Tribology and Mechanical Behavior of Coatings and Engineered Surfaces

Room Town & Country B - Session E2-2-ThA

Mechanical Properties and Adhesion II

Moderators: Carsten Gachot, Vienna University of Technology, Austria, **Alice Lassnig**, Austrian Academy of Sciences, Austria

2:00pm **E2-2-ThA-3 Reliability Assessment of Thin Films and Multilayers in Electronic Packages (Virtual Presentation)**, ***Golta Khatibi (golta.khatibi@tuwien.ac.at)***, TU Wien, Austria **INVITED**

The rapid technological advancements and market demands in microelectronic sector requires highly accelerated and practice relevant reliability assessment methods. The devices are composed of a variety of dissimilar materials with different chemical, physical and mechanical properties and length scales. The structural integrity and reliability of the systems is related to the resistance of the constituent materials and their interfaces to alternating thermomechanical loads. Design and fabrication of functional and reliable electronics requires a knowledge of fatigue and delamination behavior of the structures and understanding of the related micro-mechanisms of damage. Recently isothermal accelerated mechanical fatigue testing has been proposed as an alternative to standard thermal cycling procedures for rapid evaluation of microelectronic devices. Dedicated dynamic testing set-ups are designed to simulate the dominating loading conditions in the devices while replacing the thermo-mechanically induced strains with equivalent mechanical strains. As a result, physically meaningful lifetime curves can be obtained and the vulnerable sites of the structures can be detected in a short time.

This talk includes a brief introduction on the application of the proposed method for evaluation of various type of multilayers followed by a case study on the effect processing parameters and environment on cyclic delamination behavior of thin films. The experiments were performed by using a dynamic four-point bending setup working in a broad frequency range, equipped with an environmental chamber. Static and dynamic tests were conducted on suitable sandwich type samples prepared from semiconductor tests structures consisting of Si/SiN/TiW/Cu/Polyimid films.Crack length as well as crack opening displacement was measured intermittently at different loading amplitudes. A fracture mechanics based method was applied to derive the relationship between the delamination growth rate (da/dN) and the cyclic energy release rate (ΔG). It was found that the cyclic interfacial delamination occurred at considerably lower values of energy release rate comparing to the critical adhesion energy of the same interface under quasi static loads. Furthermore, experimentally determined crack propagation rates were explained with a power law depending on the accumulated plastic strain per loading cycle by using FEM simulations.

2:40pm **E2-2-ThA-5 A Measurement Structure for *in-situ* Electrical Monitoring of Fatigue Delamination**, ***Sebastian Moser (sebastian.moser@k-ai.at)***, *D. Tscharnuter, M. Nelhiebel, M. Reisinger, J. Zechner,* KAI Kompetenzzentrum Automobil- und Industrieelektronik GmbH, Austria; *M. Cordill,* Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Leoben, Austria

Semiconductor devices are comprised of multilayer material structures that undergo cyclic thermal loading with associated thermal stresses during service. A typical fatigue mode of such devices is delamination, which may result in impairment of the system's capability of passivating from environmental influences. At a certain stage, delamination might result in a loss of functionality in terms of mechanical, electrical, or thermal aspects sometimes leading to catastrophic failure of the device, for example, by means of bursting or local melting. It is apparent that in such a case, an accurate root cause analysis or localization of the failure is very challenging or even not possible. For this reason, the development of experimental methods capable of characterizing early-stage delamination is desired. This work introduces a specifically designed measurement structure that has been integrated into an actively heated microelectronic test chip and allows monitoring delamination *in situ* by means of electrical resistance measurements. The chip consists of a silicon substrate, a thin stack of functional layers, and a comparatively thick copper metallization (20 µm). Application of heat pulses causes significant thermo-mechanically induced strain in the copper due to its mismatch in coefficient of thermal expansion (CTE_{Cu} = 17 ppm/K) with respect to silicon (CTE_{Si} = 2.56 ppm/K). Under well-chosen experimental conditions, this drives cyclical delamination of the copper metallization from a functional barrier layer. The delamination monitoring structure presented is characterized by a layout with distinct geometric features that, when passed by the gradually advancing delamination crack front, result in characteristic responses in the electrically monitored signal. This allows a straightforward interpretation of the measurement data without having to rely on any separate calibration experiments. The functionality of the delamination monitoring structure has been proven, firstly, by a simple model that predicts the experimentally obtained curves very well and, secondly, by focused ion beam investigations at different delamination stages. A representative experimental study is presented quantifying the effect of different heating amplitudes, Δ*T*, and test environments, forming gas versus air, on the delamination rate.

3:00pm **E2-2-ThA-6 Modeling of Residual Stress Evolution in Thin Films: Effects of Growth Kinetics, Microstructural Evolution and Energetic Particle**, *E. Chason, T. Su, Z. Rao, S. Berman,* Brown University, USA; ***Diederik Depla (diederik.depla@ugent.be)***, Ghent University, Belgium

Residual stresses in thin films have significant effects on their performance and reliability.To control it, it is useful to understand how the stress is related to the processing conditions used for the film deposition.We describe an analytical model that we have developed that relates the stress to the physical processes occurring film deposition.The model explains the dependence on the growth conditions, microstructural evolution and energy of incoming particles.We have implemented this model in a least-squares fitting program to determine the kinetic parameters controlling stress.Modeling results are shown for numerous published results in the literature for different materials (Ag, Cu, Ni, Fe, Cr, Ti, Co, Mo) using evaporation and sputter deposition. The model is being developed into a web-based application that others can use to analyze their stress measurements and predict the stress under different processing conditions.

3:20pm **E2-2-ThA-7 Mechanical, Structural, Morphological and Biological Evaluation of Multilayer Coatings of HA-Ag/TiO2/TiN/Ti on Ti6Al4V Obtained by Magnetron Sputtering for Implant Application**, ***Julián Andrés Lenis Rodas (julian.lenis@udea.edu.co)***, *F. Bolívar Osorio, E. Contreras Romero,* University of Antioquia, Colombia; *A. Hurtado Macías,* CIMAV, Mexico; *P. Rico, J. Gómez Ribelles,* Valencia Polytechnic University, Spain; *M. Pacha Olivenza, M. Gonzales Martin ,* University of Extremadura, Spain

In the present study, multi-layer coatings of hydroxyapatite (HA) - Ag/TiO2-TiN/Ti were obtained on the Ti-6Al-4V alloy, by means of the magnetron sputtering technique. During its evaluation, the techniques of energy dispersive X-ray spectroscopy, X-ray diffraction (DRX), field emission scanning electron microscopy, transmission electron microscopy, micro scratch test, nano indentation, were used. The biological response was evaluated by means of I) cytotoxicity and adhesion of mouse mesenchymal stem cells, and II) adhesion and bacterial viability of Staphylococcus aureus strain. HA coatings with a Ca/P from 1.67 to 1.76 were obtained, whose structure was verified by means of DRX and Micro-Raman spectroscopy. Coatings evidenced a multi-layer architecture. A decrease in hardness and an increase in adhesion to the substrate of the coatings were obtained by incorporating the intermediate layers. The biological evaluation carried out indicated an antibacterial effect and potentially non-toxic character in the coatings.

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