ESRF	**Experiment title:** Strain in single and double epitaxial thin films of nickel	**Experiment number**: 25 02 632
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Report:

The purpose of the experiment proposed is the measurement of the lattice parameters of copper and nickel blocks that form epitaxial thin films Cu(5 nm)/Ni(t_{Ni})/Cu(100nm)/Si(001) and double nickel thin films Cu(5nm)/Ni(3nm)/Cu(t_{Cu})/Ni(3nm)/Cu(100nm)/Si(001), being t_{Ni} and t_{Cu} the nickel and copper thicknesses, respectively. Thus, we carried out scans around (440) and (443) reflections (units related to the silicon reciprocal lattice) to determine the lattice parameter of the nickel and copper blocks as function of t_{Ni} (t_{Ni} = 3, 5, 8 and 12 nm) in the case of the films and t_{Cu} (t_{Cu} = 0.5, 1.5, 2, 3.5, 5 and 6 nm) for the double films. Scans around the (4+h 4+k 0+l), with h=k ranging between 0 and 0.3 and l = 0.2 and 0.5 are grazing incidence diffraction experiments that give information about the average in-plane lattice parameter of the nanostucture. We choose this reflection since it is forbidden for the silicon lattice and the nickel and copper peaks will be clearly observer. The x-ray incidence angle α is smal and it was chosen to 0.5 and 0.2 degrees, L has to be small but not zero so we set l = 0.1, 0.2 and 0.5. Figure 1.a shows a typical scan performed for a 12 nm thick film for l = 0.2 and α = 0.5 degrees. This scan show two peaks that correspond to the copper and nickel blocks. Decreasing the incident angle makes that the scan more close to the surface; that scans are important for thin nickel films with in-plane lattice parameter close to the copper one, figure 1 b shows a scan for a double film with t_{Cu} = 2 with α = 0.5 and 0.2degrees. For the 0.2 degrees scan the copper peak has been suppressed. The scans at (44L) for l = 2.5 to 3.5 provide information to determine the lattice parameter perpendicular to the plane. In this scan we observe two well defined peaks due to the nickel and copper blocks (see figure 2).

The peaks fitted by using standard functions in the (440) scans are presented in figure 2. The copper peak is observed at fixed positions for all the samples studied while the nickel peak position changes its position depending on the block thickness thus the in-plane nickel lattice parameter increases as the nickel thickness decreases and as a result, the in-plane strain. Figure 2b shows the peak of the (440) scans obtained from the fit carried out on the nickel block peak of the double films. The peak position decreases in value and tends to be closer to the copper value as t_{Cu} increases. This fact indicates that the strain in the nickel block increases as the interlayer copper layer increases and looks to be roughly constant for t_{Cu} larger than 2 nm. We also note that the nickel peak for the double film with t_{Cu} = 0.5 nm and the 6 nm thick film has close values, but the asymptotic value obtained for the double films is closer to the copper peak than that obtained for the 3nm thick nickel films. That result suggest that the nickel blocks are more stained in the double film than in single film.

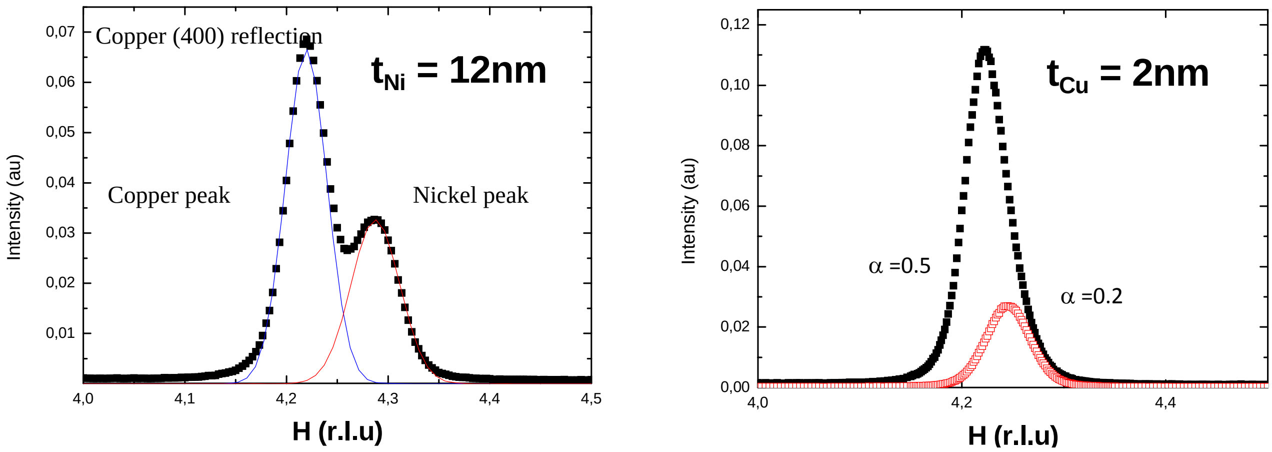

Figure 1. (4+h 4+k l=0.2) reflections in silicon reciprocal lattice units. (a) Scan carried out in a film with well defined copper and nickel peaks, (b) scans performed for two different indicent angle, α, in a double film.

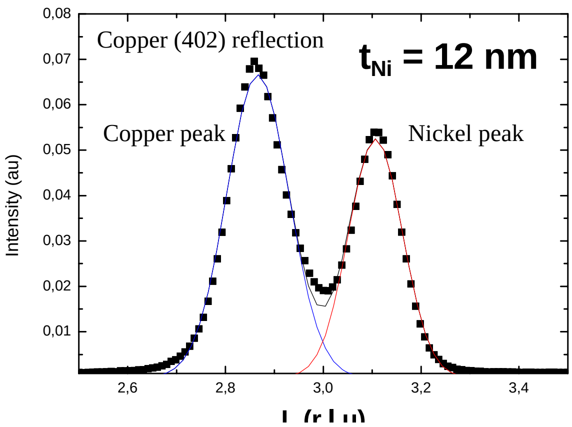

Figure 2. Scan at the (4 4 3) reflection, in silicon reciprocal lattice units.

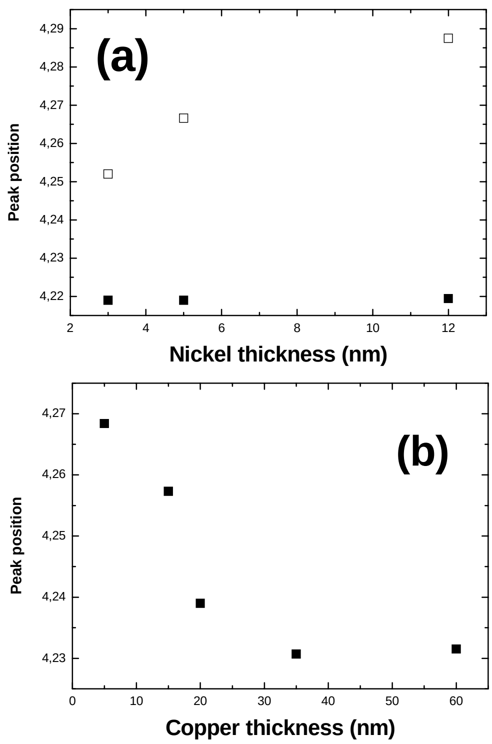

Figure 2. Peak position,in silicon rlu, for (a) nickel (white squares) and copper (solid squares) blocks forming the thin films and (b) the nickel blocks of the double film.