

# Si nanoribbon grating on Ag(110) : pentamer chain structure and template for the growth of nanomagnets

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## Abstract

The growth of self-organized nanostructures (nanodots, nanoribbons or nanostripes) on surfaces has been largely studied due to their new potential chemical/physical properties. Depending on the temperature, individual or regular arrays of Si nanoribbons can be grown on the anisotropic Ag(110) surface. For example, at room temperature, a random distribution of Si nanoribbons has been grown on Ag(110). At 460 K, uniform distribution of self-assembled Si nanoribbons has been found on the same substrate. This system is intensively investigated due to its high potential intriguing properties such as the silicene character of the Si nanoribbons reported [4]. We have recently shown the atomic structure of the Si layer to be an unprecedented Si phase composed of pentamer chains lying in the missing row of the reconstructed surface. This template was used to grow self-organized nanolines of Co dimers. Magnetic studies showed a ferromagnetic behavior at 4 K with a surprising in-plane easy axis of magnetization perpendicular to the Co nanolines and a magnetic anisotropy energy (MAE) of 0,07 meV per Co atom was measured while investigating by X-ray magnetic circular dichroism (XMCD). Other materials are being studied as the nickel that showed also self-organized nanolines of Ni dimers confirming the template reconstruction effect.

## 1. Si/Ag(110) : Template

- Deposition of Si on Ag(110) at 460 K leads to the formation of a 2D single-atom-thick Si layer composed of regularly spaced Si nanoribbons with a width of 1.6 nm.[1]
  - Among numerous models proposed in the literature, the pentamer model seems the only model that match theoretical calculations via DFT and experimental investigations by using STM and GIXD.[2]
- Pentamer chains lying in the missing row of the reconstructed surface was confirmed as the atomic structure of the Si nanoribbons grown on Ag(110).[2]

