DY 44 Growth and Fracture

Zeit: Dienstag 15:45–18:00 Raum: TU H3010

DY 44.1 Di 15:45 TU H3010

Hydrodynamic Interaction in Dendritic Solidification — •Thomas Fischaleck, Dmitry Medvedev, and Klaus Kassner — Otto-von-Guericke-Universität Magdeburg, FNW/ITP, PF 4120, D - 39016 Magdeburg

The effects of convective flow on dendritic crystal growth and pattern formation have been an active research topic for many years, but have not been fully understood on the theoretical side. This is mainly because the governing equations are considerably more complicated than without flow and microscopic solvability theory, successfully describing a single free crystal growing into its quiescent supercooled melt, is no longer applicable in its original formulation.

We present a new approach based on an asymptotic decomposition scheme and extend existing linear solvability ideas to include convective motion in the melt. In particular, we study the case of convection due to an external flow and compare theoretical results to numerical simulations.

DY 44.2 Di 16:00 TU H3010

Scaling properties of step bunches — •Joachim Krug — Institut für theoretische Physik, Universität zu Köln

Step bunching is a ubiquitous instability of vicinal crystal surfaces, which can be induced by a variety of mechanisms such as growth, sublimation or surface electromigration. Recently it has been found theoretically and experimentally that step bunches display characteristic scaling laws, which relate e.g. the height of a bunch to its width. A description of the surface shape evolution in terms of a continuum height equation suggests that step bunching instabilities fall into a few universality classes sharing the same scaling exponents. In this talk the basis of the universality scenario will be illustrated for a particular class of models, and the importance of understanding the properties of moving bunches will be emphasized. The talk is based on joint work with M. Kotrla, A. Pimpinelli, V. Popkov, F. Slanina, S. Stoyanov and V. Tonchev.

DY 44.3 Di 16:15 TU H3010

Komplexe Dynamik von elektromigrations-getriebenen zweidimensionalen Inseln — •Philipp Kuhn[1,2], Joachim Krug[2], Frank Hausser [3] und Axel Voigt [3] — [1]Fachbereich Physik, Universität Duisburg-Essen — [2]Institut für theoretische Physik, Universität zu Köln — [3]Forschungszentrum caesar, Bonn

Die Bewegung zweidimensionaler Inseln auf einer Kristalloberfläche unter dem Einfluss einer Elektromigrationskraft wird im Rahmen eines Kontinuumsmodells untersucht. Wir betrachten den Fall schneller Kantendiffusion, sodass die Fläche der Insel erhalten ist. Die Berücksichtigung der Kristallanisotropie in der Beweglichkeit der Kantenatome führt auf eine Vielfalt verschiedener Bewegungsmodi, die oszillatorisches wie irregulär-chaotisches Verhalten einschliessen. Ein Phasendiagramm der Bewegungsmodi wird als Funktion von Anisotropiestärke und Inselgrösse konstruiert. Für grosse Inseln lässt sich die oszillatorische Bewegung durch das Entstehen von stabilen, ortsfesten Facetten erklären, an denen die Insel vorbeiwandert. Die ausgewählten Facettenorientierungen können analytisch bestimmt werden.

DY 44.4 Di 16:30 TU H3010

Faceting and coarsening of a crystal surface — •Frank Hausser and Axel Voigt — Crystal Growth Group, Froschungszentrum caesar, Ludwig-Erhard-Allee 2, 53175 Bonn

The faceting and coarsening of a growing crystal surface caused by strongly anisotropic surface tension is studied. The dynamics is driven either by surface diffusion accompanied by a depositon flux normal to the interface or by attachment kinetics. In both cases the highly nonlinear evolution equations are derived from a curvature dependent surface energy.

We present detailed numerical studies for 1-dimensional surfaces. For both models, two stages in the formation of facets are found: at a first stage, a rather periodic hill-valley structure is formed. At the second stage three distinct morphologies emerge, depending on the growth rate of the surface: either faceting and subsequent coarsening occurs, or a periodic (faceted) pattern emerges, or the surface becomes rough. Moreover, in the first case, the only coarsening event is a kink ternary, i.e. a coalescence of two kinks and one antikink resulting in a kink. Also, the coarsening rate is shown to obey a power law. This results are in agreement with predictions based on a low dimensional dynamical system.

