A STUDY OF METALLIC SURFACES BY UHV STM

R. KALOUSEK AND M. SCHMID*

Institute of Physical Engineering, Brno University of Technology, Czech Republic
**Institut für Allgemeine Physik, Technische Universität Wien, Austria*

ABSTRACT

The results of atomically resolved surface structure studies performed at TU Vienna on metallic surfaces by UHV STM are presented. In particular, atomic structures of clean surfaces Pt(111), Co thin films on Pt(111), (2×4) and (√3×√3)30° superstructure of adsorbed molecules of CO on Pt(111) and Co(111), respectively, is shown and discussed.

INTRODUCTION

Heteroepitaxial growth of thin metal films has been studied for many years. Particularly, thin Co layers on Pt substrate and Co–Pt multilayers attract many researchers for the reason that they can be used as components for high density magneto-optical (MO) storage media. Besides other properties, one can observe the perpendicular magnetic anisotropy of very thin Co layers in Co–Pt multilayers necessary for MO recording [1]. Magnetic properties exhibit dependency not only on thickness of the Co layers but also on their detailed structure. Therefore, it is important to investigate atomically resolved interface formation between Co and Pt. Scanning tunneling microscopy under ultrahigh vacuum (UHV STM) is suitable for this purpose due to its very high resolution (units of angströms).

EXPERIMENT

The STM measurements were performed at an UHV chamber with pressure 5×10^{-9} Pa. All STM images were obtained in the mode of constant current. The preparation of a new clean surface of Pt(111) started with Ar^+ ion sputtering with an energy of 2 keV and followed by annealling at temperature roughly about 900°C. Co was deposited from a water-cooled electron beam evaporator, the typical evaporation rate was 1 monolayer (ML)/1 min. For some experiments the deposition was preceded by a CO dose for 5 min with pressure 7×10^{-5} Pa (the base pressure in the preparation chamber was 3×10^{-8} Pa). The cleanliness of the Pt(111) substrate and amount of adsorbed and deposited atoms was checked by Auger electron spectroscopy.

RESULTS

This section is divided into two parts. The first part is focused on low coverage of Co on Pt(111), e.g. from 0.1 ML up to several ML, and high coverage (15 ML). In the second part, we will discuss a CO superstructure on Pt(111) and on Co(111) created by high coverage (15 ML).

Low coverage of Co on Pt(111)

Pt has fcc lattice structure with lattice parameter 3.92 Å. The distance between the nearest neighbour (nn) is 2.77 Å. The upper-most layer of the crystall in the (111) plane is on Fig. 1. The white circles show atoms which belong to one primitive cell. The nn distance found experimentally by STM is 2.6 Å. The difference between tabelled and measured lattice parameters is due to drifts of the piezoceramic scanning unit in the STM (the same reason valid for other parameter differences in the paper).

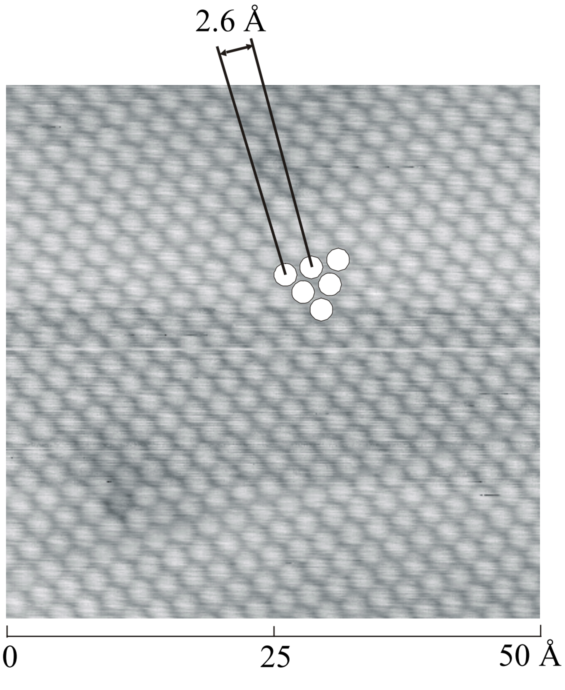

Fig. 1. STM image of Pt(111). White marked atoms belong to one primitive cell; tabelled value for distance between the nearest neighbours is 2.77 Å.

The first deposited layer shows up structure with triangular shapes appearing due to lattice mismatch of -9.4 % between the Co (nn distance is 2.51 Å) and Pt substrate. Co atoms within the triangulars have roughly the same nn distance as Pt atoms below and create still fcc structure, but atoms out from the triangulars create hcp structure with the respect to the substrate lattice (see Fig. 2). The bright border around the triangulars is a partial dislocation line.

