Mechanical properties and metallurgical evolutions of pure Aluminum along temperature ramp by HT nanoindentation

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Significant progresses in high temperature nanoindentation testing have been made during the last decade, opening the way to the investigation of thermally activated mechanisms at small length scales. Anisothermal measurements at the micron-scale of hardness, Young modulus and creep properties seem now feasible. A new methodology has been applied on a cold-rolled pure aluminum that undergoes recrystallization during a tempering ramp: Hardness upon heating and cooling varies in a different manner pointing out the occurrence of static recovery upon heating. Hardness drop is observed during the constant temperature segment, related to recrystallization, assessed by post-mortem EBSD microstructural characterizations.

Keywords: nanoindentation, anisothermal measurements, high temperature, recrystallization.

1. Introduction

Increasing wear resistance of materials at high temperature is an important challenge to reduce energy losses. A thorough understanding of materials mechanical properties at the scale of tribological contacts is key. Thank to high temperature nanoindentation, measurements up to 1000°C are now feasible. Interpreting such data remains complicated since hardness can depend on microstructural evolutions occurring upon heating. A recent paper of Baral et al.[1] has highlighted the ability of high temperature nanoindentation to investigate in-situ microstructural evolution in an aluminum alloy. However, usual high temperature nanoindentation methods are limited to the examination of processes whose evolutions are very slow. We have recently developed a new method allowing nanoindentation tests in anisothermal regime [2], making possible to follow kinetics of evolutions with characteristic time around fifteen seconds. Results on pure aluminum, obtained with this new nanoindentation methodology, are presented here.

2. Methods

One second duration nanoindentation tests were performed here to minimize the impact of temperature variations on tests during anisothermal cycle (3°C/min). Pure aluminum samples are cold laminated with a reduction of 80% of their thickness. On each sample, 400 to 500 indents were performed during the studied thermal cycles.

3. Results

Hardness versus temperature for two different thermal cycles is presented in Figure 1. Decrease of hardness is clearly visible during the heating and holding phases. During the cooling phase, hardness increases with a different slope compared to heating. The results during heating were well reproducible because the two used samples were identical. The difference seen during cooling is the results of the two different thermal cycles.

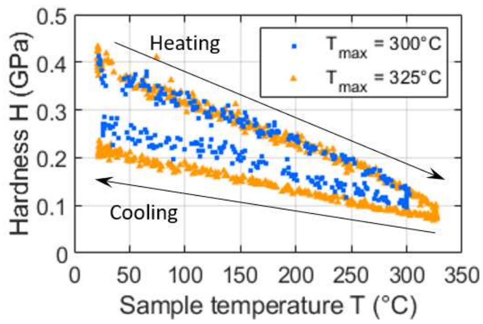

Figure 1: Hardness vs temperature for tested pure aluminum samples during 3°C/min thermal ramp cycles.

4. Discussion

Hardness decreases during heating is linked with thermal activation of viscoplasticity mechanisms as well as static recovery and recrystallization. Those hardness evolutions are the signature of the samples' microstructure changes, confirmed by EBSD measurements (Figure 2).

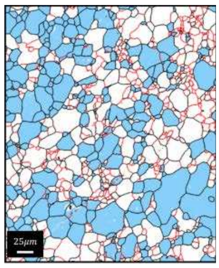

Figure 2: Microstructure of one of the studied aluminum samples after the thermal cycle up to 325°C, obtained by EBSD measurements (black: grains boundaries, red: sub-grains boundaries, blue: recrystallized grains). Recrystallization clearly occurred during the thermal cycle.

5. References

[1] Baral et al., Materials & Design, 152, 2018, 22–29.
[2] Tiphéne et al., JMR, submitted.