

# Investigation of Nanoscale Strains at the Austenitic stainless steel 316L surface using nanogauges gratings and EBSD

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## Abstract

In this study, an original approach based on the combination of both nanogauges displacements monitoring and the electron backscatter diffraction (EBSD) techniques during in-situ tensile tests performed under Scanning Electron Microscope (SEM) is proposed. The deformation and crystallographic evolutions of the microstructure components can be compared to the behavior of the material. To assess the potential of this approach, it is applied to austenitic stainless steel 316L specimen. The used of grating of nanoparticles (NPs) allows the measurement of strains at the nanoscale. Then the early strain initiations in the vicinities of twins and their evolutions during the tensile test are highlighted. The EBSD data of the zone where the NPs are deposited help in the interpretation of deformation evolution in term of texture. The strain heterogeneities expressed in strain map can be compared with crystalline misorientations and quantified from the EBSD data. The twinning and slip activities are correlated to the hardening of the material. The complementary of these techniques and the capabilities of the approach to analyse the microstructure properties are demonstrated.

## Introduction

The macroscopic behaviour of the materials is related to the evolutions of properties at the local scale. It is then determinant to study and understand the material properties within the microstructure. In this context, many characterization methods for determining material properties at the local scale have been proposed in the literature. It includes surface characterization methods (Allais et al., 1994; Clair et al., 2011) and volume characterization methods (Morgeneyer et al., 2013). Concerning surface characterization techniques, many methods have been deeply investigated and some of them are robust today. These methods can be divided into two main groups depending if they are based on the use of random or periodic gratings (Marae Djouda et al., 2017).

In the present study, an approach based on the combination of the nanogauges displacement monitoring and the EBSD techniques is proposed for analysing deformation mechanisms at the nanoscale. The early initiation of strains at the surface of the specimen and their evolutions in function of the mechanical loading is studied. The NPs play the role of nanogauges and allow obtaining the mechanical fields components evolution during the mechanical test. The plus of the method developed herein is the capability of strain measurements at the nanoscale in regard of the crystallographic orientation evolutions during a tensile test. The crystallographic orientation evolutions is obtained from data recorded at three specific loadings during the tensile test.

## Discussion

The grating of gold nanoparticles (NPs) have been deposited at the centre of the specimen surface. The in-situ tensile test of the specimen inside the SEM is conducted. During the test, SEM images of the zone containing the grating are recorded at different mechanical loadings. The crystallographic data are also recorded at three specific loading steps: no loading, elasto-plastic transition and plastic stage. The treatment of the SEM images allows to obtain the strains maps of the strain tensor components:  $\epsilon_{xx}$ ,  $\epsilon_{xy}$  and  $\epsilon_{yy}$ . The

Fig.1 shows the evolution of deformation in the tensile direction  $\epsilon_{xx}$  during the test. The inverse pole figure of the zone of the grating is shown in the Fig.1a, the twins of this region are numbered. The strain-stress curve of the sample and different loading steps at which the SEM images are recorded are shown in the Fig.1e. The first strain concentrations are situated in the vicinities of twins and appear at the elasto-plastic transition domain. These strain concentrations are followed by the slip marks which are parallel to the twin directions with loading augmentation. The strain heterogeneities are illustrated in the present method by different strain intensities in the same grain. Specific evolutions at the surface of microstructure components are observed like cross slips: i-), ii-) and iii-) (Fig.1d) and dense bundles of nanotwins. The twinning and slip activities explain the important hardening recorded in stress-strain curve. These microscopic evolutions in the strain maps and crystallographic evolution allow to approach the mechanism of deformation of this material.

