NANOSCALE PERIODICITY IN STRIPE-FORMING SYSTEMS AT HIGH TEMPERATURE THE AU/W(110) SYSTEM

J. de la Figuera, F. Léonard, N. C. Bartelt, R. Stumpf, and K. F. McCarty

Insituto de Química-Física "Rocasolano", CSIC, Madrid 28006
Universidad Autónoma de Madrid, Madrid 28049
Sandia National Laboratories, Livermore, CA 94550
juan.delafiguera@iqfr.csic.es

It has been known for many years that self-assembled stress domain patterns can occur on solid surfaces. These patterns arise from the competition between the short-range attractive interaction between atoms, leading to a phase-boundary energy, and a long-range repulsive interaction between boundaries, due to the difference in surface stress between the two phases. This repulsion is mediated by elastic deformations of the substrate. So far, such stress-domain patterns have been observed and quantified in the low-temperature sharp-interface regime, where the interfaces between the two separated phases are abrupt[1, 2]. Theories of pattern formation at crystalline surfaces have focused mainly on this sharp-interface regime[3,4]. These theories predict an exponential dependence of the periodicity of the stress-domain patterns on the strength of the competing interactions. This implies that it should be possible to tune the periodicity over large ranges, but also that the predictive power of the models is limited in the absence of extremely accurate estimates of the interactions. However, as the temperature is increased the amplitude of the modulated pattern decreases. At sufficiently high temperature, the transition to a homogeneous phase occurs. We call this temperature the order-disorder transition (ODT). As the ODT is approached, the interface width is expected to increase, eventually becoming on the order of the stripe periodicity, making the sharp-boundary theory inappropriate. In this paper we present an experimental study of Au on W(110) which shows explicitly this breakdown.We compare the detailed measured temperature dependence with the mean-field theory of the ODT and argue that nanometer-scale periodicities should be much more common than one would expect from the low-T sharp-interface theory.

Experimentally, quantitative observations near the ODT are difficult because thermal fluctuations of boundaries typically destroy the long-range order of the pat-tern. Here we study stripe formation with long-range order in the system of Au on W(110). As first observed by Duden and Bauer[5, 6], submonolayers of Au on W(110) self-assemble into stripe patterns, which consist of monolayer-thick stripes of condensed-phase Au in coexistence with stripes of a Au adatom gas (see Fig. 1a). Because of strong surface anisotropy, the stripes in this system form along a particular crystallographic direction, [110], and we are able to use low-energy electron microscopy (LEEM) to measure the amplitude (related to the Au density[7]) and wavelength of the pattern as it approaches the ODT. We demonstrate that the amplitude decreases steadily with increasing temperature and vanishes at the ODT. The modulation wavelength also decreases with temperature, depends quadratically on the reduced temperature, but has a finite value of 100 nm at the ODT.

The experimental observations serve as evidence that Au stripes observed on W(110) at high temperature are in the diffuse-interface limit of surface stress domains,with a temperature and coverage dependence qualitatively different from the oft-applied sharp-interface limit. By comparing our results with theoretical calculations of the stripe periodicity, we predict that nanometer-scale stripe patterns should be common near two-dimensional critical points.

This research was supported by the Office of Basic Energy Sciences, Division of Materials Sciences, U.S. Department of Energy under Contract No. DE-AC04-94AL85000, by the Spanish Ministry of Science and Technology through Project No. MAT2006-13149-C02-02.

References:

[1] K. Kern et al., Phys. Rev. Lett. **67** (1991) 855 .
[2] R. Plass, J. A. Last, N. C. Bartelt, and G. L. Kellogg, Nature **412** (2001) 875.
[3] O. L. Alerhand, D. Vanderbilt, R. D. Meade, and J. D. Joannopoulos, Phys. Rev. Lett. **61** (1988) 1973.
[4] V. I. Marchenko, Sov. Phys. JETP **54** (1981) 605.
[5] T. Duden, Ph.D. thesis, Technischen Universität Clausthal, 1996.
[6] E. Bauer, in The many facets of metal epitaxy, edited by D. A. King and D. P. Woodruff (Elsevier, Amsterdam,1997), Vol. 3, Chap. 2, p. 46.
[7] J. de la Figuera, N. C. Bartelt, and K. F. McCarty, Surf. Sci. **600** (2006) 4062.

Figures:

The LEEM image shows the W(110) surface with several steps (wavy lines), with monolayer high islands of Au forming a striped pattern on the surface. The field of view is 7 μm.