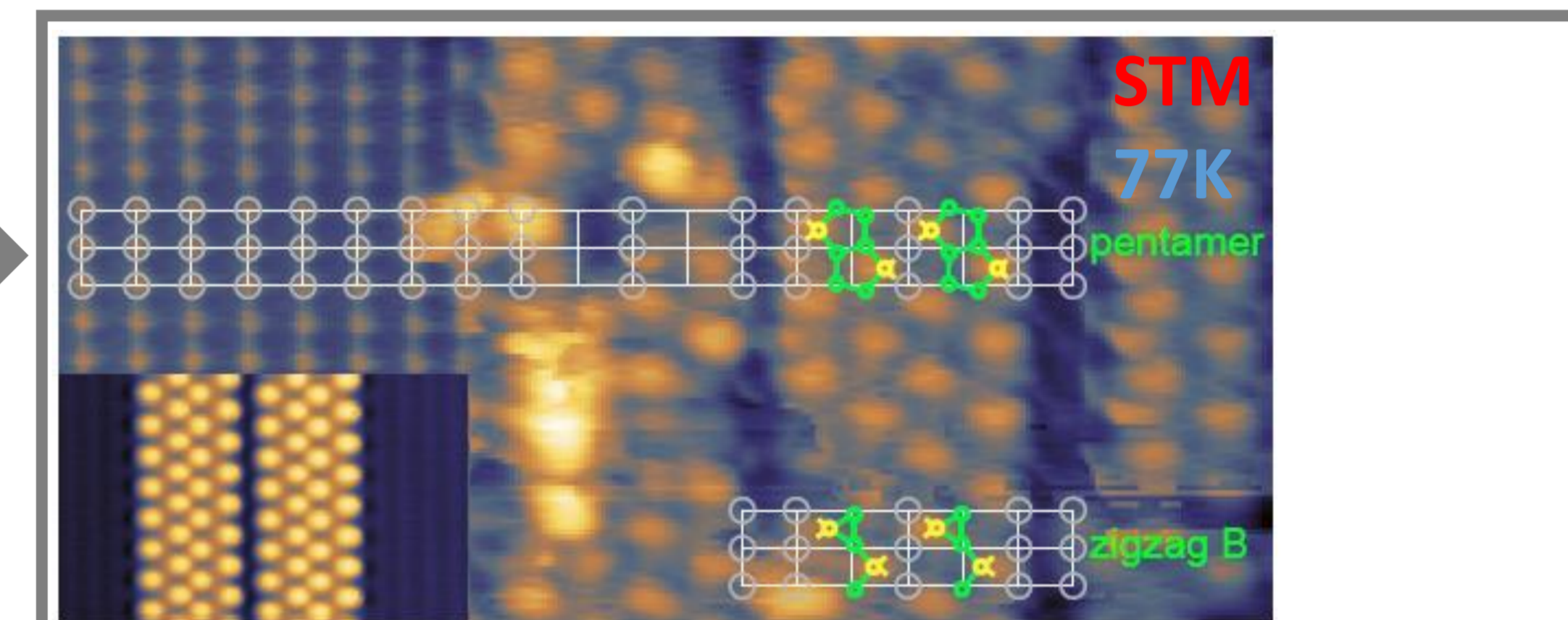


Figure 1: STM image ( $9 \times 4.5 \text{ nm}^2$ ) of Si nanoribbons below 1ML. The high resolution allows us to visualize both the Ag atoms (left part) of the (110) substrate and the protrusion of the nanoribbons (right part). Both pentamer and zigzag B models match the STM image. Si adatoms (yellow circles) appear as protrusions in the STM images whereas Si atoms in the missing rows (green circles) are not imaged.  $I = 50 \text{ nA}$ ,  $V_{\text{sample}} = 100 \text{ mV}$ . The high tunneling current used to resolve the atomic structure of the Ag(110) substrate induced a partial alteration of the Si nanoribbons. The inset in the bottom-left corner shows two unaltered Si DNRs imaged at a lower tunneling current [ $7.5 \times 4.5 \text{ nm}^2$ ],  $I = 480 \text{ pA}$ ,  $V_{\text{sample}} = 40 \text{ mV}$ .

## 2. Co/Si/Ag(110) : 1D Nanomagnets

- Deposition of Co at 220 K on the Ag(110) surface nanopatterned with the Si nanoribbon leads to the formation of Co dimer nanolines.[5]
- STM and XMCD characterizations reveal the structural and magnetic properties of the Co nanolines.

