Karlsruhe Institute of Technology

Institute for Applied Materials - Applied Materials Physics (IAM-AWP)
High-Temperature Materials Group, Campus North
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
http://www.iam.kit.edu/awp

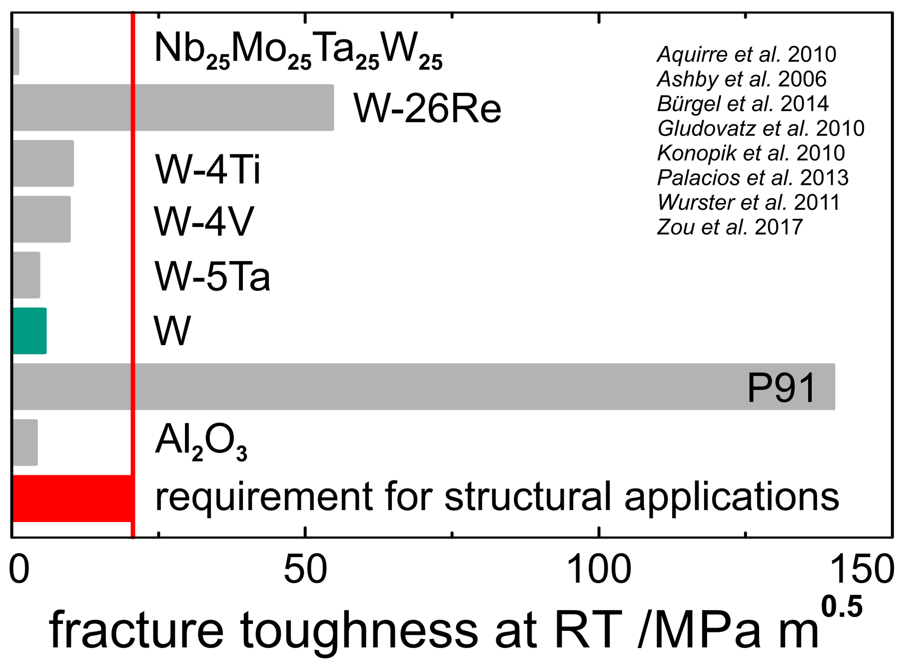
Reducing the brittle-to-ductile transition temperature of tungsten to −50 °C by cold rolling

C. Bonnekoh[a], J. Reiser[a], S. Zaefferer[b], S. Baumgärtner[a], J. Hoffmann[a], A. Hoffmann[c]
[a]Karlsruhe Institute of Technology, Germany, [b]Max-Planck-Institut für Eisenforschung GmbH, Germany, [c]Plansee SE, Austria

