Time-Resolved Reflection Surface X-ray Diffraction of Pb Films on Si(111)-(7x7) at Low Temperatures

H. Hong,[1] Z. Wu,[2] H. Chen,[1,2] M. Holt,[3] T.-C. Chiang,[1,3]

[1] *Fredrick Seitz Materials Research Laboratory, University of Illinois, Urbana, IL, U.S.A.*

[2] *Department of Material Science and Engineering, University of Illinois, Urbana, IL, U.S.A.*

[3] *Department of Physics, University of Illinois, Urbana, IL, U.S.A.*

Introduction

Pb films grown at low temperatures have drawn much attention due to their ability to form islands with uniform heights.[1] It has been suggested that the driving force for the islands of magical heights is of electronic origin. Surface tension and strain may not drive these flat top islands.

Experiments

Measurements were conducted on the UNI-CAT surface/interface diffractometer at the undulator beamline of the sector 33-ID. The surface/interface diffractometer is equipped with a UHV chamber, which has MBE capabilities. The sample temperature was controlled by a direct current flow through the sample, which was cooled with liquid nitrogen. Deposition was made from an effusion cell, and the deposition rate was calibrated with a crystal-thickness monitor.

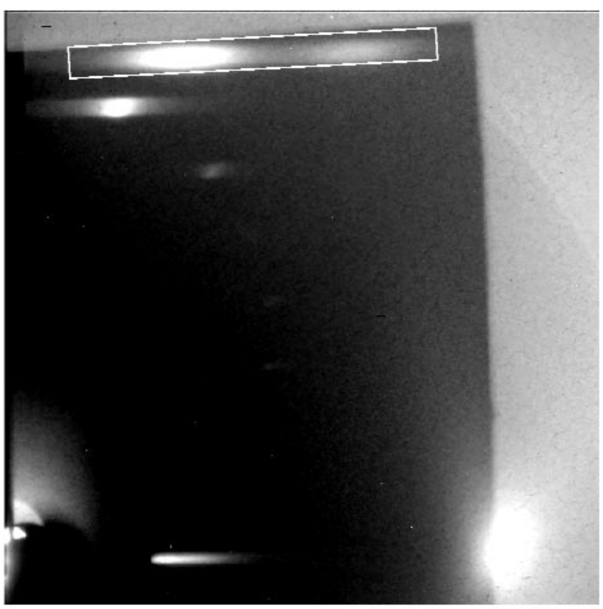

FIG. 1. A RSXD image. The white rectangle is the area of integration.

Reflection surface x-ray diffraction (RSXD) is a method to observe and collect reflected high-energy electron diffraction (RHEED)-like surface diffraction patterns with x rays.[2] One can collect surface diffraction patterns as the surface goes through changes, such as deposition, etching and thermal annealing. At the same time we can take the advantage of x-ray scattering for precise structural determination. RSXD allows for the simultaneous measurement of fractional diffraction patterns, crystal truncation rods, reflectivity and diffraction from the film. The CCD images were taken without interrupting deposition. Exposure times vary from 0.5 to 10 seconds. The typical deposition rate was 1 monolayer (ML) per few minutes.

Results

Figure 1 shows a typical RSXD image. The shot was taken at the completion of 4 MLs of Pb at 150K. The boxed area of the image shows the intensities of superimposed diffraction, originated from Pb ($\bar{1}$ 1 1) and Pb (2 0 0). One can also see the first ring of (n/7 0) peaks from Pb(8x8) on Si(111)-(7x7). These (7x7) peaks are persistent throughout the deposition processes. The sudden increase in the intensities of these peaks at the commencement of deposition indicates the decoration by Pb over Si-(7x7) reconstruction. As the deposition proceeds, the intensity ratios between (7x7) peaks change. Close to completion of the first wetting layer, (8/7 0) becomes strongest. This is a firm confirmation on the Pb (8x8) wetting layer commensurate to the underlying Si(111)-(7x7) structure.[3]

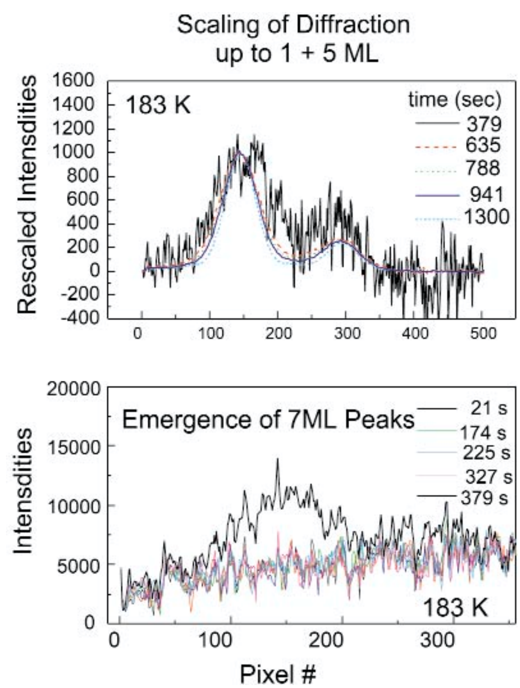

FIG. 2. Time evolution in intensity profiles of Pb diffraction.

To investigate the formation of flat-top islands with uniform heights, the intensities in the boxed area were integrated through the same Qz [the momentum transfer in the direction of Pb (111)]. The intensity profiles at different points in the deposition are shown in Fig. 2. The intensities are scaled to produce the same peak heights. The line shapes of the profiles are not exactly same. The detailed line-shape analysis told that the heights of islands changed from 5 to 7 MLs. They are not always 7 MLs, the reported magical height. This difference may be due to the uninterrupted deposition. In this experiment, islands are under kinetic equilibrium between the deposition flux and adatom diffusion. Islands of the 7-step uniform height may require short annealing after the deposition is stopped The scattering from islands appears abruptly at 1.8 MLs (379 s.). This indicates there is a critical number of atoms necessary to form flat-top islands.

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