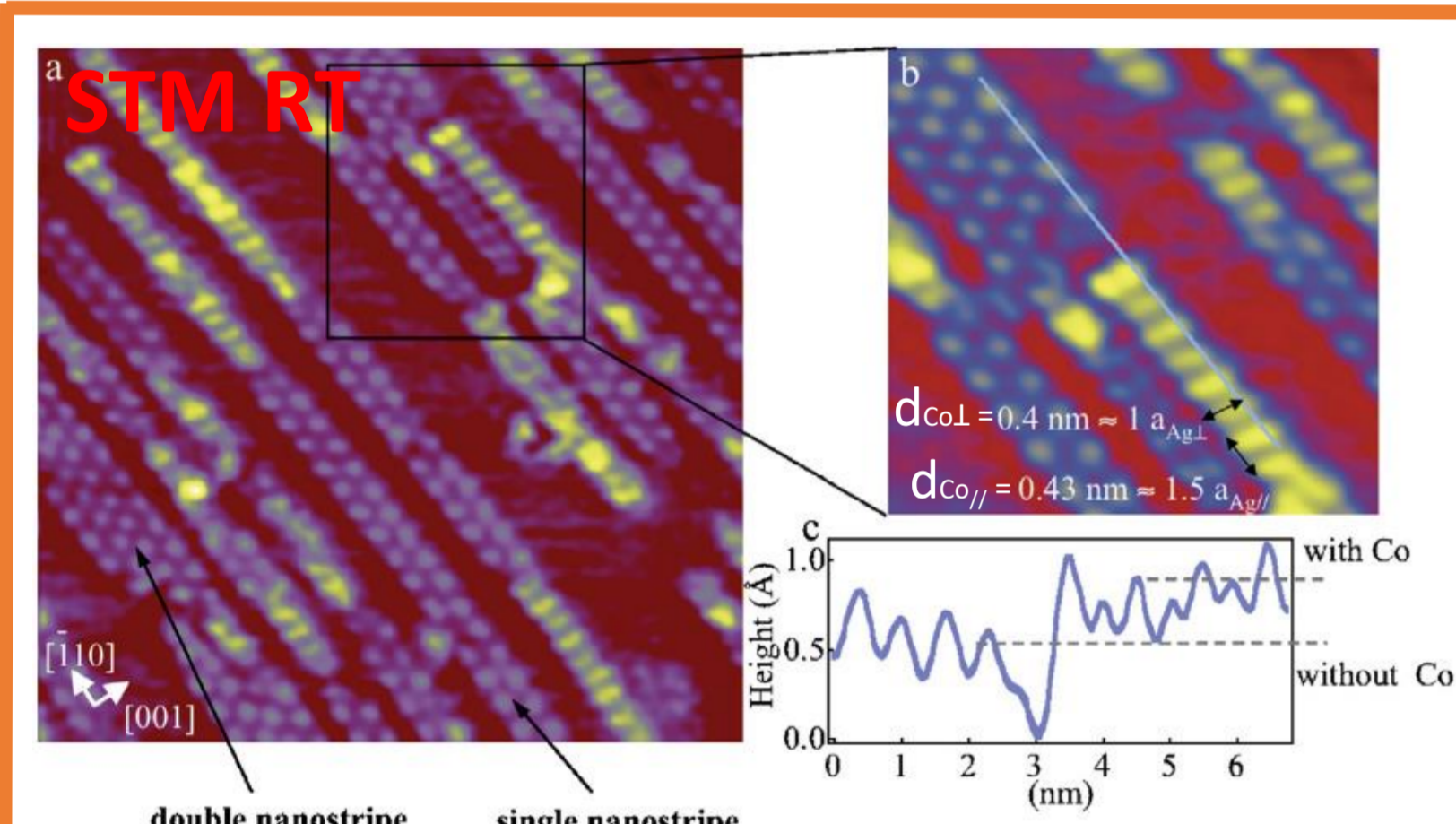


Figure 3: (a) STM image ( $17 \text{ nm}^2$ ) of a low coverage of Co deposited at RT on Ag(110) partially covered by Si nanoribbons:  $I = 1.3 \text{ nA}$ ,  $V = 0.55 \text{ V}$ . For clearer representation, the Ag substrate is shown in red, the Si nanostripes in purple and the additional protrusions in yellow. (b) Close view ( $7 \text{ nm}^2$ ) of the area indicated in (a) by the square box. (c) height profile along the transverse line in (b).

