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Growth of Strained Epitaxial Cu Films on Ru(0001) Monitored by Surface X-ray Diffraction

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In this paper, we describe x-ray scattering studies of the behavior

changes in the electron density caused by material deposition, since the scattering contribution from the crystal bulk is minimal. This follows from Equation 1 on which the above models are based.

$$I(Q_z) = \left| \frac{1}{1 - e^{-iQ_z} e^{\frac{-c_0}{\mu}}} \cdot \sum_b f_b e^{iQ_z z_b} + \sum_s f_s e^{iQ_z z_s} \right|^2 \qquad (1)$$

Q_z corresponds to the momentum transfer of the scattered x-rays normal to the surface and c_0 is the Ru lattice constant normal to the surface. The variable μ represents the x-ray penetration depth. Summations are over bulk (b) and surface (s) atoms in a single unit cell. Within the summations, f_b and f_s are atomic scattering factors of the bulk and surface atoms, respectively, and z_b and z_s are the positional vector components normal to the surface of the respective atomic layer. The first term, which calculates the effect of the break in symmetry at the surface, approaches 0 for $Q_z = 1$. The diffracted intensity is then strongly dependent on the last term of Equation 1, which represents only the diffraction amplitude of the surface structure. It follows that for an even number of deposited Cu layers on the Ru(0001) surface, the intensity reaches a local maximum for $I(Q_z=1)$, whereas for an odd number of layers there is a minimum as can be seen in Figure 1. The integrated intensity of transverse scans at $Q_z = 1$ during Cu deposition should, therefore, oscillate with a period which is equivalent to the deposition of two layers.

Figure 2 shows the experimental results of the anti-Bragg peak intensity behavior for deposition up to 6 ML of Cu on Ru(0001) and for several substrate temperatures. Instead of monitoring the (0,0,0,1) anti-Bragg reflection, we measured the nearby (0,0,0,0.9) reflectivity to avoid possible multiple scattering at the (0,0,0,1) which is not accounted for in equation 1. For temperatures between 500 and 850 K and up to a Cu coverage of 3ML, the growth of three Cu layers on top of the Ru substrate is apparent from the two intensity maxima and minima of the anti-Bragg reflection in Figure 2. After deposition of the third

Cu coverages above 2 ML, a 2 layer surface reconstruction is formed together with Cu(111) bulk-like islands [22]. New diffraction peaks appear after exposures above 2 ML at a lattice vector appropriate for bulk Cu(111). The intensity of these new peaks continues to grow with exposure.

Conclusions

The growth behavior

[10] H Wolter, K. Meinel, Ch. Ammer, K.

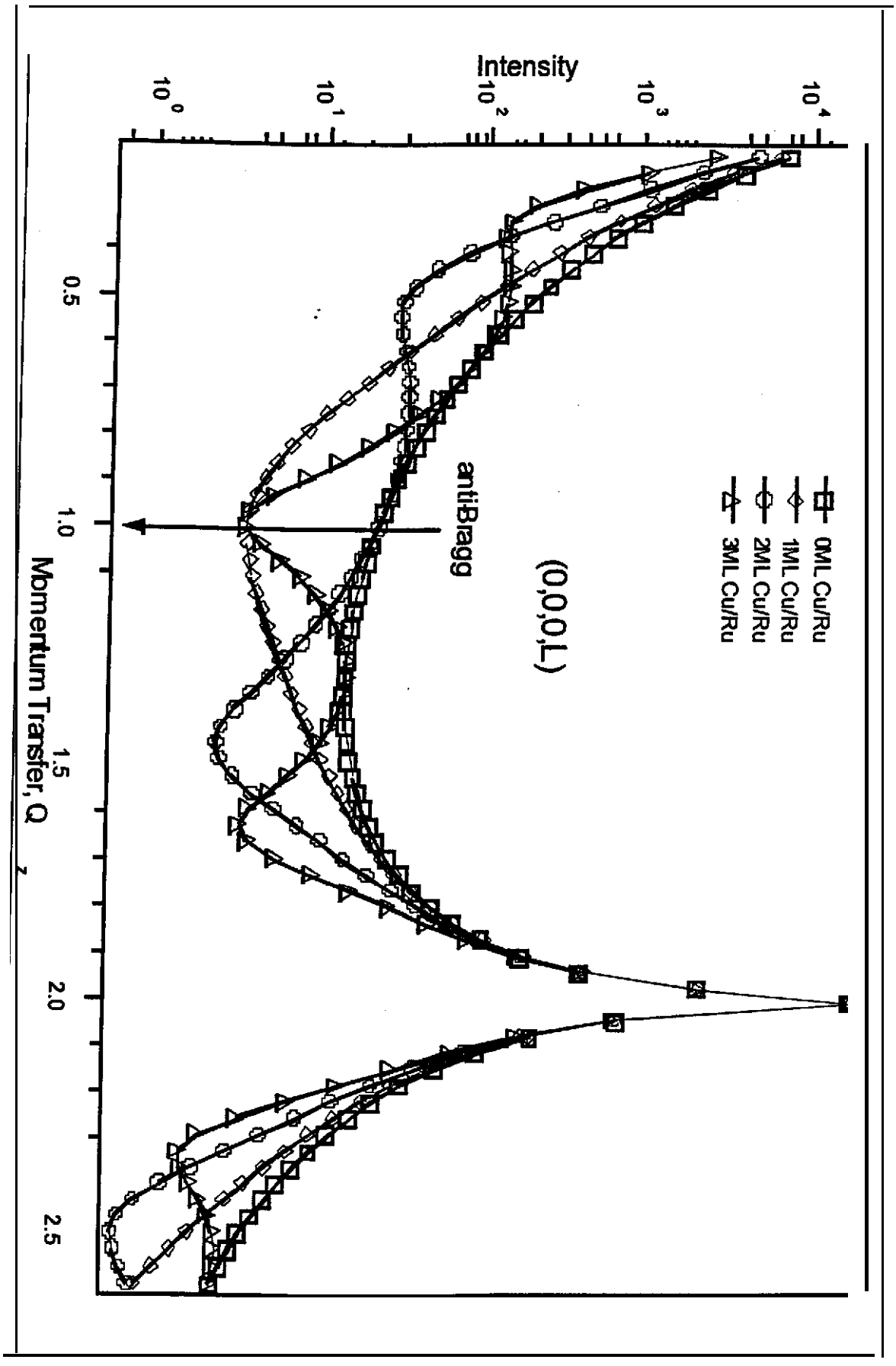
Intensity
10^0
10^1
10^2
10^3
10^4
0.5
1.0
1.5
2.0
2.5
Momentum Transfer, Q_z
antiBragg
(0,0,L)
0ML Cu/Ru
1ML Cu/Ru
2ML Cu/Ru
3ML Cu/Ru

