STM and LEEM characterization of the interaction between magnesium grown on Ru(0001) and hydrogen

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Magnesium is a readily available non-toxic metal whose hydride (MgH_2) is being studied as a potential hydrogen storage medium, owing to its large content of 7.6% by weight of hydrogen. Magnesium is known to grow as almost perfect thin films on many substrates; in some instances, like in the case of refractory metals, with very sharp interfaces. Since a layer of MgO/$Mg(OH)_2$ grows onto the magnesium surface when it is exposed to air, changing its reactivity, the understanding of the interaction between the surface of the magnesium layer and hydrogen is of the utmost importance. Most of the few works that have been devoted to the preparation of magnesium on refractory metals study its growth on W(110) substrates [1,2]. A study about the epitaxial growth of magnesium on Ru(0001) using low-energy electron diffraction (LEED) [3] reported that magnesium keeps its own in-plane spacing when growing on such substrate, owing to the large mismatch between their respective in-plane lattice spacings (around 18%). This results in a moiré pattern on the magnesium surface, and an overlayer film without significant strain. Additionally, not much has been published about scanning tunnel microscopy (STM) characterization of epitaxial growth of magnesium up to two monolayers at room temperature.

This work is a continuation of our recent studies about the growth and hydrogenation of magnesium on Ru(0001) substrates in ultra-high vacuum [4,5]. The characterization techniques we have employed are STM and low-energy electron microscopy (LEEM), an in-situ technique that provides real-time observations at different temperatures with spatial resolution of nanometres. Magnesium was grown to a thickness of one to ten atomic layers by evaporating a rod heated by electron bombardment at a pressure in the low 10^{-10} Torr range, with a typical deposition rate of about one monolayer per minute. Up to a temperature of 430 K, the films present a layer-by-layer growth with three levels exposed at the most. The submonolayers of magnesium, detected only by STM and only in the first two atomic layers, show a moiré pattern with a periodicity of 12 Å, as can be seen in figure 1. Dark-field LEEM experiments show that films with a higher number of monolayers present stacking faults and, on stepped areas, screw dislocations are observed by STM (see figure 2), owing to the mismatch of the step heights of magnesium and ruthenium in these areas. Electron reflectivity shows quantum size effects in the unoccupied bands, indicating an abrupt interface between magnesium and ruthenium for the thicker films. Additionally, we have studied the exposure to H and H_2 of the growing films by LEEM and STM. While growth in an H_2 atmosphere produces no significant change in the magnesium films, LEEM measurements have demonstrated the nucleation of dark islands as soon as H is fed into the vacuum chamber; further exposure to H leads to their almost covering completely the field of view. Using a mass spectrometer, we have performed thermal desorption experiments in these dark islands (see figure 3), which show that hydrogen is the only gas desorbed, with a sharp peak around 470 K coinciding with the disappearance of the islands in the LEEM images. At higher temperatures, only a faint trace of them remains on the surface.

References

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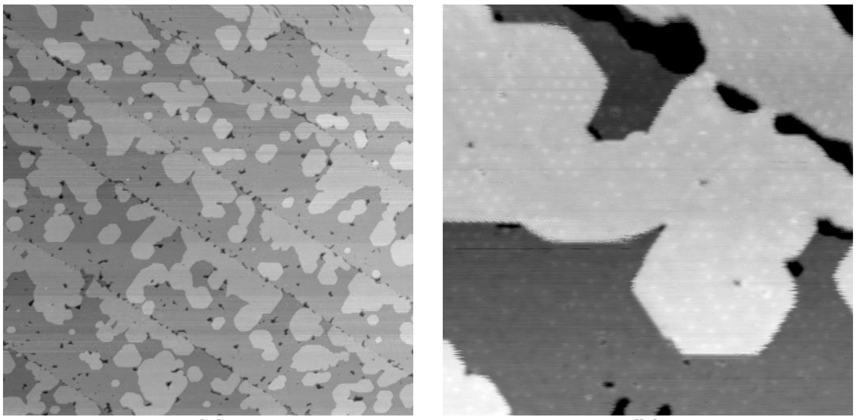
Figures



(a) **(b)**

Figure 1. STM images of a magnesium film with an almost complete first monolayer and islands of the second monolayer. a) 4500-Å wide image, and b) 550-Å wide image, in which the moiré in the islands can be seen.

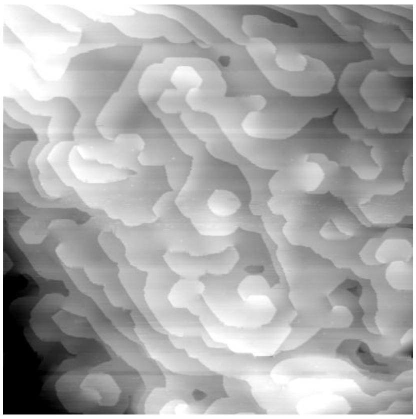


Figure 2. Screw dislocation in stepped areas seen by STM (image width and height: 3500 Å).

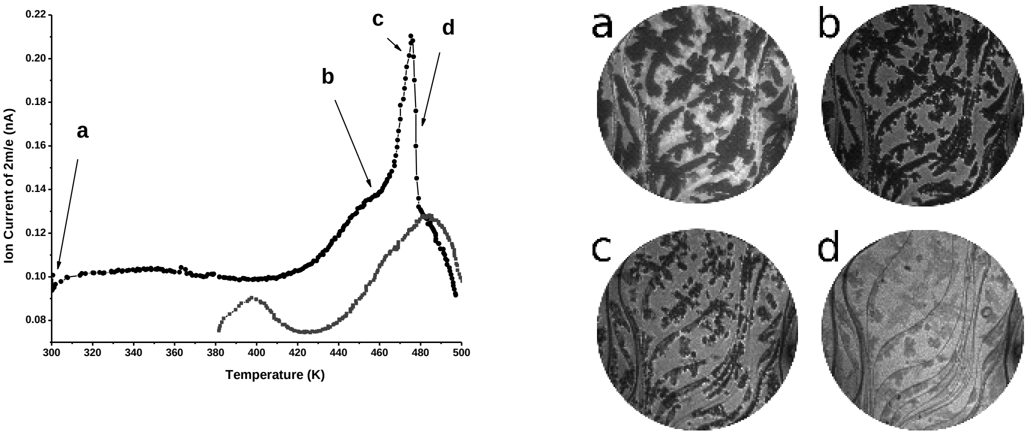


Figure 3. Thermal desorption measurements carried out in the dark islands of magnesium films with ten atomic layers grown under exposure to H_2 (lower curve) and H (upper curve). Labelled temperatures in the upper curve correspond to each of the LEEM images on the left (field of view is of 15 µm).