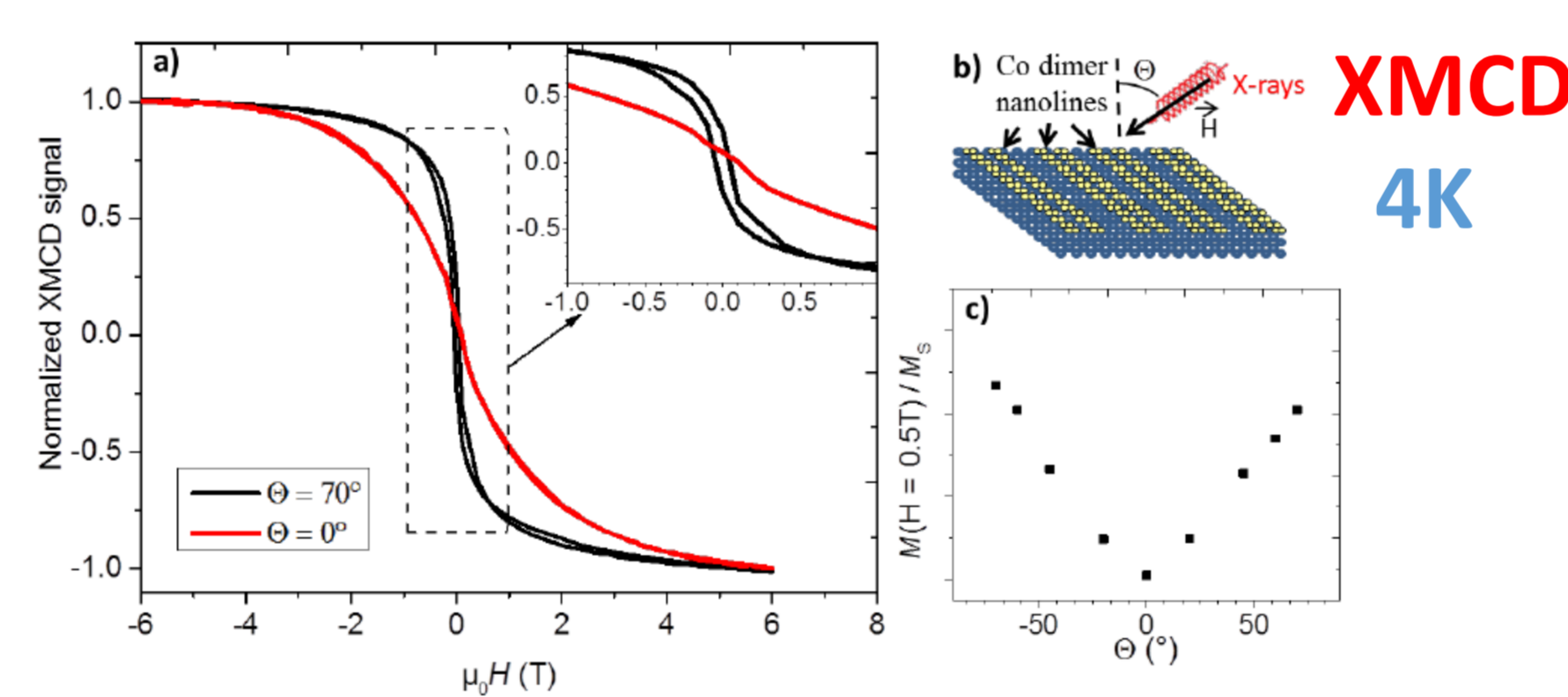


Figure 4: (a) Hysteresis loops of 2 ML<sub>Co</sub> on Si/Ag(110) measured at 4 K at normal ( $\Theta = 0^\circ$ ) and grazing ( $\Theta = 70^\circ$ ) incidences. The curves have been normalized to their saturation value. (b) Schematic representation of the measurement configuration: incident light and magnetic field are parallel and form an angle  $\Theta$  with the surface normal in the plane perpendicular to the Co nanolines. (c) Variation of the magnetization at 0.5 T normalized to the saturation magnetization ( $M_S$ ) as a function of the incidence angle,  $\Theta$ .