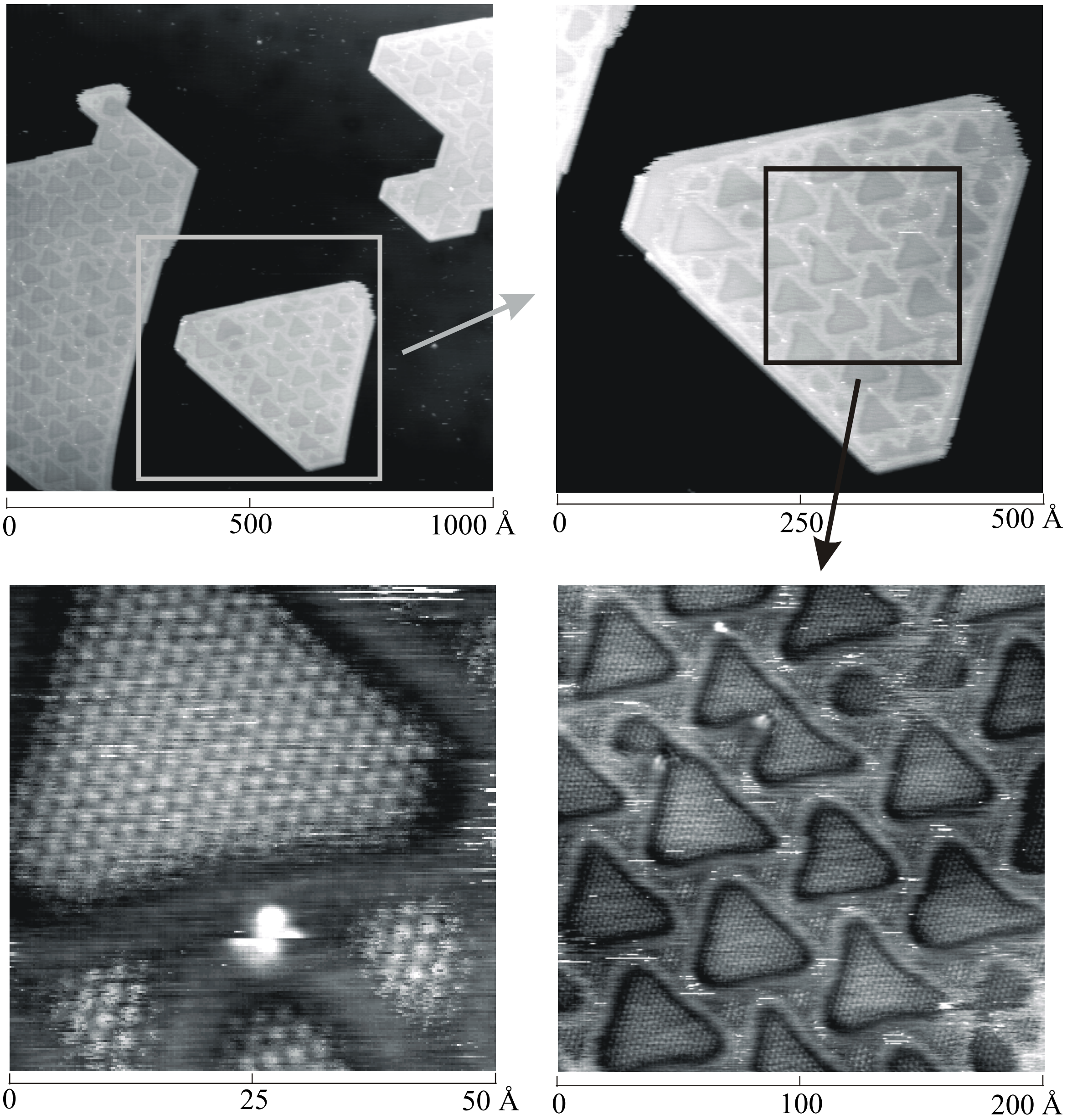

Fig. 2. First Co layer on Pt(111). Atoms within triangulars create fcc structure, atoms out from the triangulars create hcp structure with the respect to the substrate Pt lattice. The bright border around the triangulars is a partial dislocation line.

The moiré structure appears on the second layer (see Fig. 3). This is a result of different in-plane lattice spacing between the Co overlayer and Pt lattice. The periodicity of the moiré structure was found as 12.7±1.1 Co atoms resulting in a Co in-plane lattice constant contracted by (7.9± 0.7) % as compared to the Pt(111) in-plane lattice distance [2].

