MM 17: Topical Session (Symposium MM): Fundamentals of Fracture

Joint session: Mechanical Properties at Small Scales and Fundamentals of Fracture: Small Scale Fracture Experiments and Ceramics

Time: Monday 17:30–19:00 Location: TC 006

MM 17.1 Mon 17:30 TC 006

Micromechanical testing of glasses at room temperature - the effect of strain rate in micropillar compression and impact nano-indentation — •Christoffer Zehnder[1], Hanno Rempel[1], Jan-Niklas Peltzer[1], James S.K.-L. Gibson[1], Doris Möncke[2], and Sandra Korte-Kerzel[1] — [1]IMM, RWTH Aachen University, Germany — [2]Vaxjö University, Sweden

It is well known that the mechanical properties of glasses are closely related to their atomic structure. The exact structure-property-relationship, however, is only poorly understood even for fundamental mechanisms like shear and densification and their influence on the transition between plastic deformation and fracture. Nanomechanical test methods like micropillar compression and impact nano-indentation can help fill this gap. In this study a sodium-boro-silicate glass is quenched to different temperatures to induce changes in the atomic structure. Micropillar compression was used to introduce plastic deformation into these glasses at room temperature in an uniaxial stress state. By increasing the strain rate it is shown that deformation shifts from stable crack growth to brittle failure. Impact nano-indentation showed a hardness plateau for high strain rates. Changing the glass structure leads to a shift of the corresponding strain rates to different values. These findings are analysed against the background of the glass structure and occurrence of shear and densification is discussed.

MM 17.2 Mon 17:45 TC 006

In situ fracture tests of brittle interfaces at the microscale — Giorgio Sernicola, Ben Britton, and •Finn Giuliani — Imperial College, London, UK

The fracture toughness of ceramics is often dominated by the structure of their grain boundaries. Our capacity to improve the performance of ceramic components depends on our ability to investigate the properties of individual grain boundaries. This requires development of new fracture testing methods providing high accuracy and high spatial resolution. Our approach uses a double cantilever geometry to obtain stable crack growth and we calculate the fracture energy under a constant wedging displacement. The tests are carried out within an SEM, this has two benefits: the sample is well aligned for a controlled test and images are recorded during the test for later analysis. Crucially this allows us to use beam deflection and crack length rather than critical load to measure fracture toughness. Our tests have proved it is possible to initiate and stably grow a crack in a controlled manner in ceramic materials for several microns. This approach has been validated on SiC where it gives a good approximation of the surface energy and then extended to SiC bi-crystals along with Ni-alumina interfaces where crack blunting and bridging mechanism can be observed and measured.

MM 17.3 Mon 18:00 TC 006

Micro-Mechanical Testing of Transition Metal (Oxy)Nitride Coatings — •James Gibson, Shahed Rezaei, Holger Ruess, Oliver Hunold, Stephan Wulfinghoff, Jochen Schneider, Stefanie Reese, and Sandra Korte-Kerzel — RWTH Aachen

Transition metal (oxy)nitride coatings are used in polymer forming operations for a combination of outstanding wear resistance and chemical compatibility with the polymer materials. Varying the chemical composition and deposition parameters for the coatings will optimise mechanical properties by a combination of chemistry and microstructural optimisation. By developing a representative model for these materials, these materials can be rapidly and efficiently prototyped and improved.

The effect of thin film composition and temperature on the elastic, plastic and fracture properties of transition metal nitride and oxynitride coatings was invested by nanoindentation and micro-cantilever bending. Vanadium and titanium aluminium nitride and oxynitride coatings were manufactured by high-power impulse magnetron sputtering on silicon substrates. Notched micro-cantilever beams were used to determine values of fracture toughness. Tests were carried out to 500C in-situ using a Nanomechanics inSEM system. Results are explained via DFT modelling of the coating chemistry, and integrated into a cohesive-zone element finite element model.

MM 17.4 Mon 18:15 TC 006

Onset of damage and anisotropic fracture behaviour of LiTaO3 and LiNbO3 single crystals — •Manuel Gruber[1], Raul Bermejo[1], Peter Supancic[1], Maxim Popov[2], Alexander Leitner[3], and Daniel Kiener[3] — [1]Institut fuer Struktur- und Funktionskeramik, Montanuniversitaet Leoben, Austria — [2]Materials Center Leoben Forschung GmbH, Leoben, Austria — [3]Department of Materials Physics, Montanuniversitaet Leoben, Austria

The requirements on new materials used in mobile communications are governed by the constantly growing data transfer rates. Single crystal piezoelectric materials, e.g. LiTaO3 and LiNbO3, have qualified as good candidates for accurate and efficient frequency filters and are thus also considered for the newest 5G mobile network standards. To optimize the functionality of the filters, a particular orientation and surface conditioning of the single crystal substrate must be ensured. This can affect the structural integrity of the functional material in response to external thermo-mechanical loading.

In this work, the onset of surface damage was assessed using nanoindentation techniques and could be correlated to weaker cleavage planes, where traces of plastic deformation (twinning) together with cracks on the contact surface were observed. Strength and fracture toughness of LiTaO3 and LiNbO3 were measured using biaxial bending on wafer samples of different orientations and in-situ SEM bending of notched micro-cantilevers loaded with a nanoindenter-tip, respectively. Experiments were supported by atomistic modelling, which could validate the experimental observations by calculating cleavage fracture energies.

Topical Talk MM 17.5 Mon 18:30 TC 006

Crack dynamics in brittle crystals: the varying cleavage energies. — •Dov Sherman and Merna Shaheen Mualim — School of Mechanical Engineering, Tel-Aviv University, Tel-Aviv, Israel

We investigated cracks dynamics in quasi-statically loaded silicon crystal on two low energy cleavage systems,(110)[1-10] and (111)[11-2]. The experiments were performed in air and under Ar at atmospheric pressure (low oxygen) to imitate vacuum, at low and high driving forces. The experimental energy speed relationships were compared with Freund equation of motion to extract the varying cleavage energies. An important variable in these experiments was the gradient of the energy release rate, dG0/da, denoted Theta. We show that at low Theta(<0.5 J/m2/mm), the cleavage energy is environmental, cleavage system, and crack speed dependent. At high Theta (>0.5 J/m2/mm), however, the stress corrosion cracking mechanisms vanished for both cleavage systems. The cleavage energy at initiation and propagation remain the same, but linearly increases as Theta increasing. We also specified the range of crack speed where crack dynamics is governed by the Griffith barrier. We indicate on an important physical fact in this investigation, i.e., the curvature of the crack front that giving rise to bond breaking mechanisms in form of kinks along the crack front. Crack propagation by kinks is governed by Theta, with complex advance or formation energies that determines the macroscopic cleavage energy. We therefore connect between the macroscopic cleavage energy and the microscopic crack front bond breaking mechanisms.