Master Internship

Can be followed with a PhD

University of Poitiers, Institut Pprime, France

Preparation and Characterization of Homogeneous Nanotwinned Gold Thin Films

Supervisors: **Anny Michel and Pierre-Olivier Renault**

Keywords: **gold thin film, twins, sputtering, transmission electron microscopy, X-ray diffraction, pole figures, mechanical and electrical properties**

Context:

A crystalline sample is called nano-twinned if it is structured with nanoscale twins (figure 1). Nano-twinned metals show a priori contradictory properties: they are simultaneously strong and ductile, stable from the thermodynamic point of view, and their electrical conductivity does not suffer from the impurities or grain boundaries otherwise needed for reaching such unusual mechanical behaviours. Applications for electronic circuits on stretchable substrates are foreseen.

At the university of Poitiers, we grow single crystalline nanotwinned gold thin films. Figure 1c presents such a film: the black rectangles are the twins. We see also several dislocations (the linear defects) and dark areas evidencing thickness or orientation heterogeneities. These areas as well as the dislocations are detrimental for the electrical conductivity. Moreover, during tensile tests, they participate to the plastic deformation of the film, leading to difficulties in deconvoluting the twins and dislocations contributions. The purpose of this internship is to prepare and characterize homogeneous thin films, without other defects than the twins.

Various optimizations of the sputtering conditions are envisaged: deposition temperature, substrate, acceleration voltage, etc. The student will work with several techniques:

- Physical vapor deposition (sputtering) of the thin films.
- Transmission electron microscopy (TEM) (i) bright field images with large field of view of the sample, (ii) dark field images to select one chosen twin family, (iii) in high-resolution mode to show the roughness of the twin boundaries (figure 1b).
- X-Ray diffraction to determine with pole figures the twinned volume on a representative (millimetric) scale.
- Focused ion beam to prepare thin foils for TEM and to observe the film surfaces in scanning electron microscopy.

All these instruments and techniques are available at the university of Poitiers.

This internship pertains to a project recently granted to the laboratory (principal investigator: Pierre Godard) whose main objective is to understand the deformation mechanisms of these nanotwinned thin films, and to understand how these mechanisms impact the electrical properties. TEM and three-dimensional X-ray images will be compared with atomistic simulations. **A PhD thesis will be proposed in this project (starting date: October 2020)**. It is thus of paramount importance to have homogeneous, well characterized samples for this project.

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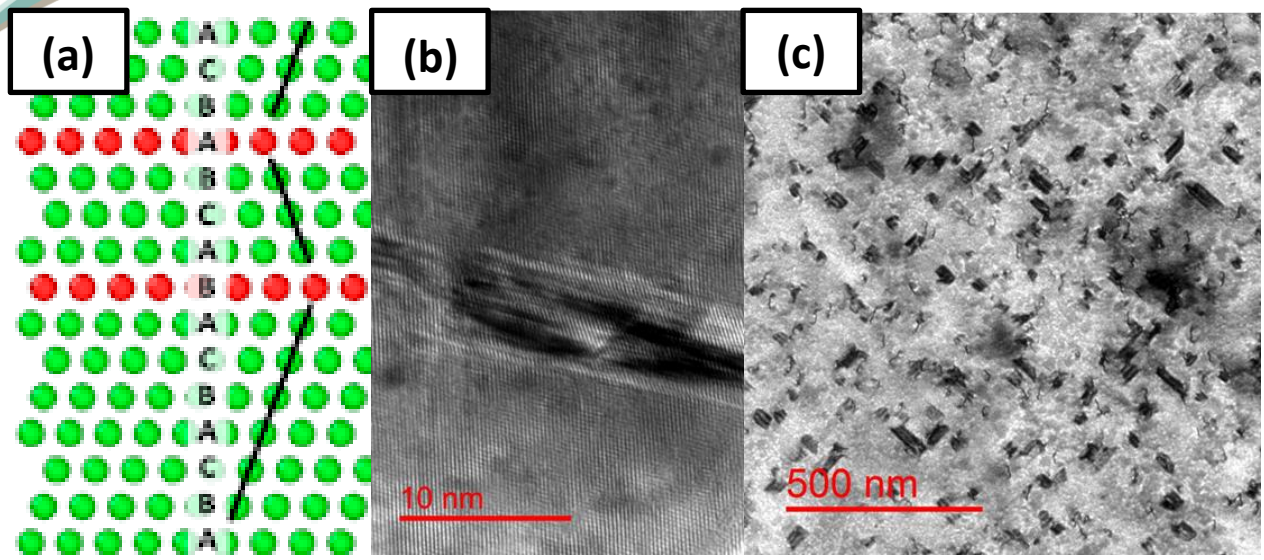

Figure 1: (a) Schematic of a twin. In the matrix, the atomic planes are in the order ABCABC; in the twin (bordered with the red planes) the order is reversed; image from S. Karewar et al, Acta Mater, 142 (2018) 71.
(b) and (c) TEM images of a 50 nm thin film: (b) zoom-in in high-resolution of a twin after deformation, (c) image in bright field, revealing the twin size and orientation distributions.

Dates: the internship is available from February to September 2020, with a vacation period in August.

Funding: the wage is defined according to the collective agreements on salary scales for internship in France, about 550€ per month.

Working laboratory: Institut PPRIME (https://www.pprime.fr) – Futuroscope-Chasseneuil (15 km from Poitiers city, France)

Required skills/qualification: the applicant has to be in final year of Master and/or engineering school with a background in solid-state physics or materials science. He/she should show a strong interest in experiments. Experience in transmission electron microscopy will be an asset.

Application: send a CV and a cover letter to the contacts below before December 2019.

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