1054 CD
DOI: 10.1017/S1431927606067365
Microsc Microanal 12(Supp 2), 2006

EBSD Study of the Role and Activation of Mechanical Twinning in the Plastic Deformation of 316L Stainless Steel

Xianglin Wu,* Xiao Pan,* James C. Mabon,** and James F. Stubbins*

* Department of Nuclear, Plasma and Radiological Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801
** Frederick Seitz Materials Research Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL 61801

Type 316L stainless steel has been widely used as a structural material for current Light Water Reactors and continues to be selected as a candidate material for various advanced nuclear applications due to its superior strength and corrosion resistance properties. Examples are ITER and the conceptual design of Generation IV reactors. However, certain irradiation conditions lead to the development of a damaged microstructure where plastic flow is confined to very small volumes or regions of material, as opposed to the general plastic flow observed in unirradiated materials. This process is referred as *flow localization.* Previous study [1] shows that the true stress at the onset of necking, defined as the "*critical stress,*" is a constant regardless of the irradiation levels. This critical stress appears to be insensitive to the irradiation dose but exhibits a strong dependence on the test temperature. The role of mechanical twinning in plastic deformation and its influence on the temperature dependence of critical stress are investigated in this study with electron backscattered diffraction (EBSD) orientation mapping of 316L stainless steel under tensile loading conditions from room temperature to 400^{o}C.

Fig. 1 shows the temperature dependence of the critical stress, yield strength and critical twinning stress. From room temperature to 200^{o}C, there is a sharp drop of critical stress before it levels out at higher temperatures. However, the temperature has a weak influence on the yield strength over the entire temperature range. The difference between critical stress and yield strength determines the strain hardening capacity of materials. In addition to dislocation flow, twinning is a possible deformation mechanism in this system. The critical twinning stress is proportional to the stacking fault energy, which is a positive function of temperature. The temperature dependence of the stacking fault energy directly determines the temperature dependence of critical twinning stress [2].

Fig. 2 shows the EBSD orientation maps of 316L stainless steel tested from room temperature to 200^{o}C. The undeformed material shows an equiaxed grain structure with no discernable deformation. For the material strained to the onset of necking at room temperature, mechanical twinning is clearly evident. The intersection of the twinning systems divides the grains into subgrains. Significantly fewer mechanical twins can be found in the sample loaded to uniform elongation at 100^{o}C. In the case of the material tested at 200^{o}C, to the plastic instability point, the twinning system is completely absent. The activation of the mechanical twinning system is determined by the critical twinning stress. At room temperature, the critical twinning stress is smaller than the ultimate strength activating twinning and promoting strain hardening. In the case of 200^{o}C, however, the critical twinning stress is larger than the ultimate strength and the twinning system is not activated. In this case, dislocation-based planar slip dominates the plastic deformation process leading to lower ductility at temperatures above 200^{o}C.

During plastic deformation of 316L stainless steel, with its low stacking fault energy, the Brass-type texture is preferred due to the activation of the mechanical twinning. Fig. 3 shows the texture evolution of 316L stainless steel deformed at room temperature.

References

[1] X. Wu, X. Pan, M. Li and J.F. Stubbins, Journal of Nuclear Materials, 343 (2005) 302-307

[2] T.S. Byun, Acta Materialia, 51 (2003) 3063-3071

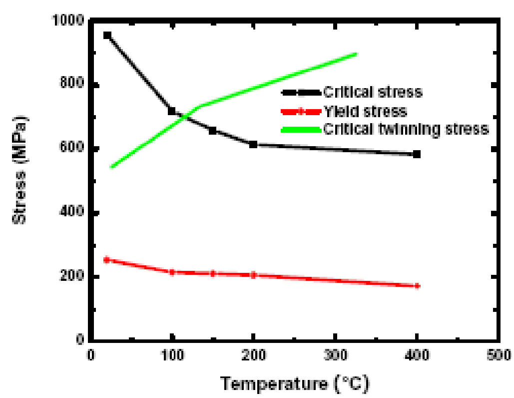


FIG. 1. Temperature dependence of critical stress, yield strength and critical twinning stress.

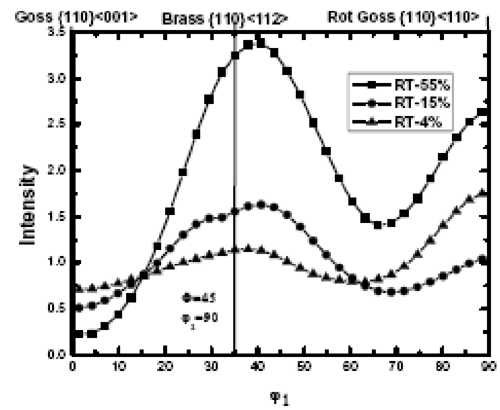
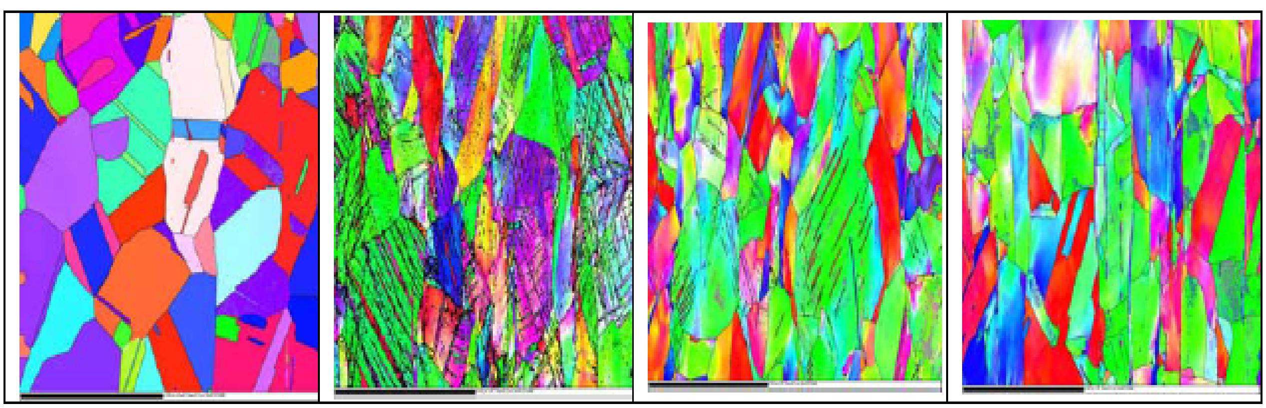


FIG 3 Texture evolution during plastic deformation of 316L SS at room temperature; data from EBSD ODF



(a) (b) (c) (d)

FIG. 2. EBSD orientation maps show the crystal orientation and twinning structure for (a) undeformed 316L SS and at the point of uniform elongation at (b) RT, (c) 100ºC and (d) 200ºC.

https://doi.org/10.1017/S1431927606067365 Published online by Cambridge University Press