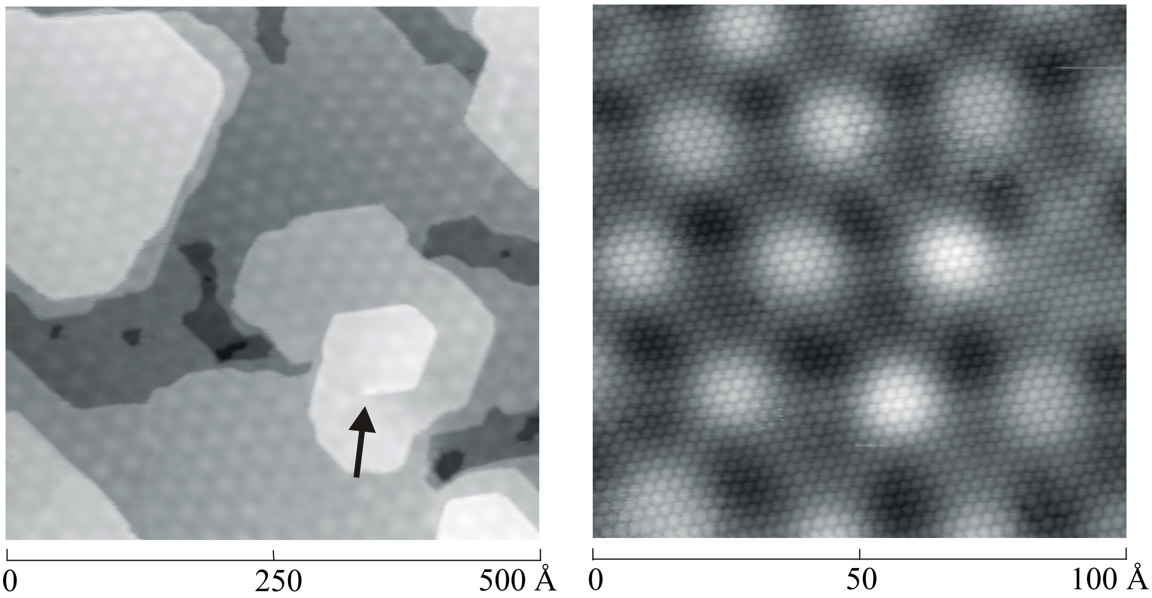

Fig. 3. Second and next layers of Co on Pt(111). Contracted in-plane lattice spacing of the Co overlayer and the Pt(111) surface. The black arrow points to the beginning of the atomic step. The film has still an epitaxial growth mode.

From the STM images (see Figs 2–3) it is obvious that in case of low coverage (several ML) of Co on Pt(111) the growth is almost epitaxial (layer by layer). If we focuse on higher coverages (more than about 10 ML) the growth changes from a two–dimensional to a three–dimensional mode. Such a growth is called the heteroepitaxial or Stranski–Krastanov mode. The 2D growth is preferred if the sum of the surface free energy of the adsorbate and its interface free energy is larger than the substrate free energy, the 3D growth is the oposit case.