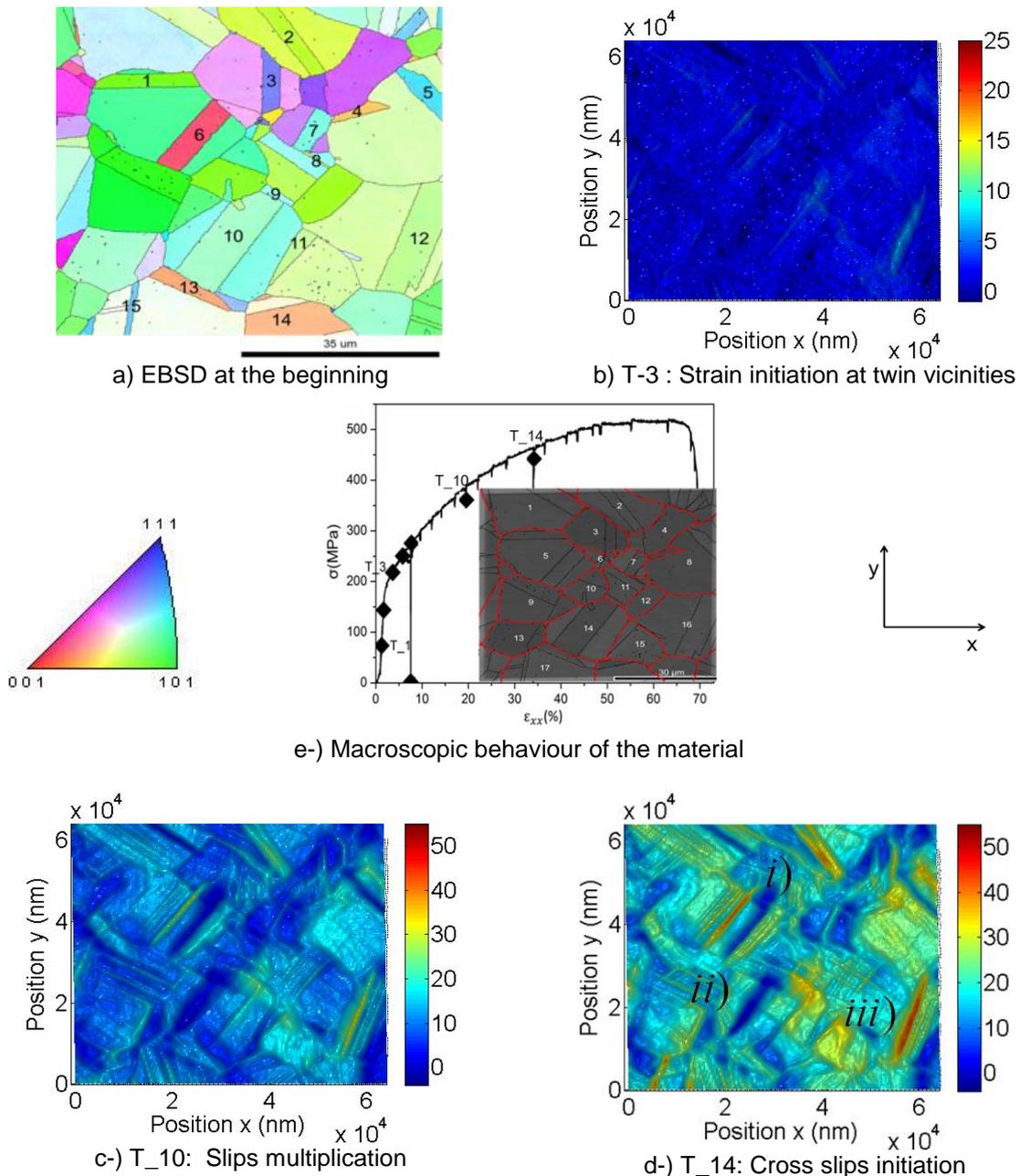


Fig.1: evolution of strains in the tensile direction  $\varepsilon_{xx}$  calculated from strain tensor. Strain are in percent (%).

## Conclusion

The process developed herein based on the combination of nanogauges grating and EBSD techniques is a promising method of analysing the material properties at the local scale.

## References

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