Figure 1

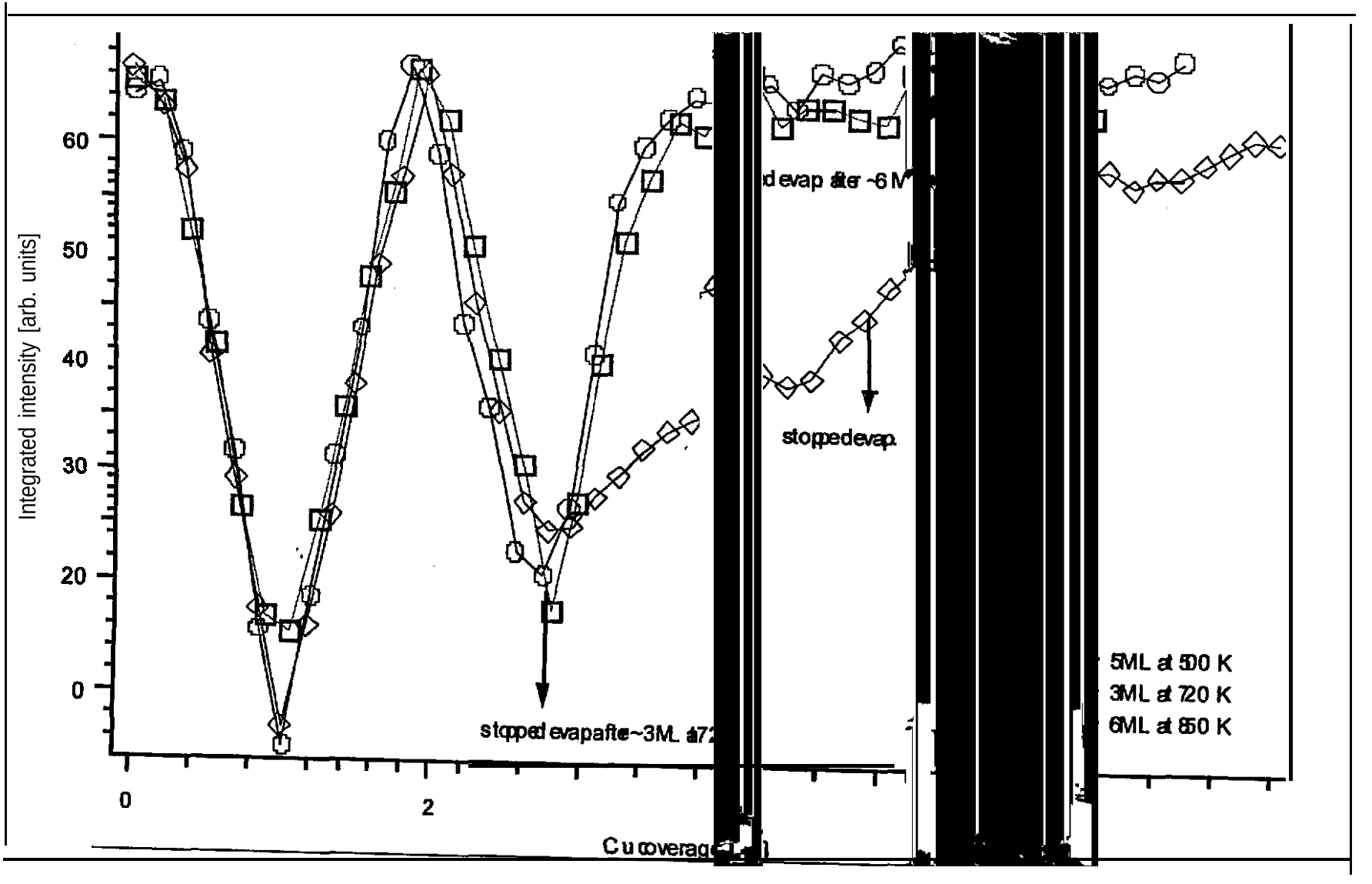
Integrated intensity [arb. units]
60
50
40
30
20
0
0
2
stoppedevap.
5ML at 500 K
3ML at 720 K
6ML at 850 K

Figure 2