On the interest of the Berkovich and conical tip shape to identify interactions between dislocations in nickel single crystals from the residual topography

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ABSTRACT

Renner et al. [1] have demonstrated that, in the case of a single crystal indentation, the distribution and dimensions of the plastic pile-up around a Berkovich imprint are sensitive to the relative orientation between the indenter and the crystal, for experimental and numerical cases. They have also presented the sensitivity of the residual topography to the parameters which controls the hardening on each slip systems. Indeed, these authors have introduced that using residual topographies could bring more information to reliably identify plastic parameters by inverse method [2]. On the other hand, the sole geometry of the Berkovich indenter was used for these studies. Therefore, the variation of the relative orientation between the indenter and the crystal on residual topographies must be studied in terms of information richness compared to an axisymmetric indenter, like a conical one. In the single crystal plasticity law used in this study [3], three parameters drive the hardening intensity (r_0, b, Q) and six parameters, the dislocation interactions hardening $(h_1, h_2, h_3, h_4, h_5, h_6)$. The use of the residual topography as an input for the finite element updating method (FEMU) is therefore promising to identify these interaction parameters. One of the challenges with this method is to design the experiments to have a well posed problem for the interaction parameters identification, particularly to ensure the stability and uniqueness of the solution, if there is one.

The present work concerns the tip shape contribution to the identification of the coefficients driving the interaction between dislocations. We quantify the information brought to the identification process by a Berkovich imprint and we confront it with the equivalent conical (70.3°) imprint, presented in figure 1 b) and d). The comparison criterion is the identifiability of these parameters. Berkovich imprint information richness will be studied by varying the azimuth angle figure 1 a) and c). In this study, we used interaction matrix coefficients from the literature[4].

Finally, for each topography and combination of topographies, an identifiability index is calculated [2], [5]. This index quantifies the conditioning of the inverse problem which would consists in identifying those six interaction matrix components using the FEMU method. Based on this identifiability study we could design our experiments and guide the interactions between dislocations identification.

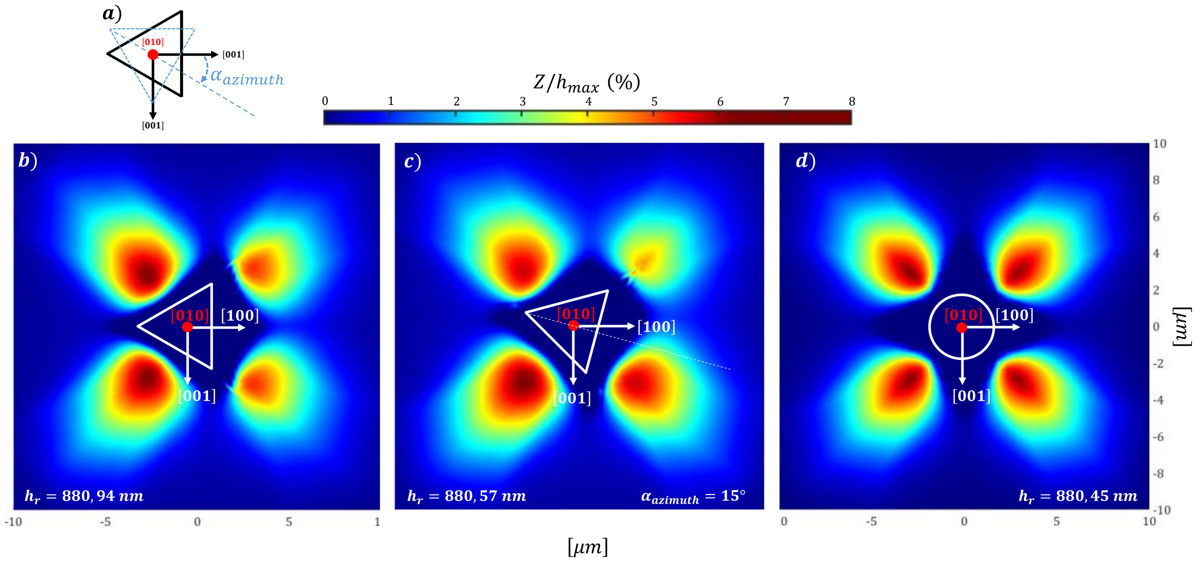

*Figure 1 :**a**) Schematic representation of the azimuth angle. **b**) Simulated residual topographies using Berkovich indenter tip. **c**) Simulated residual topographies using Berkovich indenter tip and a variation of 15° of the azimuth angle. **d**) Simulated residual topographies using equivalent conical indenter tip. Their respective residual depth normalizes both topographies, noted $\mathbf{h_r}$. The maximal indentation depth is 0.9 μm and only the positive part is represented for both topographies. The crystal orientation is also represented against the shape of the indenter.*

KEYWORDS

Identifiability, Interaction matrix, Crystal plasticity

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