MM 54: Biomaterials and Biological Materials IV

Time: Thursday 11:45–13:00 Location: TC 006

MM 54.1 Thu 11:45 TC 006

Hierarchical macroscopic fibrillar adhesives: In situ study of buckling and adhesion mechanisms on flat and wavy surfaces — •Christina Bauer[1,2], Elmar Kroner[1], Norman Fleck[3], and Eduard Arzt[1,2] — [1]INM - Leibniz Institute for New Materials, Campus D2 2, Saarbruecken, Germany — [2]Saarland University, Campus D2 2, Saarbruecken, Germany — [3]Cambridge University Engineering Department, Trumpington Street, Cambridge, CB2 1PZ, UK

Nature uses hierarchical fibril structures to adhere temporary to any kind of surfaces. To understand the effect of hierarchy, the adhesion and buckling of macropatterned adhesives in contact with flat and wavy surfaces was investigated. Macroscopic models possessing up to three hierarchy levels in the range of 0.3 to 4.8 mm were fabricated from polydimethylsiloxane by a soft molding process. For both flat-ended and mushroom-shaped samples, experimental and theoretical studies indicate that the buckling load for hierarchical structures is 4-5 times less than that needed to induce buckling in the single-level structures due to a change in the buckling mode. Such buckling events lead to a loss in surface contact, which diminishes adhesion. Consequently, the number of hierarchy levels was found to strongly influence adhesion.

MM 54.2 Thu 12:00 TC 006

Understanding Macroscopic Interfacial interactions based on Single Molecule Energy Landscapes — Sangitha Raman, Thomas Utzig, Philipp Stock, and •Markus Valtiner — Max-Planck-Institut für Eisenforschung GmbH, Department for Interface Chemistry and Surface Engineering,D-40213 Düsseldorf, Germany

Understanding cell adhesion on metals and oxides, cell-cell interaction or interfaces in biomaterials based on single molecular level details relies on understanding the scaling of single molecule interactions towards integral interactions at the meso- and macroscopic scale. Here, we discuss how one can decipher the scaling of individual single acid-amine interactions towards the macroscopic level, where a large number of these bonds interacts simultaneously, using a synergistic experimental approach combining Surface Forces Apparatus (SFA) experiments and single molecule force spectroscopy (SMFS). We show that equilibrium SFA measurements scale linearly with the number density of acid-base bonds at an interface, providing acid-amine interaction energies of $10.9 \pm 0.2\,kT$. SMFS similarly converges to an interaction energy of $11 \pm 1\,kT$, with unbinding energy barriers of $25\,kT \pm 5\,kT$. Finally, we will also show how other specific adhesive bonds such as the Amine/Gold binding can be successfully studied in the contest of our approach. As such, our experimental strategy provides a unique framework for molecular design of novel functional materials through predicting of large-scale properties such as adhesion, self-assembly or cell-substrate interactions based on single molecule energy landscapes.

MM 54.3 Thu 12:15 TC 006

The influence of reversible cross-links on the mechanical properties of chain-bundle systems — •S. Soran Nabavi and Markus A. Hartmann — Institute of Physics, Montanuniversität Leoben, Leoben, Austria

Although biological materials use a very limited number of base elements to build their structures, these structures show an enormous diversity of mechanical properties. One effective strategy to increase the toughness of these materials is using reversible cross-links in their structures. These so called sacrificial bonds can be found in a large variety of biological materials e.g. bone, wood and in softer fibers like silk and byssal threads. We use Monte Caro simulations to examine the influence of grafting density and cross-link density on the mechanical properties of the chain bundle by determining load-displacement curves. Most surprisingly the results show that only two cross-links are sufficient to break the backbone of the system although the cross-links are weaker than the covalent bond by factor of four. This failure is caused by the topology of the interchain cross-links in the chain bundle where sacrificial bonds are distributed in an ordered arrangement. This backbone failure weakens the strength of the material, but increases the amount of work to elongate the system as well as the apparent stiffness of the bundles. These results bear important implications for the understanding of natural systems and for the generation of strong and ductile biomimetic polymers.

MM 54.4 Thu 12:30 TC 006

Quantum-mechanical study of isotropic elastic properties of amorphous $CaCO_3$ — •Martin Friák[1,2], Gernot Pfanner[2], David Holec[3], Biyao Wu[2,4], Helge Otto Fabritius[2], Dierk Raabe[2], and Jörg Neugebauer[2] — [1]Institute of Physics of Materials AS CR, v.v.i. Brno, Czech Republic — [2]Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf, Germany — [3]Montanuniversität Leoben, Leoben, Austria — [4]RWTH Aachen University, Aachen, Germany

Nearly 80 % of all known animal species are protected by an exoskeleton formed by their cuticle. The cuticle represents a hierarchically structured multifunctional bio-composite based on chitin and proteins. Some groups like Crustacea reinforce the load-bearing parts of their cuticle with amorphous $CaCO_3$ (ACC) in the form of nano-scopic particles. As these particles are too small to be probed experimentally, we use quantum-mechanical methods to determine the phase stability and elastic properties of ACC employing a supercell approach. Our study is focused on the identification of a suitable computational supercell to be used as a structural model for ACC. Amorphous $CaCO_3$ lacks any periodic structural order and it is thus perfectly incompatible with the concept of computational supercells that are periodically repeated by inherent boundary conditions applied in most of computational programs. To address this challenge, we have tested a series of supercells with increasing number of atoms (from 30 to 1000) as structural models for ACC. Aiming at elastically isotropic properties of ACC, we analyze the converging size dependence of our results.

MM 54.5 Thu 12:45 TC 006

Natural crash protection: pomelo peels as inspiration for metal foams with improved impact resistance — •Paul Schueler[1], Sebastian Fischer[2], Marc Thielen[3], Thomas Speck[3], Andreas Bührig-Polaczek[2], and Claudia Fleck[1] — [1]Materials Engineering, Institute of Technology, Berlin, Germany — [2]Foundry Institute, RWTH, Aachen, Germany — [3]Plant Biomechanics, University Freiburg, Freiburg, Germany

In biology, structuring often leads to enhanced properties. Inspired by the pomelo peel that exhibits an impact energy dissipation of over 90 % we develop metal based foam structures. Examples for transferred structural principles are sandwich arrangements of foam layers with varying cell sizes that greatly reduce scatter of the strength values, and fibre reinforcements of the foams that locally stabilise cells by redistributing the load. On a lower hierarchical level, we evaluate the influence of strut microstructure and of the strut and cell geometry. We combine mechanical testing with different imaging techniques: video recordings allow us to evaluate the foams' macroscopic failure mechanisms during low- and high-speed compression tests, while in situ testing in the SEM or lab/synchrotron micro-CT gives 2D/3D-information on deformation and crack development on the microscale, on cells or single struts deformed to defined strain values. We now better understand the deformation mechanisms of the bio-inspired foam structures at different hierarchical levels as well as the influence and interactions of the single hierarchical levels.