Motivation

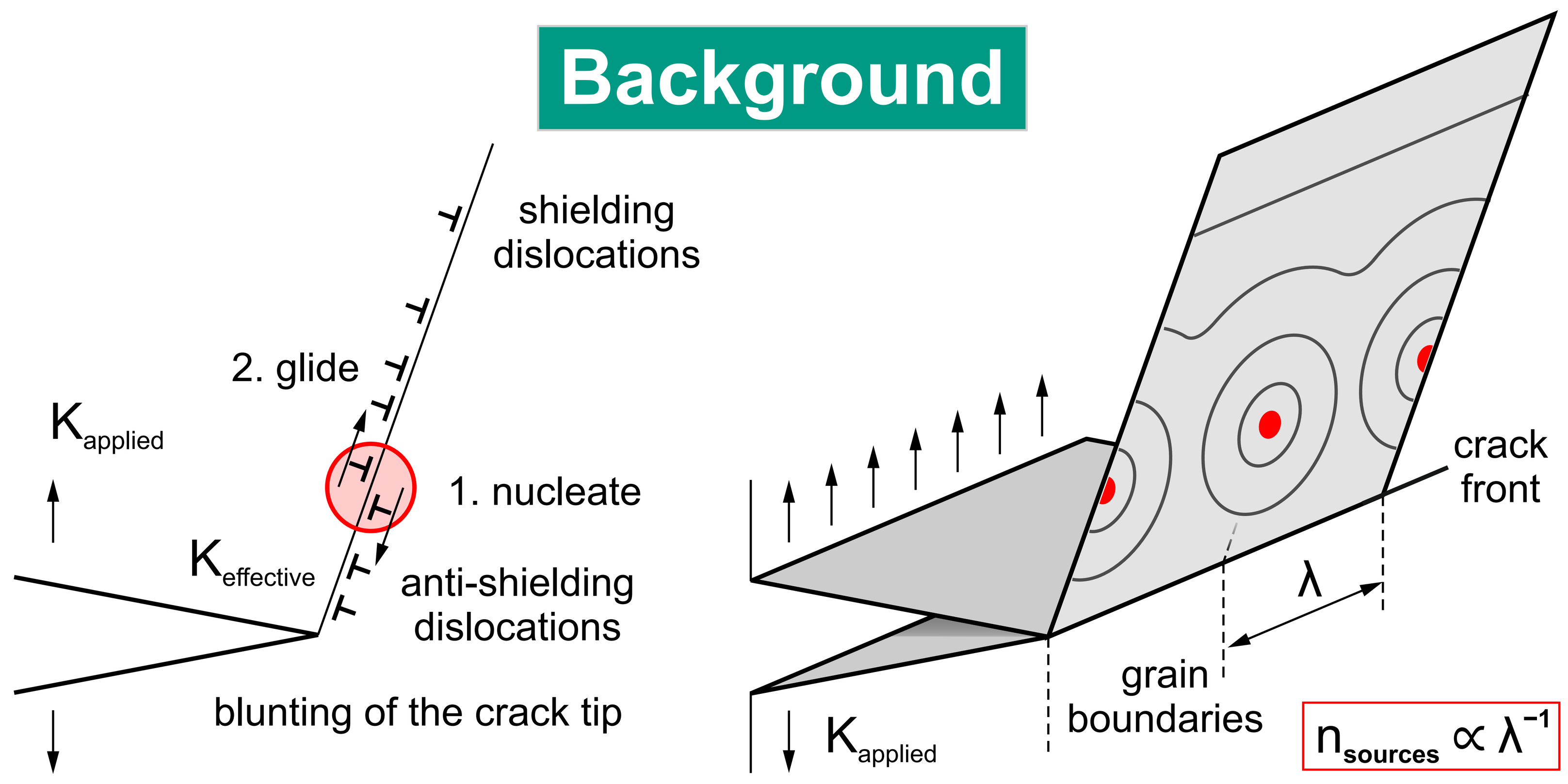
Tungsten is a promising candidate as a first wall material in fusion reactors and for the piping system of solar powered power stations running a liquid natrium based heat exchange system. Despite its outstanding properties, the extreme brittleness of commercial tungsten prevents a successful usage as structural material until now.