DY 44.5 Di 16:45 TU H3010

Ostwald Ripening of two-dimensional island — •Axel Voigt and Frank Hausser — Crystal Growth group, research center caesar, Ludwig-Erhard-Allee 2, 53175 Bonn

Ostwald ripening in homoepitaxy in the submonolayer regime is studied by means of classical LSW theory and large-scale numerical simulations. The simulations indicate, that the coarsening kinetics of the average island size is described by a $t^{1/a}$ power law, where $2 \leq a \leq 3$. For the two limiting cases of diffusion limited ripening and kinetics limited ripening the analytical results of the LSW theory are reproduced by the simulations. Besides the scaling law we also investigate island size distribution functions and the influence of anisotropic setp-edge energies and edge diffusion.

DY 44.6 Di 17:00 TU H3010

Slow crack propagation in heterogeneous materials — •Jan Kierfeld[1] and Valerii Vinokur[2] — [1]MPI für Kolloid- und Grenzflächenforschung, Potsdam — [2]Materials Science Division, Argonne National Laboratory

We consider crack nucleation and propagation in a heterogeneous two-dimensional material. Using the generalized Griffith criterion for crack propagation we derive an equation of motion for the crack tip position, which includes dissipation, thermal noise and quenched random forces due to heterogeneities. Depending on the exponent characterizing the power-law decay of the random forces we find qualitatively different behavior of propagating cracks. Sufficiently long-range random forces, as they are realized for frozen dislocations, lead to complete crack arrest thus preventing fracture. Random impurities lead to slowly propagating cracks with creep dynamics. Our results explain the enhanced fracture stability of certain heterogeneous materials, in particular, of work-hardened materials with frozen dislocations.

DY 44.7 Di 17:15 TU H3010

Fast Crack Propagation, Martensitic Transformations and the Grinfeld Instability — •R. Spatschek, M. Hartmann, E. Brener, and H. Müller-Krumbhaar — IFF, Forschungszentrum D-52425 Jülich

Fracture is an intriguing irreversible phenomenon that plays an important role in our day-to-day-life. It is commonly believed that crack propagation is dictated by microscopic details in the vicinity of the tip. However, we present a counterintuitive and surprisingly simple continuum theory which describes crack growth only by (macroscopic) surface diffusion or phase transformations in combination with the dynamical theory of elasticity. It predicts the complicated dynamics of a fast moving crack tip, the saturation of the steady state velocity appreciably below the sound speed, blunting of the crack and a tip splitting instability for high applied tensions. Phase field calculations confirm and illustrate these generic results. They also us allow to study elastically induced martensitic (solid-solid) transformations and melting and crystallization. Also, they demonstrate the development of stressed corrugated solid surfaces in contact with their melt phases (Grinfeld instability), leading to the formation of fast moving and interacting melt fingers. In contrast to earlier theories, it contains a self-consistent selection of the tip radius and the propagation velocity.

DY 44.8 Di 17:30 TU H3010

Explosive Metastable Pitting Corrosion on Stainless Steel (Experiment) — •Monika Bölscher[1], Christian Punckt[1], John L. Hudson[2], Alexander Mikhailov[1], and Harm H. Rotermund[1] — [1]Fritz-Haber Institut der Max-Plank-Gesellschaft, Abteilung für physikalische Chemie, Faradayweg 4-6, 14195 Berlin — [2]University of Virginia, Department of Chemical Engineering, 102 Engineers' Way, Charlottesville, VA, USA

Stainless steel is an alloy specially designed to be corrosion resistant. This resistance is due to a protective oxide layer, which forms naturally on the metal surface in the presence of oxygen. However, all stainless steels are susceptible to pitting corrosion, which can lead to severe damage of the material. It is observed, that pitting corrosion is preceded by the appearance of metastable pits. When metastable pits occur, the surface is eroded locally but the reaction stops after a few seconds and the oxide layer rebuilds. The onset of metastable pitting corrosion is investigated theoretically and experimentally.

Our experimental results show an exponential growth of surface activity and a rapid increase of the number of pits. These findings are consistent with a model, which explains the onset of corrosion as an explosive autocatalytic process.

DY 44.9 Di 17:45 TU H3010

Explosive Metastable Pitting Corrosion on Stainless Steel (Theory) — •Christian Punckt[1], Monika Bölscher[1], Alexander Mikhailov[1], John L. Hudson[2], and Harm H. Rotermund[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Abteilung Physikalische Chemie, Faradayweg 4-6, 14195 Berlin — [2]University of Virginia, Dept. of Chemical Engineering, 102 Engineer's Way, Charlottesville, VA

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Numerical simulations based on a new phenomenological model lead to a fresh understanding of the onset of corrosion. Metastable pits interact with each other and an explosive autocatalytic growth of the number of pits is found. This approach is supported by experimental results.