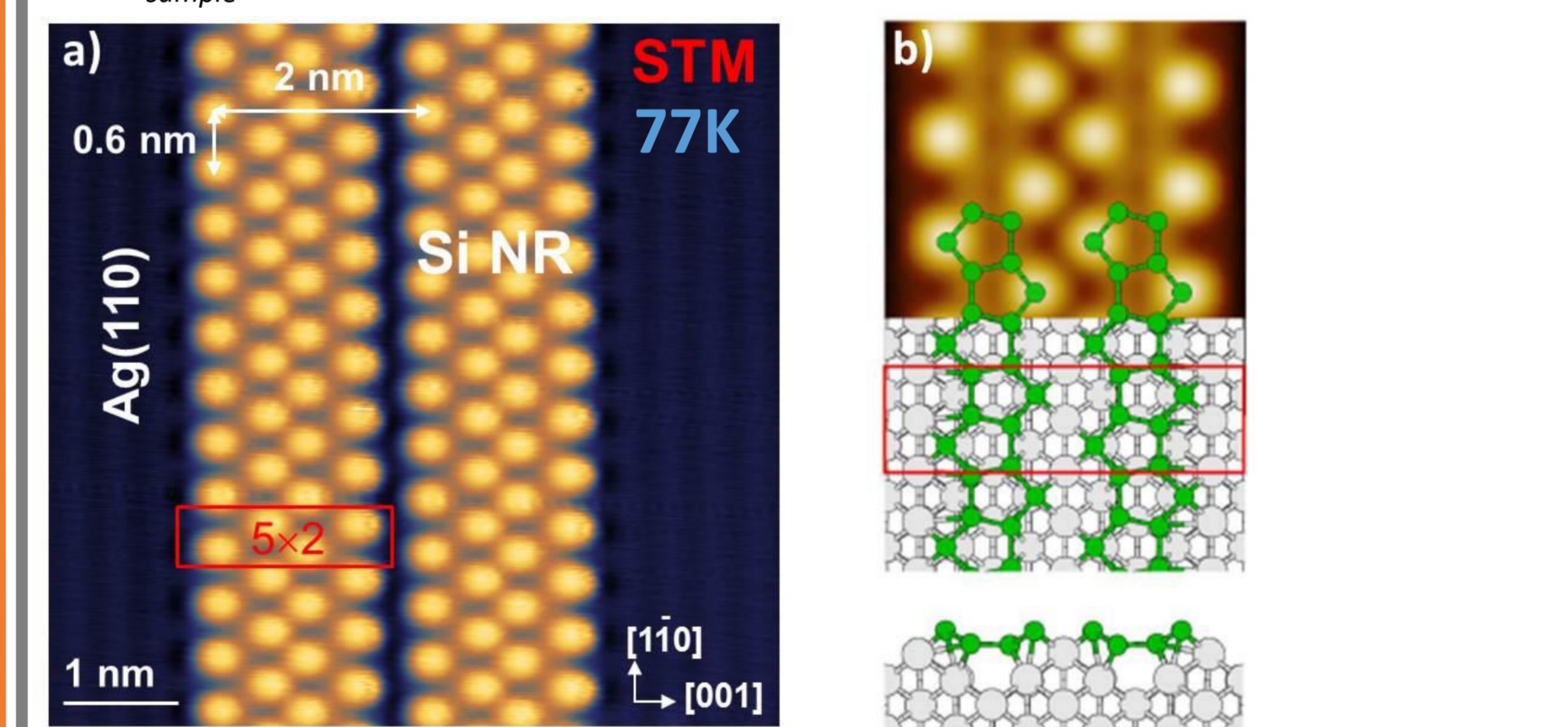


Figure 2: a) STM image (77 K) of Si nanoribbons below completion of the Si monolayer.  $I = 480 \text{ pA}$ ,  $V_{\text{sample}} = 40 \text{ mV}$ . The atomic rows of Ag(110) are visible. b) Schematic model of a Si nanoribbons on the missing row reconstructed Ag(110) surface and the corresponding simulated STM image.