A reduction of the BDTT by a significant margin is inevitable before W can be applied as a powerful structural material.



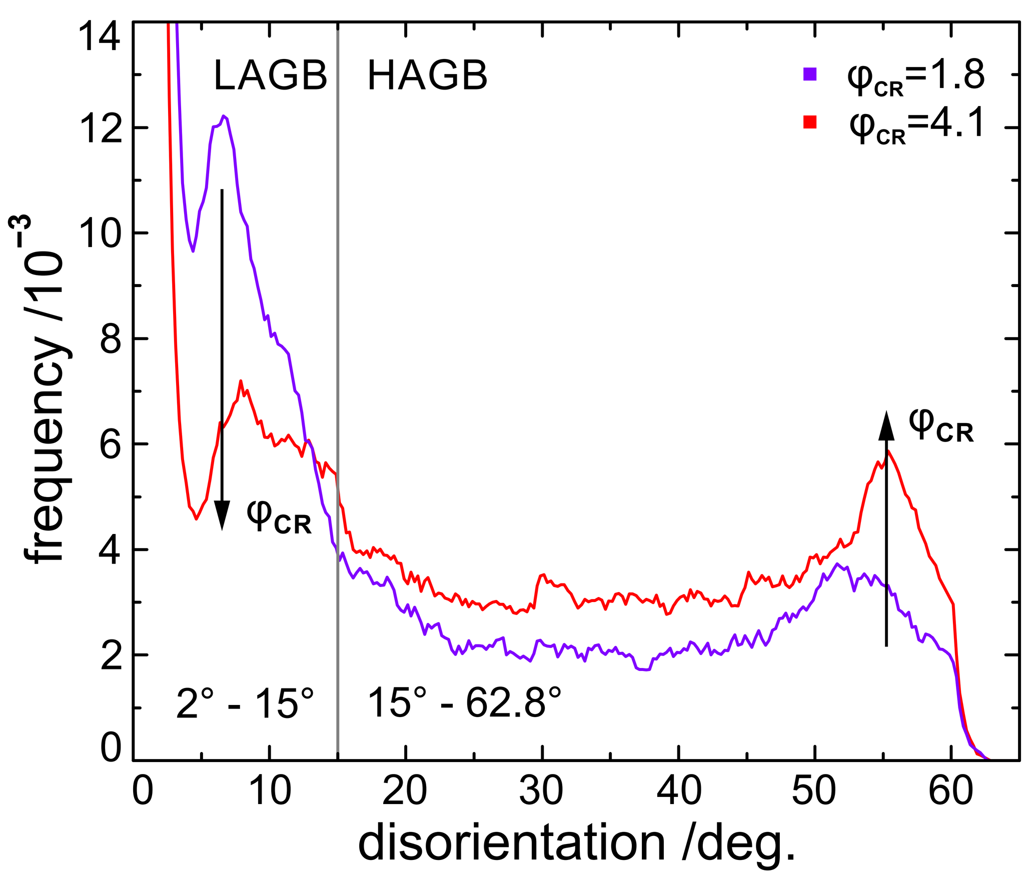
The selected approach of our tungsten research team is the toughening of W and the shifting of its high BDTT of ~600 °C by applying a cold deformation achieved by severe cold rolling.

