7 presents a novel method developed for profiling of tin corrosion on the PCBA surface. Paper 8 focuses on analysing the feasibility of corrosion prediction by circuit simulation using the combined empirical information from above works assuming parasitic circuit formation. Finally, chapter 16 provides an overall discussion, conclusions, and suggestions for future work.

Overall, the investigations clearly showed the importance of deliquescence RH of ionic contaminants for the degradation of surface insulation resistance and electrochemical migration. This is related to the increase of water layer thickness as a medium for ion transport. Under thin water layers, the concentration of ionic contaminant, bias voltage, and local pH formation are the factors influencing the formation of tin dendrites. Investigation of electrochemical migration under pulsed voltage has shown that the reduction of duty cycle prolongs the time to failure. Under these test conditions, the precipitation of tin hydroxides is more favourable, and fewer metal ions get to reduce at the cathode. Corrosion study of Au-Al wire bonds in iodine environments has shown that the Al metallization and Al-rich intermetallic phases are most susceptible to corrosion. The failure mechanism involves oxidation of Al via formation of Al iodides and consequent formation of Al oxides and/or hydroxides. The method developed for tin corrosion profiling using tin ion indicator gel provides a clear indication of tin corrosion and tin ions movements on the PCBA surface, giving valuable information for corrosion prediction or failure analysis.

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