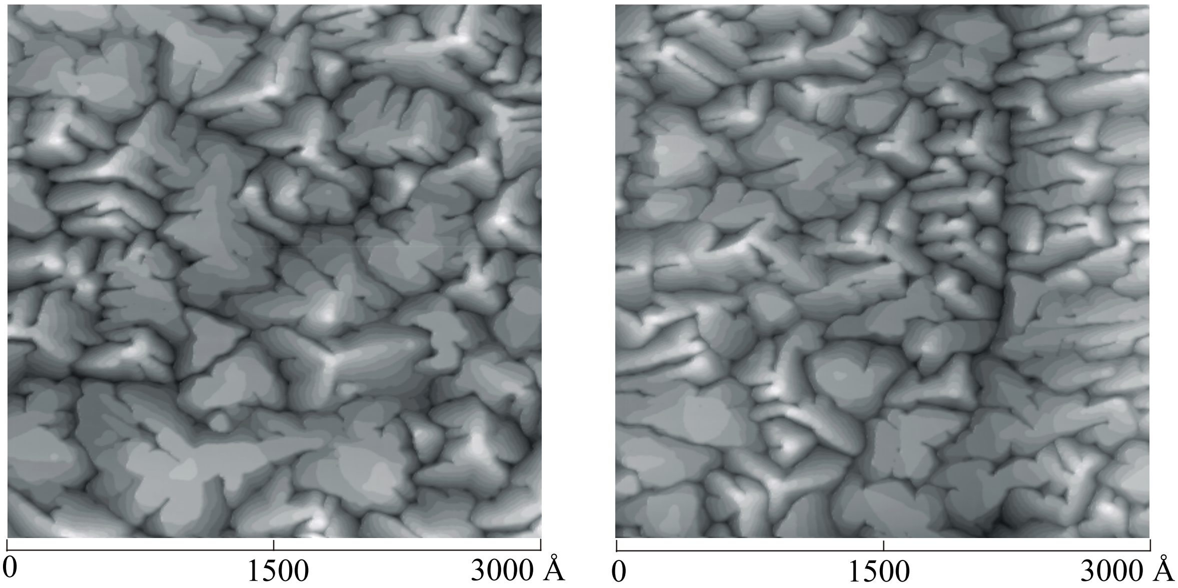

Fig. 4. High coverage of Co on Pt(111). 15 ML-thick-Co film has already a 3D growth mode.

During heteroepitaxy the energetic difference changes its sign at a critical layer thickness [2]. A 15 ML-thick-Co film shows a 3D growth mode (see Fig. 4). One of the proofs that Co grows preferably in an fcc stacking sequence instead of hcp is the observable stacking fault plane intersecting an fcc (111) surface with the typical 2/3 and 1/3 steps (see Fig. 5). This kind of stacking fault may only exist in an fcc stacked film [2].

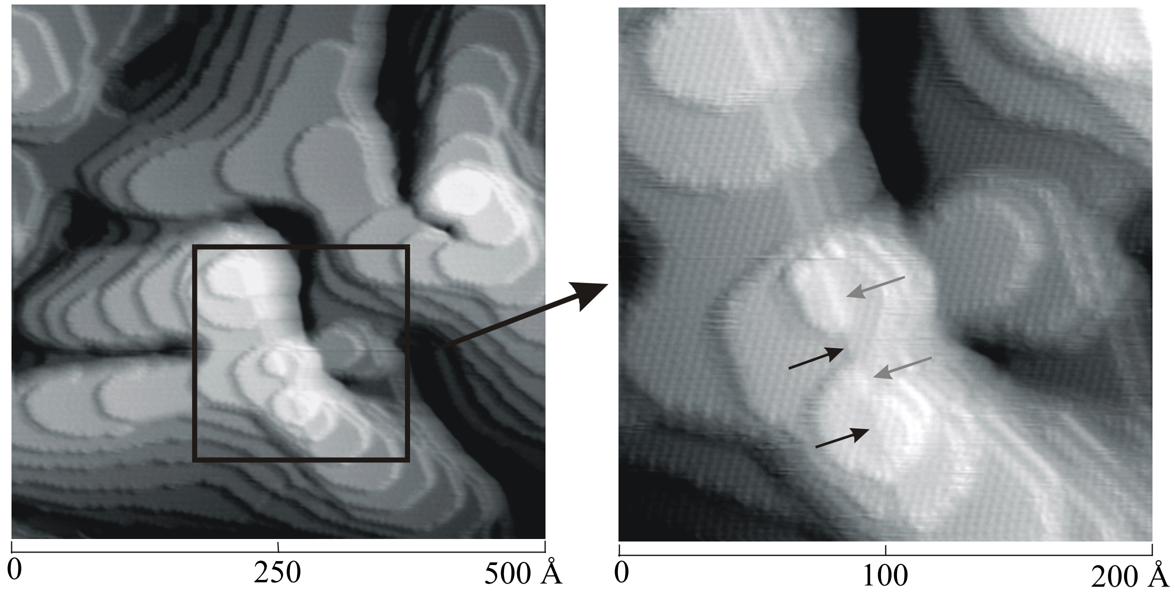

Fig. 5. Stacking fault in a Co island (15 ML-thick-film). Black and grey arrows point to 2/3 and 1/3 step, respectively. Contrast is enhanced by applying a differential filter.

CO superstructure on Pt(111) and Co(111)

The interaction of an adsorbed CO molecule with a Pt(111) or Co(111) surface is weak, especially in case of the Pt(111) surface. Therefore, during imaging by STM the surface diffusion of adsorbed molecules is as a rule too high in comparison with standard scanning velocities unless the CO creates some more stable structure (see Fig. 6). On Pt(111) CO forms a (2×4) superstructure with 50 % molecules (darker ones) sitting on the “bridge” (between two substrate atoms) and 50 % molecules on the “top” (brighter ones). The Co(111) surface was created by a higher coverage (5 and more ML) of Co on Pt(111). CO forms $(\sqrt{3}\times\sqrt{3})30^\circ$ superstructure on Co(111).