Background

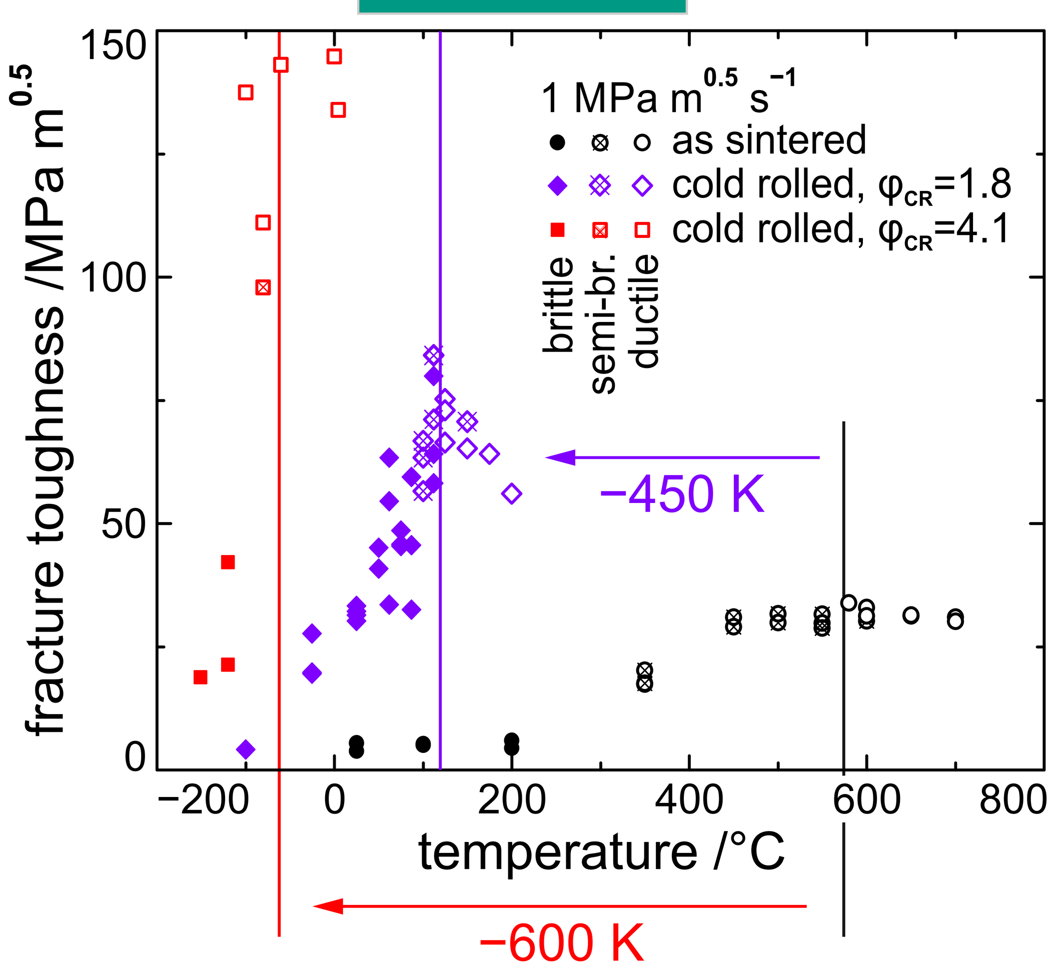


According to *Roberts* (1993) the BDTT correlates with the emission of dislocations close to the tip. If grain boundaries act as dislocation sources, the BDTT will decrease with reduced grian size.

