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Dynamic Recovery as a Strengthening Mechanism

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Introduction

Many studies have reported hardening induced by static recovery in ultrafine-grained (UFG) and nanocrystalline (NC) metals. In conventional metallurgy, recovery can be either static or dynamic. The main difference is that dynamic recovery takes place during deformation, where the applied stress assists the process and allows it to occur at lower temperatures than static recovery. Therefore, if static recovery can harden UFG and NC metals, dynamic recovery may also do so.

Objectives

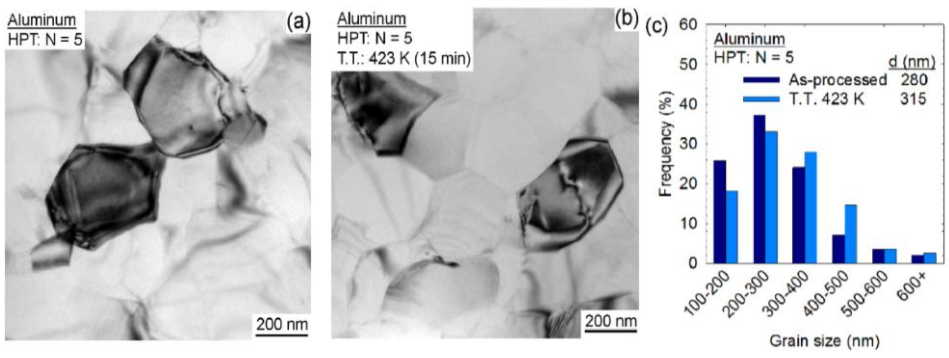
The aim of this work is to evaluate whether dynamic recovery strengthens nanostructured aluminum during deformation and how it affects elongation.

Methodology

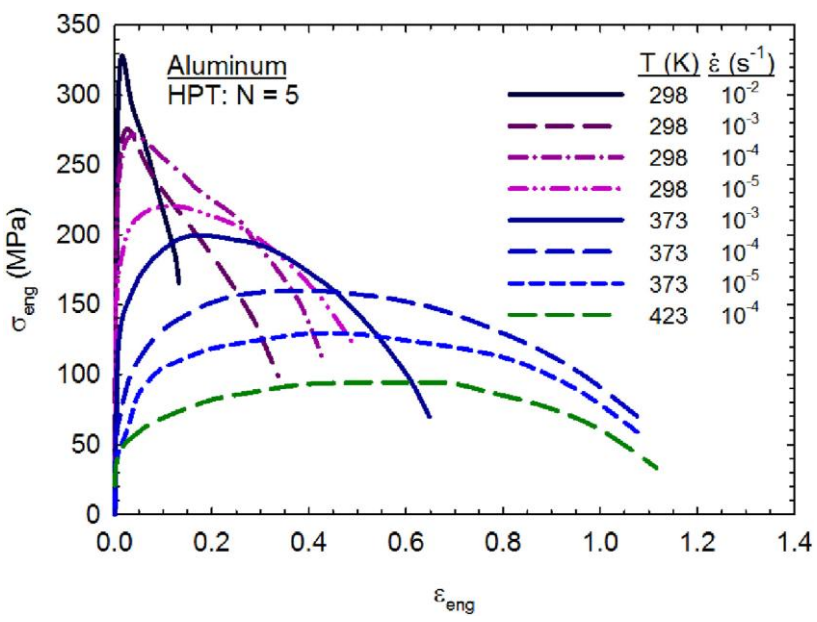
Commercial purity aluminum (>99.0%) was processed by 5 turns of HPT (6 GPa, room temperature). The grain size and its stability at 423 K were evaluated by TEM. Tensile tests were carried out from 10^{-2} s^{-1} to 10^{-5} s^{-1} at 298–423 K, and plane strain compression tests were performed with strain rate changes. Crystallite size, microstrain and dislocation density were estimated by XRD and Rietveld refinement.

Results and Discussion

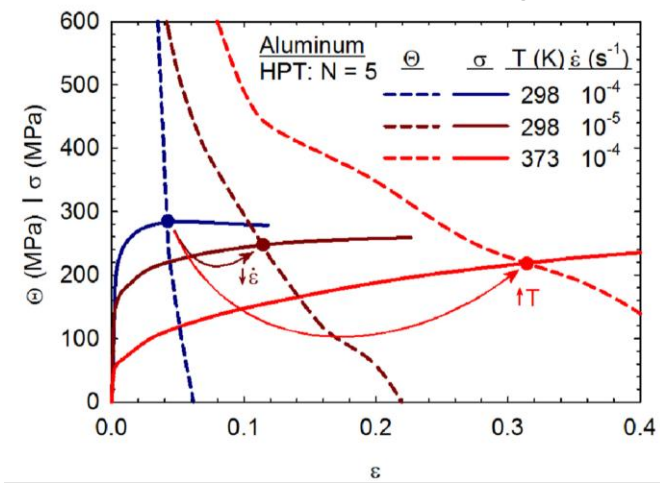
Microstructure after HPT and after annealing at 423 K for 15 min:



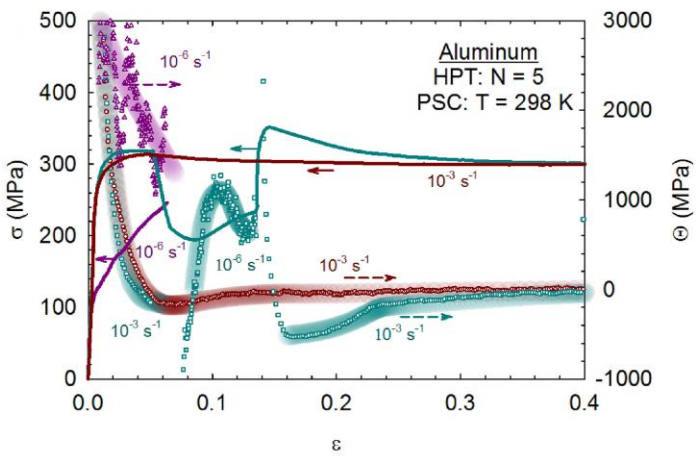
Tensile tests at different strain rates and temperatures:



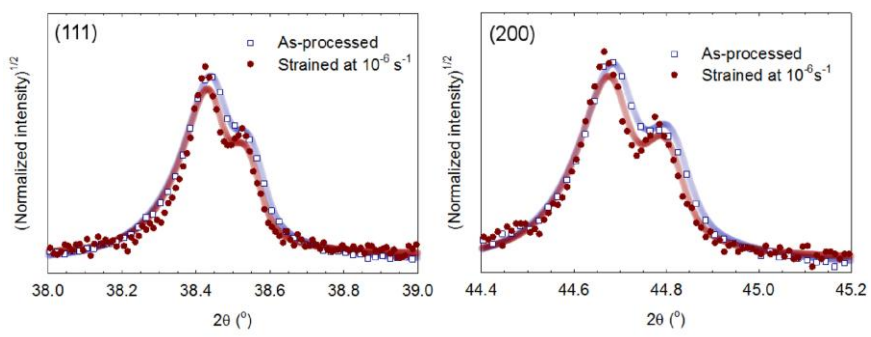
Decreasing the strain rate and/or increasing the temperature increases the uniform elongation:



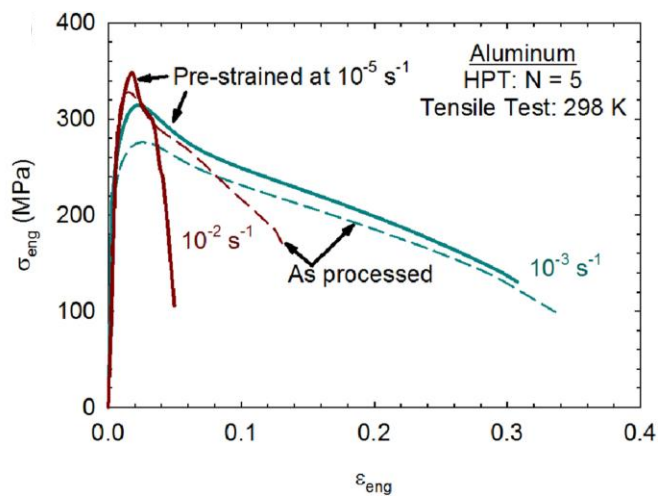
Plane strain compression (PSC) tests with different strain rates:



After PSC at 10^{-6} s^{-1}, the sample was analyzed by X-ray diffraction and compared with the initial state:



Low strain rate pre-straining increases the flow stress at higher strain rates:



Conclusion

Ultrafine-grained aluminum with a grain size of 280 nm exhibits different flow behavior depending on the strain rate and temperature. At low strain rates and/or higher temperatures, the flow curves show strain hardening by defect annihilation caused by dynamic recovery, which increases the uniform elongation. With fewer defects, a higher stress is needed to continue the deformation, causing hardening.

References and Acknowledgments

CARVALHO, Amanda P. et al. Strengthening nanostructured metals through dynamic recovery. Journal of Materials Research and Technology, v. 35, p. 754-763, 2025.

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