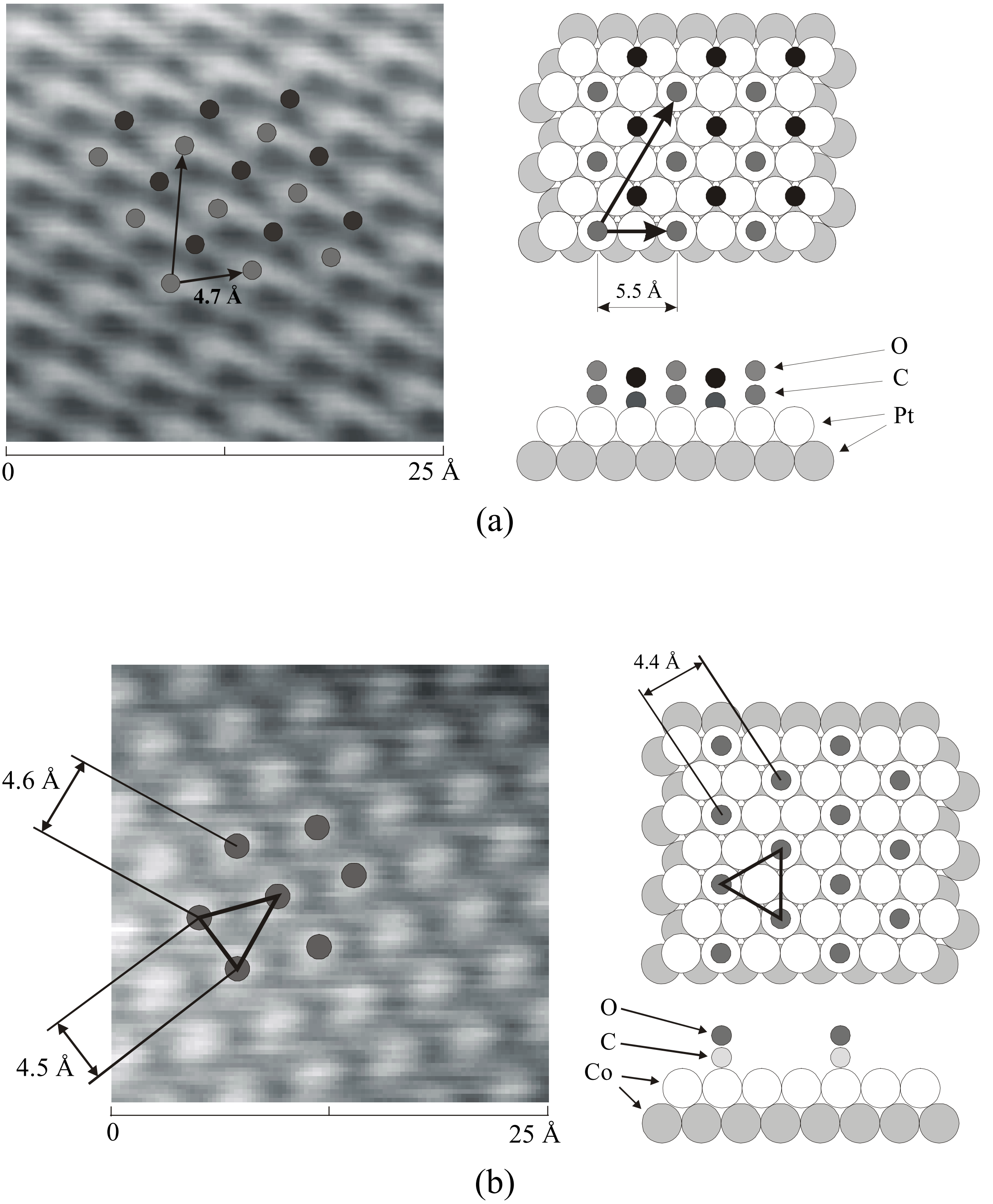

Fig. 6. (a) CO-(2×4) superstructure on Pt(111); (b) CO-(√3×√3)30° superstructure on Co(111).

CONCLUSIONS

The UHV STM technique is a very powerful tool for imaging metallic surfaces at an atomic scale. In particular, processes taking place during deposition of Co on Pt(111) can be observed and discussed. Structural analysis of the STM images revealed that Co grows on Pt(111) preferably in an fcc stacking sequence. Although, only conducting samples can be analysed by STM, also structures of low coverage of adsorbated molecules (for instance CO) on metallic surfaces is visible.

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