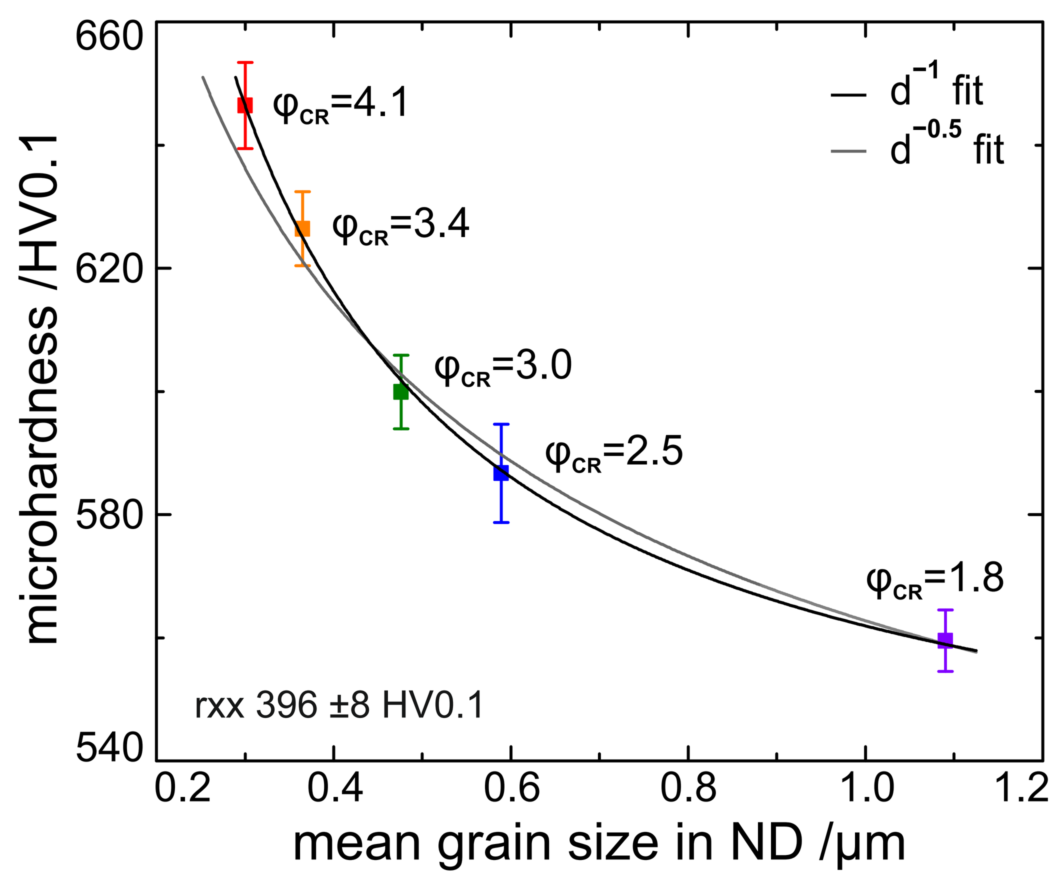
Results



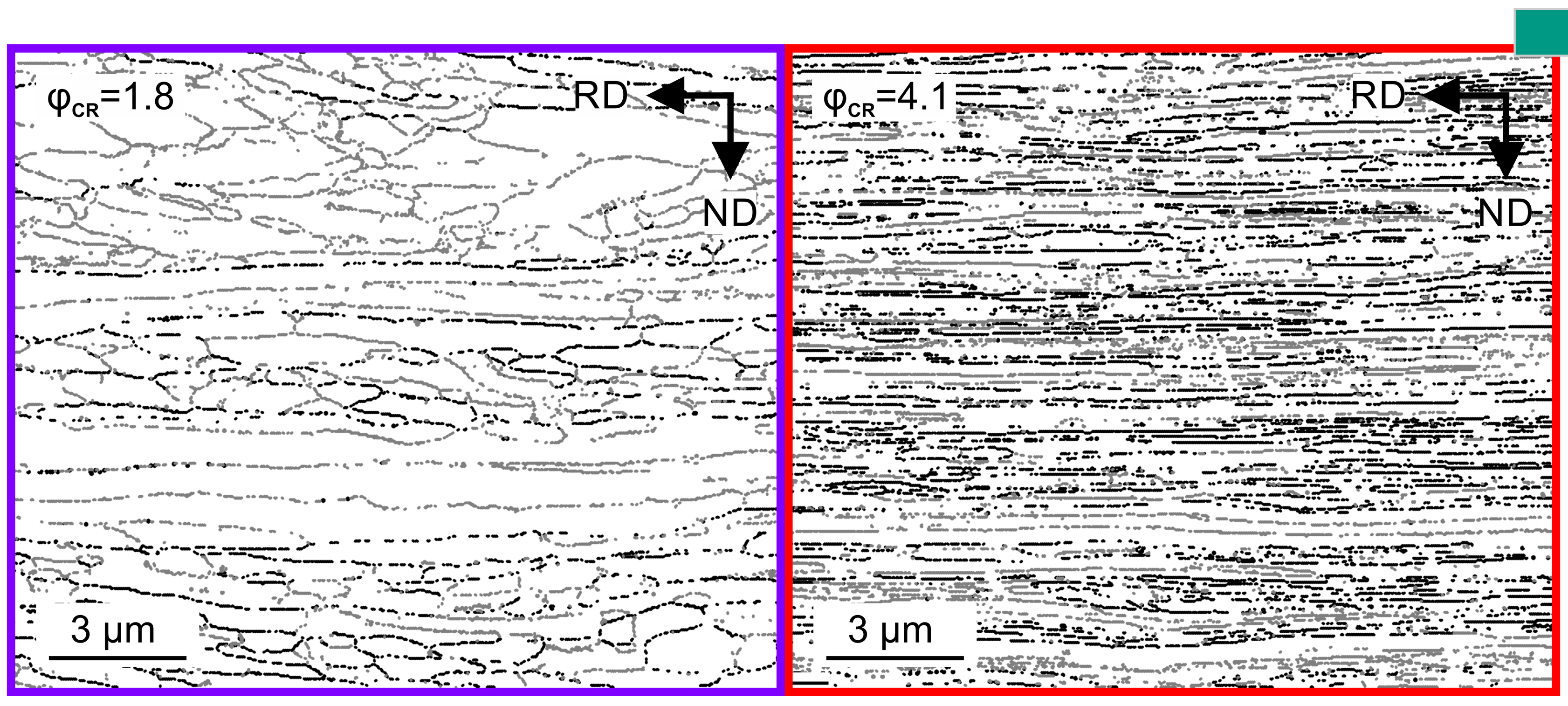
Two maxima are observed for both materials. The weakly deformed microstructure exhibits a high amount of LAGBs. The HAGB-peak of the severely deformed specimen correlates with the texture components.