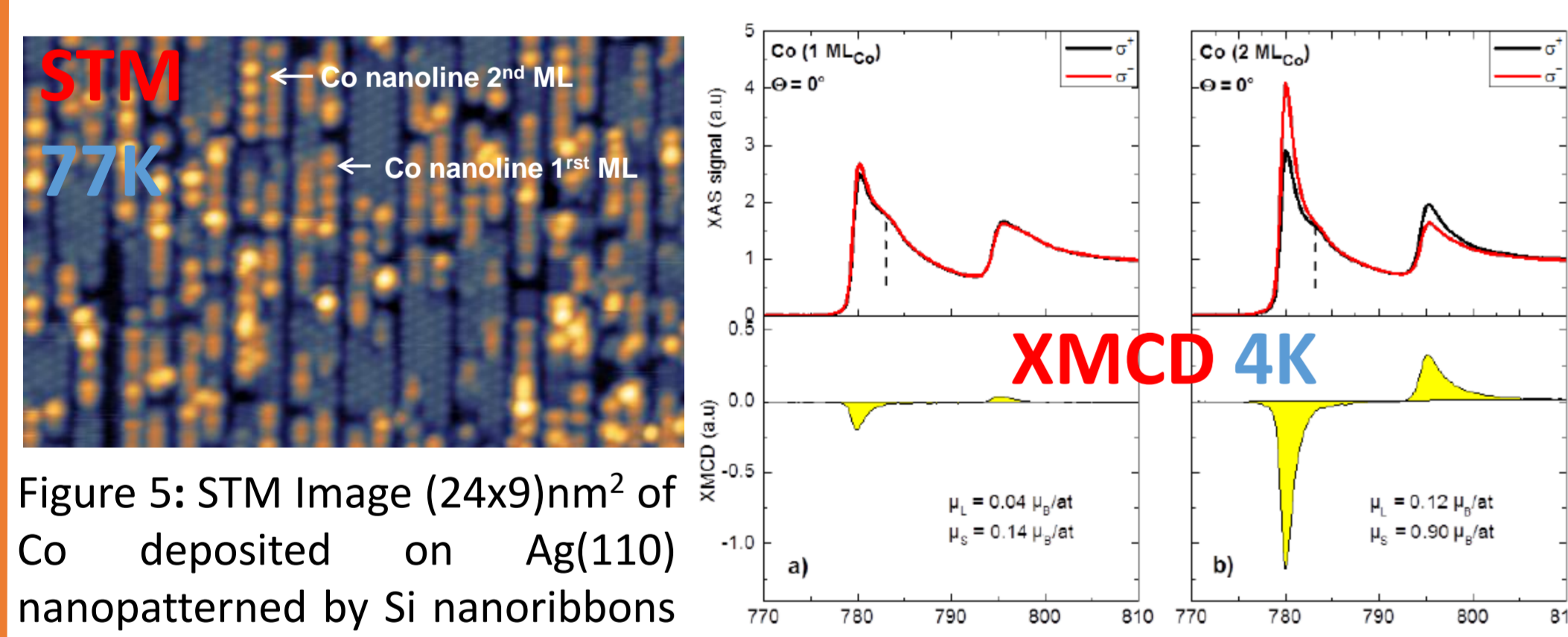


Figure 5: STM Image ( $24 \times 9 \text{ nm}^2$ ) of Co deposited on Ag(110) nanopatterned by Si nanoribbons at 220K showing the first and second monolayer of Co nanolines.  $I = 2 \text{ nA}$ ;  $V_{\text{sample}} = 0.1 \text{ V}$ .

