Reviews on Advanced Materials and Technologies, (2019), vol. 1, no. 1, pp. 62-67

Review of Mechanisms of Nanograin Generation

N.V. Skiba[1,2]

[1]Institute of Problems of Mechanical Engineering, Russian Academy of Sciences, Bolshoy 61 VO, St. Petersburg 199178, Russia
[2] Peter the Great St. Petersburg State Polytechnic University, Politechnicheskaya 29,St. Petersburg 195251, Russia

Received: November 25, 2019 Corresponding author: N.V. Skiba

Abstract. A brief review of the theoretical models which describe specific plastic deformation mechanisms of nanograin generation in nanocrystalline and ultrafine-grained materials is presented. In the framework of the models, formation of new nanograins and nanograin chains occur through stress-driven splitting and migration of grain boundaries near crack tips and grain boundary structures containing disclination dipoles and quadrupoles. Stress-driven migration of mobile grain boundaries serves as a specific plastic deformation mode and results in formation of new nanograins and nanograin chains.

REFERENCES

[1] A.K. Mukherjee, *An examination of the constitutive equation for elevated temperature plasticity*, Mater. Sci. Eng. A, 2002, vol. 322, no. 1-2, pp. 1 - 22.
[2] C.S. Pande and K.P. Cooper, *Nanomechanics of Hall-Petch Relationship in Nanocrystalline Materials,* Progr. Mater. Sci., 2009, vol. 54, no. 6, pp. 689-706.
[3] R.Z. Valiev and T.G. Langdon, *The Art and Science of Tailoring Materials by Nanostructuring for Advanced Properties Using SPD Techniques,* Adv. Eng. Mater., 2010, vol. 12, no. 8, pp. 677-691.
[4] C.C. Koch, I.A. Ovid'ko, S. Seal, and S. Veprek, *Structural Nanocrystalline Materials: Fundamentals and Applications* (Cambridge, Cambridge University Press, 2007).
[5] Y. Estrin and A. Vinogradov, *Extreme grain refinement by severe plastic deformation: A wealth of challenging science*, Acta Mater., 2013, vol. 61, no. 3, pp. 782-817.
[6] T. Sakai, A. Belyakov, R. Kaibyshev, H. Miura, and J.J. Jonas, *Dynamic and post-dynamic recrystallization under hot, cold and severe plastic deformation conditions*, Prog. Mater. Sci., 2014, vol. 60, pp. 130-207.
[7] M. Dao, L. Lu, R.J. Asaro, J.T.M. De Hosson, and E. Ma, *Toward a quantitative understanding of mechanical behavior of nanocrystalline metals*, Acta Mater., 2007, vol. 55, no. 12, pp. 4041-4065.
[8] T.J. Rupert, D.S. Gianola, Y. Gan, and K.J. Hemker, *Experimental observations of stress-driven grain boundary migration*, Science, 2009, vol. 326, no. 5960, pp.1686-1690.
[9] D.S. Gianola, S. Van Petegem, M. Legros, S. Brandstetter, H. Van Swygenhoven, and K.J. Hemker, *Stress-assisted discontinuous grain growth and its effect on the deformation behavior of nanocrystalline aluminum thin films*, Acta Mater., 2006, vol. 54, pp. 2253-2263.
[10] S. Cheng, Y. Zhao, Y. Wang, Y. Li, X.-L. Wang, P.K. Liaw and E.J. Lavernia // *Phys. Rev. Lett*. **104**

(2010) 255501.
[11] S.V. Bobylev and I.A. Ovid'ko, *Nanograin nucleation initiated by intergrain sliding and/or lattice slip in nanomaterials*, Appl. Phys. Lett., 2008, vol. 92, article 081914.
[12] S.V. Bobylev and I.A. Ovid'ko, *Nanograin Nucleation through Splitting and Migration of Grain Boundaries in Deformed Nanomaterials*, Rev. Adv. Mater. Sci., 2008, vol. 17, no. ½, pp. 76-89.
[13] I.A. Ovid'ko, N.V. Skiba, and A.K. Mukherjee, *Nucleation of nanograins near cracks in nanocrystalline materials*, Scripta Mater., 2010, vol. 62, no. 6, pp. 387-390.
[14] S.V. Bobylev, N.F. Morozov, and I.A. Ovid'ko, *Cooperative grain boundary sliding and nanograin nucleation process in nanocrystalline, ultrafine-grained, and polycrystalline solids*, Phys. Rev. B, 2011, vol. 84, article 094103.
[15] N.F. Morozov, I.A. Ovid'ko, and N.V. Skiba, *Stress-driven Formation of Nanograin Chains in Nanocrystalline and Ultrafine-grained Materials,* Rev. Adv. Mater. Sci., 2011, vol. 29, no. 2, pp. 180-186.
[16] S. Zghal, M.J. Hytch, J.-P. Chevalier, R. Twesten, F. Wu, and P. Bellon, *Electron microscopy nanoscale characterization of ball-milled Cu-Ag powders. Part I: Solid solution synthesized by cryo-milling*, Acta Mater., 2002, vol. 50, no. 19, pp. 4695-4709.
[17] Y. Champion, C. Langlois, S. Guerin-Mailly, P. Langlois, J.-L. Bonnentien, and M. Hytch, *Near-Perfect Elastoplasticity in Pure Nanocrystalline Copper*, Science, 2003, vol. 300, no. 5617, pp. 310-311.
[18] X.Z. Liao, Y.H. Zhao, Y.T. Zhu, R.Z. Valiev, and D.V. Gunderov, *Grain-size effect on the deformation mechanisms of nanostructured copper processed by high-pressure torsion*, J. Appl. Phys., 2004, vol. 96, no. 1, pp. 636-640.
[19] M.Yu. Gutkin, K.N. Mikaelyan, A.E. Romanov, and P. Klimanek, *Disclination Models of Misorientation Band Generation and Propagation*, Phys. Stat. Sol. (a), 2002, vol. 193, no. 1, pp. 35-52.
[20] A.E. Romanov, V.I. Vladimirov, *Disclinations in crystalline solids*, In: F.R.N. Nabarro (Ed.), Dislocations in Solids (North Holland, Amsterdam, 1992, Vol. 9, pp.191-402).
[21] M.Yu. Gutkin, I.A. Ovid'ko, and N.V. Skiba *Crack-stimulated generation of deformation twins in nanocrystalline metals and ceramics*, Philos. Mag., 2008, vol. 88, No. 8, p. 1137-1151.
[22] R.G. Munro, *Evaluated Material Properties for a Sintered alpha-Alumina*, J. Am. Ceram. Soc., 1997, vol. 80, no. 8, pp. 1919-1928.
[23] C.J. Smithells and E.A. Brands, *Metals reference book*, London, Butter-worths, 1976.
[24] J.P. Hirth and J. Lothe, *Theory of dislocations*, Wiley, New York, 1982.
[25] T. Watanabe, H. Yoshida, T. Saito, T. Yamamoto, Y. Ikuhara, and T. Sakuma, *Grain boundary energy and atomic structure in alumina bicrystals*, Mater. Sci. Forum, 1999, vol. 304-306, pp. 601-606.
[26] G.C. Hasson and C. Goux, *Interfacial energies of tilt boundaries in aluminium. Experimental and theoretical determination*, Scripta Metall, 1971, vol. 5, no. 10, pp. 889-894.
[27] X. Wu, N. Tao, Y. Hong, G. Liu, B. Xu, J. Lu, and K. Lu, *Strain-induced grain refinement of cobalt during surface mechanical attrition treatment*, Acta Mater, 2005, vol. 53, no. 3, pp. 681-691.