

Scientific Report
35th IUVSTA Workshop
**“Pattern Formation and Atomic Processes in Epitaxial Growth
and Ion Erosion”,**
Trofaiach, Austria, June 9th – June 13th 2002.

The workshop was attended by 48 participants (among them 5 ladies) from 13 countries: Austria, Belgium, Byelorussia, China, Finland, France, Germany, Italy, Japan, The Netherlands, Russia, Spain, and USA. The workshop program comprised 23 invited talks, 9 contributed talks and 18 poster presentations. The aim of the workshop was a multidisciplinary view on atomic processes and pattern formation during epitaxial growth and ion erosion. It brought together experts and students from the fields of homoepitaxial and heteroepitaxial growth as well as ion erosion of solid surfaces. Strong emphasis was given to the theoretical interpretation of the experimentally obtained results, documented by 7 talks from theorists and to the applications of nanopatterned surfaces.

The workshop started on Sunday evening with an introductory talk by C. Teichert (Leoben) on self-organized semiconductor nanostructures illustrating different routes towards spontaneous pattern formation and their potential applications as templates for subsequent deposition of various materials.

The morning and afternoon sessions on Monday can be summarized under the title: Instabilities and atomic scale investigations in epitaxial film growth. One focus was on the modeling and analytical description of step bunching and step meandering instabilities developing during growth on vicinal surfaces (talks by J. Krug, Essen, and T. Ala-Nissila, Helsinki). One remarkable feature in this respect was a first qualitative description of the atomistic origin of step bunching instabilities on Si(001) on the basis of anisotropic sticking and anisotropic diffusion. Three talks based on scanning tunneling microscopy experiments emphasized the necessity of atomic scale investigations for deciphering kinetics and energetics of pattern formation processes (talks by F. Buatier de Mongeot, Genova, M. Schmied, Vienna, and T. Michely, Aachen). The phenomenon of metastable hut cluster formation in homoepitaxy on Al(110) described in one of these talks is one example for an unexpected new kinetic instability, which will stimulate further atomic scale experiments and kinetic model for its detailed understanding. Two additional talks were related to the development of a correct theory for nucleation on islands, overcoming the mean approach, and to the problem of metal thin film growth on quasi crystals with the ultimate goal of achieving coherent, layer-by-layer growth of a metal on a substrate of fivefold symmetry (P. Politi, Florence, and P. Thiel, Ames).

A highlight on Monday was the Poster Session starting at 5.00 p.m. It included a one-hour introductory session, where each of the 18 posters was orally presented for 3 minutes. Among the 18 posters grouped around the topics "Pattern Formation in Epitaxial Growth", "Ion Bombardment Induced Pattern Formation", and "Applications of Self Organized Surface Patterns" three student posters were awarded with Student Poster Prize of the 35th IUVSTA Workshop, sponsored by the Vacuum Society of Austria (ÖVG). These were: "Faceting and formation of domain patterns on vicinal Ag surfaces induced by an organic adsorbate" presented by S. Schmitt (Würzburg), "Nanoscale dislocation patterning in PbTe on PbSe(001) heteroepitaxy" presented by K. Wiesauer (Linz) and "Stacking-fault islands on Ir(111)"

presented by C. Busse (Aachen). As P. Thiel from the Poster Prize Committee mentioned during the Prize Ceremony on Wednesday evening: “The quality of all posters was outstanding, not only in layout and design but also in scientific content. This made the selection of the prize winners to a difficult task”. The scientific discussions during the well-visited poster session were indeed lively and intense, stimulating the communication between young scientists and Ph. D. students (the majority of the poster presenters) and the senior scientists in the field of pattern formation.

The morning session on Tuesday was mainly devoted to quantum dot formation in semiconductor heteroepitaxy. It started with a theory talk (V. Shukin, Berlin/St. Petersburg) dealing with the thermodynamic and kinetic contributions to pattern formation. It clearly revealed the complexity and difficulty in modeling atomic processes responsible for quantum dot formation. New experimental results were presented for III-V, IV-IV, and IV-VI growth systems. The influence of the substrate vicinality was discussed by I. Berbezier (Marseille). A comprehensive view on strain-induced formation of 3D quantum dot arrays in superlattices was presented by G. Springholz (Linz) whereas M. Tringides reported on uniform-height island growth of Pb on Si(111). The potentials of combining strain-driven pattern-formation with pre patterning via lithography techniques was vividly illustrated by T. Ogino (Atsugi).

The sessions on Tuesday afternoon and Thursday morning dealt with pattern formation by ion erosion. Sputter erosion is a highly efficient and versatile method for nano- and micro-patterning solid surfaces and about one third of the survey talks and oral contributions were devoted to this subject covering the wide range of ion energies from hundreds of eV to MeV. Detailed studies of ion beam induced changes of the morphology of Ag (110), Cu (110) and Rh (110) surfaces as function of fluence and temperature were presented by the Genova group (Boragno, Molle, Valbusa, et al.), while Poelsema (Twente) reported on faceting of Cu (100). New developments using focussed ion beams to produce nanometer-sized ripples, dots and holes, including the fabrication of nanopores for single-molecule detectors in bio-systems, were presented by M. Aziz (Harvard). K. P. Lieb (Göttingen) reported on the first measurements of the dispersion relation of sputter waves on Si. M. Rauscher (Stuttgart) and A. K. Hartmann (Göttingen) addressed improved theoretical concepts of sputter erosion. The production of nanodots on III-V semiconductors and silicon were covered by S. Facsko (Aachen) and L. Vazquez (Madrid). The recent discovery of lamella structures in NiO/SiO₂ bilayers under 90-350 MeV noble gas ion irradiations was outlined by A. Fey (Stuttgart). J. Weaver (Illinois) reviewed the very important field of defect structures and surface modifications in semiconductors induced by (combined) keV electrons and photons. Self-organisation of solid surfaces under irradiation is a lively and challenging field with many surprises achieved and technological applications in sight. It combines phenomena and concepts from the atomic to the mesoscopic length scales.

On Wednesday morning pattern formation in magnetic thin films on metal substrates has been discussed in talks by P. Zeppenfeld (Linz) and S. Pütter (Hamburg). These talks included the presentation of new methods for magnetic and structural characterization of the resulting nanostructures and their control by adsorbate induced surface reconstruction or substrate vicinality. Self-organization in epitaxial growth of organic thin films on a variety of substrates was reported by R. Resel (Graz). Formation of organic nanostructures on inorganic crystalline substrates was also presented in 5 posters illustrating the growing efforts in this field.

It was the intention of the organizers to present also insights from slightly different fields, namely pattern formation in bulk materials. The corresponding two “off-topic” talks were very much welcomed by the participants. J. Schilling reported on the efforts of the group of

U. Gösele (Halle) to obtain large-area monodomain porous alumina with pore sizes down to 25 nm. This material can be used for photonic crystals and as templates for magnetic nanowires or organic and inorganic nanotubes. In a fascinating talk P. Fratzl (Leoben) reported on the hierarchical architecture of biological materials as bone and wood and nature's way to accommodate changing mechanical needs.

Ample time was provided for discussions between the sessions. This had been intensively used by the participants to continue fruitful discussions started during the sessions and to consider possible bilateral and multilateral international collaborations between participating groups of all three fields: homoepitaxy, heteroepitaxy and ion erosion. In this way, the workshop also strengthened the already existing collaborations between theorists and experimentalists.

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Trofaiach, June 13th, 2002