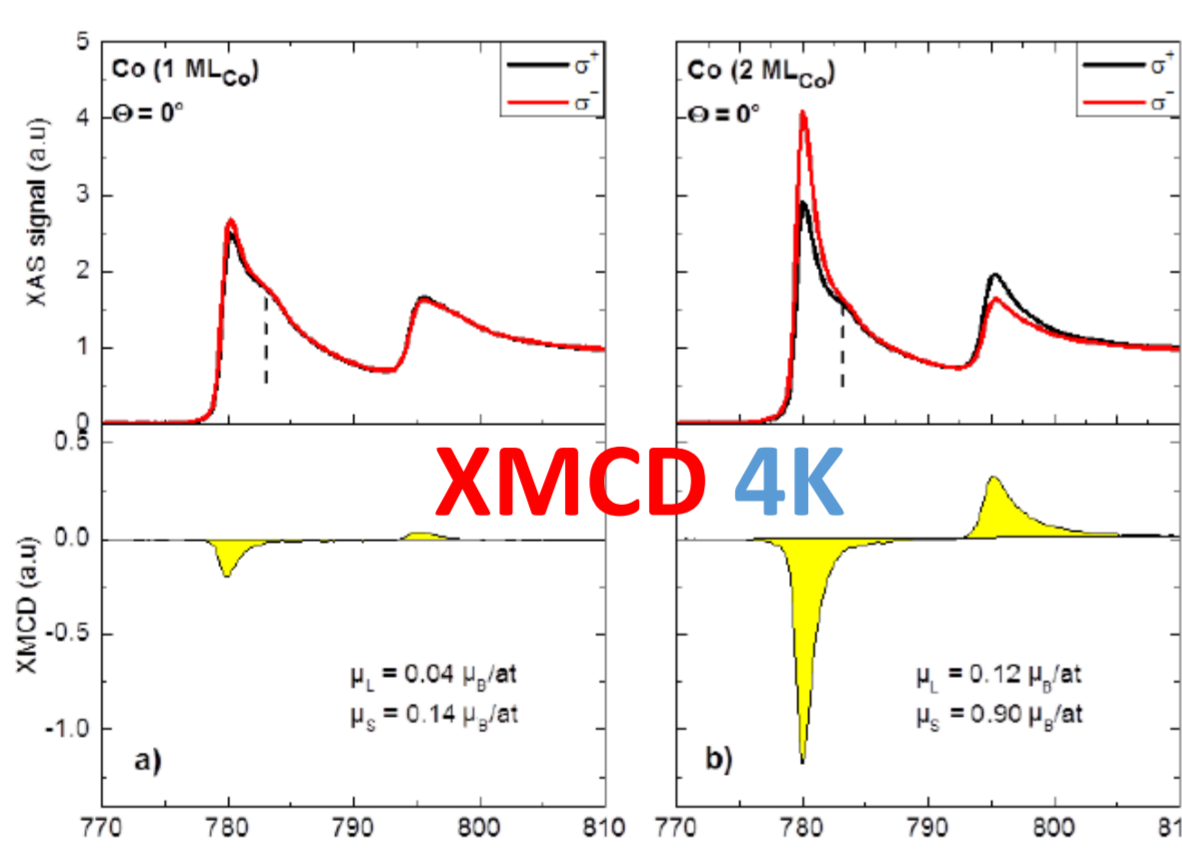


Figure 6: XAS spectra taken at normal incidence ( $\Theta = 0^\circ$ ) for both helicities ( $\sigma^+$  and  $\sigma^-$ ) at 4 K with a magnetic field of 6 T and corresponding XMCD signals for (a) 1 ML<sub>Co</sub> and (b) 2 ML<sub>Co</sub> on Si/Ag(110). Orbital and spin magnetic moments in both structures were determined by applying the sum rules.

## 3. Ni/Si/Ag(110) : Preliminary results

- Deposition of Ni at 300 K on the Ag(110) surface nanopatterned by Si nanoribbons leads to the formation of Ni dimer nanolines.
- Similar atomic structure for Ni and Co has been found.

