ESRF

	Experiment title: Critical Behavior at the Disordering of the Ge(113) (3x1) Reconstruction	**Experiment number:** SI-151
Beamline: ID3	**Date of Experiment:** from: 24/1/96 to: 1/2/96	**Date of Report:** 3/3/97
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Report:

Transformations between the different phases of a uniaxial overlayer on a substrate allow 2D critical behavior to be studied experimentally. In particular, according to universality, the disordering of a (3x 1) commensurate (C) solid is expected to conform to the J-state chiral Potts model [1,2]. Surprisingly, there is still no consensus theoretically on the phase diagram of such systems. One possibility is that there exists a direct transformation upon changing the temperature between the C-solid phase and an incommensurate (IC) fluid phase for small chirality, defined as the free energy difference between light and heavy domain walls. At larger chirality, there is a two step disordering process, with the C-solid passing through an IC-solid phase before going to the fluid phase. The goal of the present experiment was to determine the critical behavior of the disordering of the Ge(113) (3x1) reconstruction, thus helping to shed light on the phase behavior of three-fold degenerate uniaxial systems.

Several days before the experiment, two heating schemes were tested in the UHV end station at ID3 in collaboration with beamline staff. A Ge wafer (14 x 5 x 0.5 mm^3) was mounted so that a direct current could be passed through it for heating, and also a more traditional electron bombardment heating arrangement was used for a larger sample (12 x 10 x 2.5 mm^3). The electrical leads for the direct current had been enlarged compared to a previous attempt, but it was found that intermittent noise did not allow the power supply to achieve sufficient stability. The electron bombardment heating could be stabilized to about 0.2” by using the analog signal from a pyrometer in a feedback loop controlling the acceleration voltage of the electrons. It was necessary to use a holder where a hole in the molybdenum sample plate allowed direct bombardment of the Ge sample by the electrons. Without this hole, unexplained jumps in temperature of the sample occured which could not be damped by the temperature controller.

Well-ordered commensurate (3x1) peaks were produced by Ar+ sputtering at roughly 600°C, and the progress could be monitored by measuring the reconstruction peak width. Transverse widths were typically 0.03" at the (5/3,-l) commensurate position, corresponding to domains at least 4000Å in extent. Slits were used to define the acceptance of the detector, and the incidence and exit angles were held near the critical angle to reduce thermal diffuse scattering from the bulk.

Peak positions and peak widths as a function of temperature both along (x) and perpendicular to (y) the direction of the incommensurability were extracted by fitting together Q_x and Q_y scans at the (5/3,-l) reconstruction peak. A 2D Lorentzian profile on a slowly varying background was used with no resolution correction. In figure 1 are plotted the ratio of the incommensurability (ϵ) and the inverse correlation length (κ_x) and the ratio of the two inverse correlation lengths for temperatures at least 5°C above the transition. The temperature independence demonstrates that these variables scale in the disordered phases with the same exponents. This agrees with predictions for the chiral melting universality class for the ratio ϵ/κ_x [2], and the values are consistent with a previous LEED study [3]. The disordering of the Si(113) (3x1) reconstruction was rather different [4], with anisotropic scaling of the correlation lengths and a much larger value of ϵ/κ_x.

The peak position of the scattering as a function of temperature is plotted in figure 2. Open symbols are for 0.5mm in-plane slits, and filled symbols are for 2mm slits. Measurements during heating are represented by circles, and cooling by squares. The solid line is a power-law in reduced temperature $t = (T-T_c)/T_c$ with T_c = 1055K and an exponent of $\bar{\beta}$ = 0.66. This is consistent with the previous LEED results as well as the value found for Si(113). It is not possible to rule out a smaller value of $\bar{\beta}$ around 0.5, but the zero chirality Potts model value of 5/6 is not consistent.

A closer look at the behavior near T_c is shown in the inset. Below 1040K the peak shifts to smaller values, consistent with thermal expansion of the lattice, but then shifts to larger values until T_c. In this range the peak widths are constant or decrease somewhat as the temperature is raised, perhaps due to an annealing effect. This strange behavior seems to indicate that there are two possible transitions, which would place the disordering of Ge(113) (3x1) notin the chiral melting universality class, but in a region of the phase diagram where an intervening IC-solid phase is expected. The intensity of the scattering in this temperature range deviates from the expected variation of the commensurate order parameter, which could explain the necessity of using a large thermal gradient to fit the intensity reduction seen before [SI-90 Report]. This phenomenon must be confirmed with further study.

Figure 1

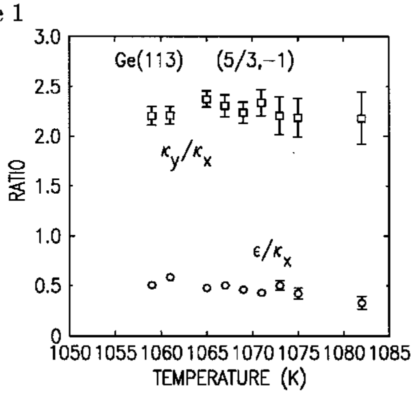
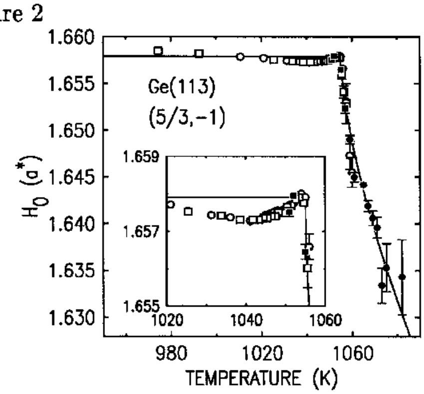


Figure 2



[l] See M. den Nijs, in ***Phase Transitions*** and ***Critical Phenomena,*** edited by C. Domb and J. L. Lebowitz (Academic Press, Orlando, 1988), Vol. 12. and references therein.

[2] D. A. Huse and M. E. Fisher, Phys. Rev. Lett. 49, 793 (1982); D. A. Huse and M. E. Fisher, Phys. Rev. B 29, 239 (1984).

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[4] D. L. Abernathy, R. J. Birgeneau, K. I. Blum, and S. G. J. Mochrie, Phys. Rev. Lett. 71, 750 (1993); D. L. Abernathy, S. Song, K. I. Blum, R. J. Birgeneau, and S. G. J. Mochrie, Phys. Rev. B 49, 2691 (1994).