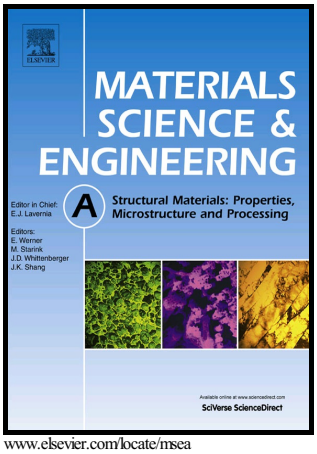
Simultaneous enhancement of strength and plasticity by nano B2 clusters and nano-γ phase in a low carbon low alloy steel

G. Han, Z.J. Xie, B. Lei, W.Q. Liu, H.H. Zhu, Y. Yan, R.D.K. Misra, C.J. Shang



www.elsevier.com/locate/msea

PII: S0921-5093(18)30738-X
DOI: https://doi.org/10.1016/j.msea.2018.05.080
Reference: MSA36518

To appear in: *Materials Science & Engineering A*

Received date: 15 January 2018
Accepted date: 21 May 2018

Cite this article as: G. Han, Z.J. Xie, B. Lei, W.Q. Liu, H.H. Zhu, Y. Yan, R.D.K. Misra and C.J. Shang, Simultaneous enhancement of strength and plasticity by nano B2 clusters and nano-γ phase in a low carbon low alloy steel, *Materials Science & Engineering A,* https://doi.org/10.1016/j.msea.2018.05.080

Simultaneous enhancement of strength and plasticity by nano B2 clusters and nano-γ phase in a low carbon low alloy steel

G. Han[1, 2], Z.J. Xie[1], B. Lei[3, 4], W.Q. Liu[5], H.H. Zhu[6], Y. Yan[2], R.D.K. Misra[7,*], C.J. Shang[1,*]

[1.]Collaborative Innovation Center of Advanced Steel Technology, University of Science and Technology Beijing, Beijing 100083 China

[2.]Institute of Advanced Materials and Technology, University of Science and Technology Beijing, Beijing 100083 China

[3.]Institute of Physics, Chinese Academy of Sciences, P.O.Box 603, Beijing 100190, China

[4.]University of Chinese Academy of Sciences, Beijing 100190, China

[5.]Institute of Materials, School of Materials Science and Engineering, Shanghai university, Shanghai 200444, China

[6.]State Key Laboratory for Advanced Metals and Materials, University of Science and Technology Beijing, Beijing 100083 China

[7.]Laboratory for Excellence in Advanced Steel Research, Department of Metallurgical, Materials and Biomedical Engineering, University of Texas at El Paso, El Paso, TX, USA, 79968

dmisra2@utep.edu (R.D.K. Misra)
cjshang@ustb.edu.cn (C.J. Shang)

***Corresponding authors:** Tel: +86 010 62332428, Fax: +86 10 62332428.

Abstract

Nano B2 FeCu ordered clusters and multiphase microstructure consisting of intercritical ferrite, tempered martensite and nano-γ phase (reverted austenite) were obtained by two-step heat treatment involving intercritical annealing and intercritical tempering. The experimental steel with nano Cu precipitates and nano-γ phase exhibited high strength and high ductility combination. The yield strength and total elongation of the experimental steel increased from 758 MPa and 16.8% to 984 MPa and 29.5% after the second step intercritical tempering for 5 min. High resolution transmission electron microscopy (HRTEM) and three-dimensional atom probe (3DAP) studies provided evidence to support that high density of nano B2 FeCu ordered clusters contributed to high strength. First principle calculations suggested that the feasibility of B2 FeCu nano-ordered clusters, and the stability of B2 structure is related to the coherent stress field at the interface between clusters and the BCC-Fe matrix. The average size of B2 FeCu nano-ordered clusters was 4 nm with a lattice constant of 0.2893 nm and an orientation relationship of $(1\ 1\ 0)_{B2} /\!/ (1\ 1\ 0)_{\alpha}$ and $[0\ 0\ 1]_{B2} /\!/ [0\ 0\ 1]_{\alpha}$. 9R Cu without twinned structure was discovered at different tempering times. The proportion of Cu in Cu precipitates varied from 24.4 at.% to 61.2 at.% with change in crystal structure and increase in the