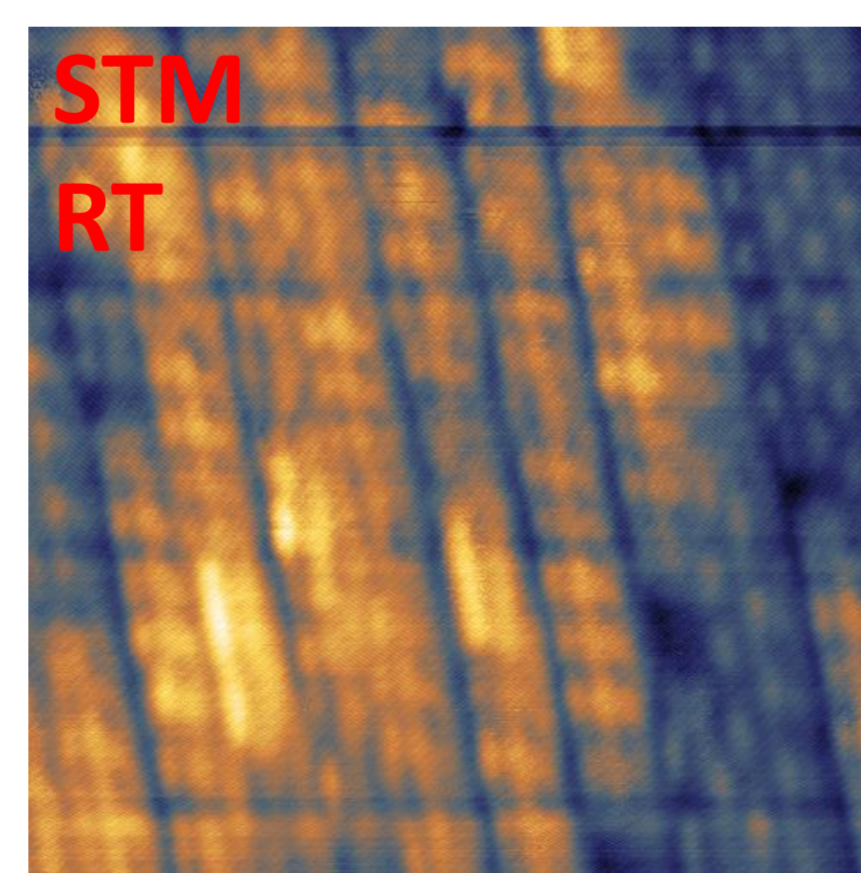
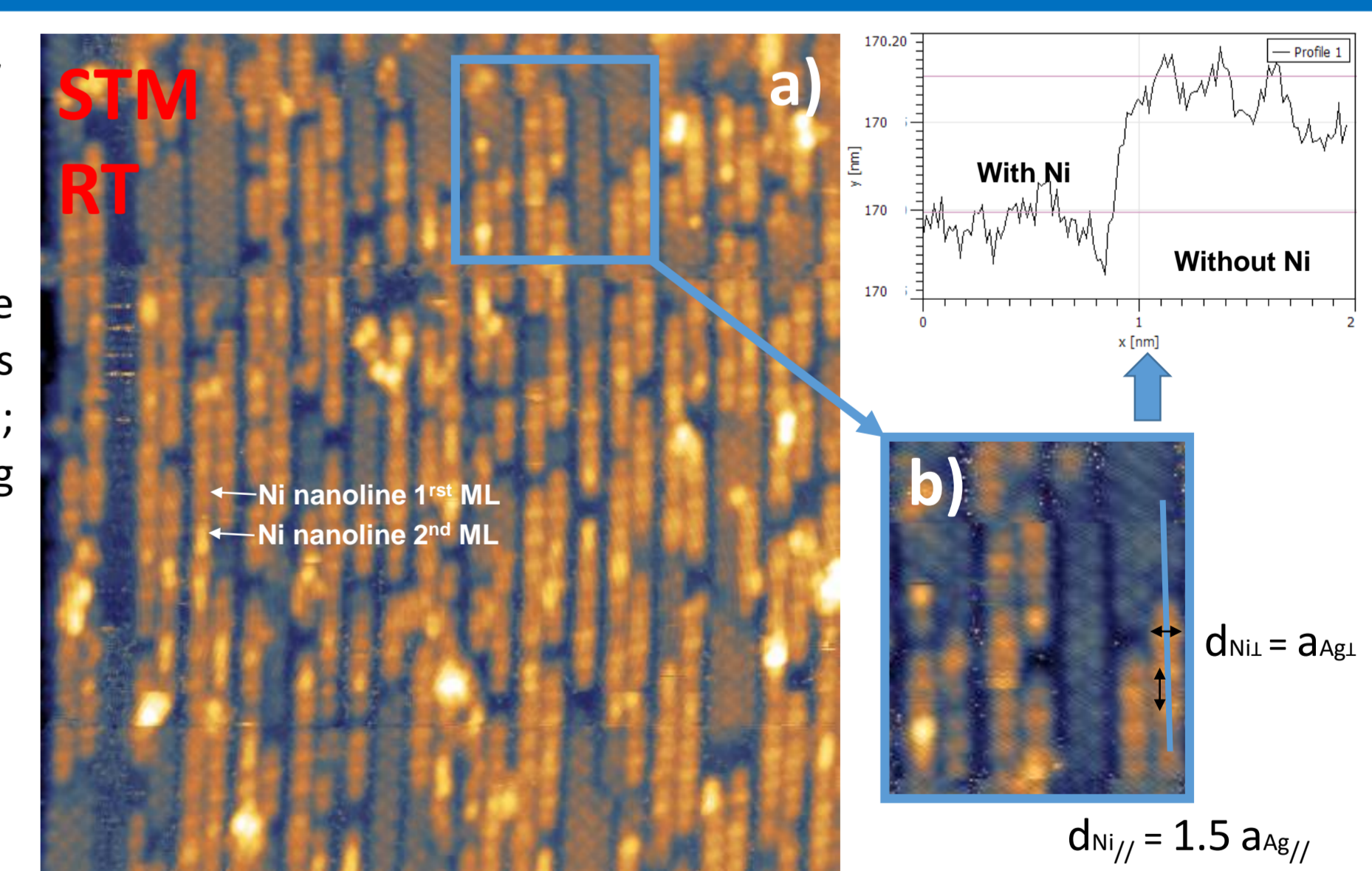


Figure 7: STM images of a low coverage of nickel deposited on the Si nanoribbons grown on Ag(110) at RT; a) ( $30 \times 30 \text{ nm}^2$ );  $I = 100 \text{ pA}$ ;  $V = -3 \text{ V}$ ; height profile along the transverse line in (b)

Figure 8: STM images ( $9 \times 9 \text{ nm}^2$ ) of deposited nickel on the Si nanoribbons grown on Ag(110) at RT;  $I = 500 \text{ pA}$ ;  $V = 2 \text{ V}$ .



## Conclusion and Outlook

- Ni and Co have similar atomic configurations after the deposition on Si/Ag(110) which highlights the effect of the template on the morphology of the surface-supported nanostructures. Therefore, the Si/Ag(110) can be used to guide the self-organized growth of different materials.
- For the future work, iron (Fe), holmium (Ho) and metal-ligand systems will be tried to be grown on this template and then their structure and magnetic properties will be studied.

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