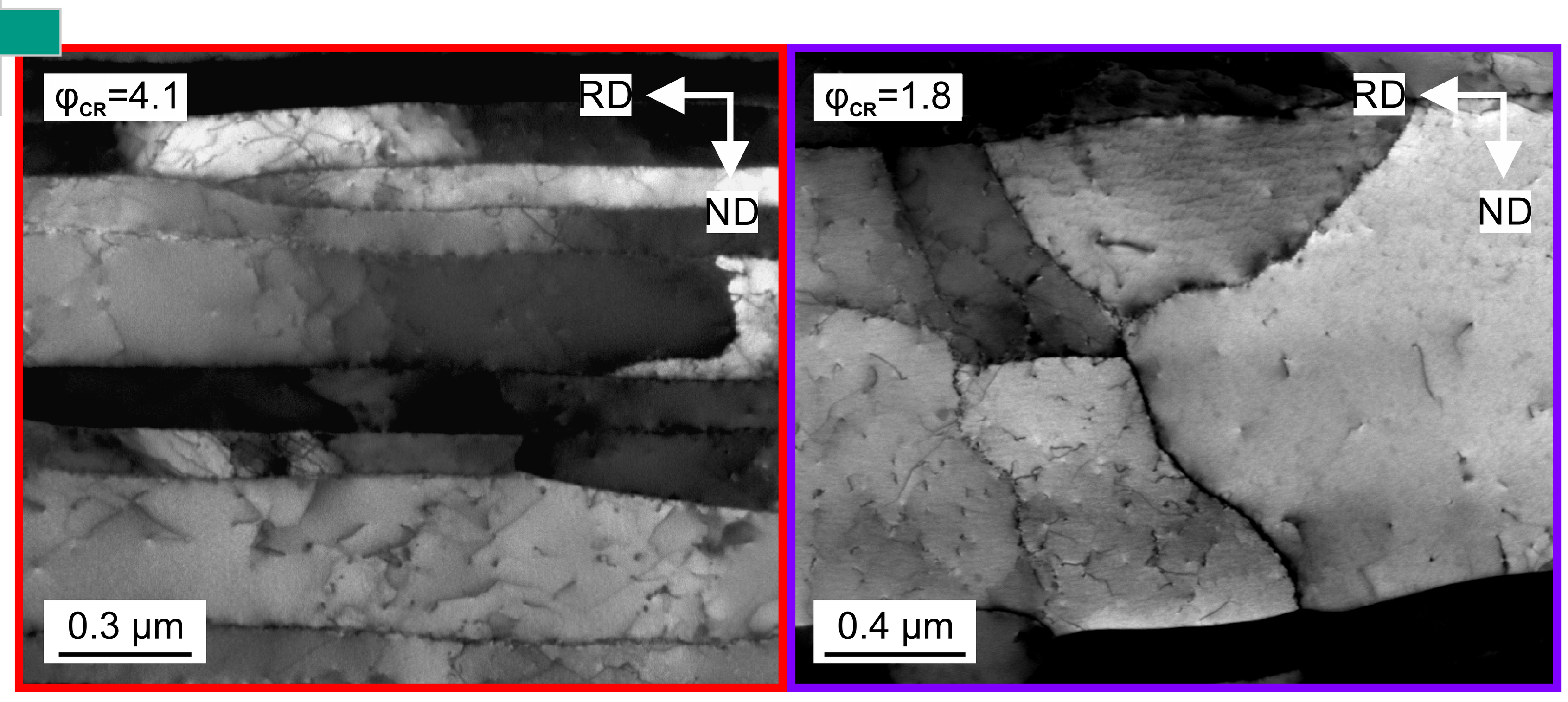
A massive shift of the BDTT of around −600 °C took place during cold rolling. Further tests revealed a negligible size effect of about 50 K. Reduction of the BDTT is caused by microstructural modifications during the severe cold rolling.



A strong work hardening was detected. Interestingly, the hardening exceeds the predictions of the Hall–Petch law. A hyperbolic approach describes very well the hardening behavior of fine-grained and ultrafine-grained tungsten.



Grain boundary character maps of a low deformed sample and of a highly deformed specimen are represented with view in T-direction. HAGBs are drawn in black, LAGBs are grey.



Electron channeling contrast imaging (ECCI) was applied to get a first idea of the dislocation structure and the number of dislocations. An unexpected low dislocation density was observed.

Conclusion

Severely cold rolled W exhibits a tremendous low BDTT of around −50 °C. Cold deformation transforms W in a grain boundary rich material with a growing fraction of HAGBs. The hyperbolic hardening is interpreted as residual stresses in addition to the hardening caused by the Hall–Petch effect. Because of the finding of an unexpected low dislocation density within most grains, the source of these residual stresses is assumed to be located close to the grain boundaries. The author supposes that W transforms into a grain boundary-controlled material, with highly stressed grain boundaries which are promoting dislocation nucleation. A highly boosted dislocation emission rate leads in accordance with *Roberts et al.* to a lowered BDTT.

Please also note the talk of *J. Reiser et al.* in session Refractory Metals - Materials 1, RM9 on tuesday 15:20, and the poster of *S. Bonk et. al.* Rm62 both dealing with severe cold rolled W.