Reviews on Advanced Materials and Technologies, 2024, vol. 6, no. 1, pp. 29–34
DOI: 10.17586/2687-0568-2024-6-1-29-34

A Brief Review on Mechanisms of Plastic Deformation and Fracture Toughness Enhancement in Bimodal Metal-Graphene Composites with Nanotwinned Structure

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Abstract. A brief review of the theoretical models which describe mechanisms of the plastic deformation and fracture toughness enhancement in bimodal metal-graphene composites with nanotwinned structure is presented. In the framework of the models, the plastic deformation in such composites occurs due to the lattice dislocation slip and the grain boundary sliding in nanocrystalline/ultrafine-grained matrix, and the lattice dislocation slip and the migration of the twin boundaries in large grains with nanotwinned structure. Within the review, the migration of nanotwin boundaries in the large grains releases in part local stresses near crack tips and provides the fracture toughness enhancement in bimodal metal-graphene composites with nanotwinned structure. At the same time, the presence of the graphene inclusions in metal-matrix induces the crack bridging effect which also increases the fracture toughness of bimodal metal-graphene composites.

Acknowledgements. The research is funded by the Ministry of Science and Higher Education of the Russian Federation for IPME RAS (theme no. 124041100008-5).

Citation: Rev. Adv. Mater. Technol., 2024, vol. 6, no. 1, pp. 29–34

View online: https://doi.org/10.17586/2687-0568-2024-6-1-29-34

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REFERENCES

[1] L.L. Zhu, J. Lu, Modelling the plastic deformation of nanostructured metals with bimodal grain size distribution, *Int. J. Plast*., 2012, vol. 30–31, pp. 166–184.
[2] A.G. Sheinerman, Plastic deformation of metal/graphene composites with bimodal grain size distribution: a Brief Review, *Rev. Adv. Mater. Technol.*, 2020, vol. 2, no. 4, pp. 1–8.
[3] L. Zhu, C. Wen, C. Gao, Guo X, Chen Z, Lu J, Static and dynamic mechanical behaviors of gradient-nanotwinned stainless steel with a composite structure: Experiments and modeling, *Int. J. Plast*., 2019, vol. 114, pp. 272–288.
[4] N.V. Skiba, Crossover from deformation twinning to lattice dislocation slip in metal–graphene composites with bimodal structures, *Crystals*, 2020, vol. 10, no. 1, art. no. 47.
[5] S.V. Bobylev, M.Yu. Gutkin, A.G. Sheinerman, Yield strength of metal–graphene composites with a homogeneous and bimodal grain structure, *Mech. Solids*, 2020, vol. 55, pp. 22–31.
[6] N.V. Skiba. Deformation mechanism of bimodal metal graphene composites with nanotwinned structure, *Mater. Phys. Mech*., 2021, vol. 47, no. 5, pp. 676–680.
[7] X. Guo, R. Ji, G.J. Weng, L.L. Zhu, J. Lu, Micromechanical simulation of fracture behavior of bimodal nanostructured metals, *Mater. Sci. Eng. A*, 2014, vol. 618, pp. 479–489.
[8] X. Guo, X.Y. Dai, G.J. Weng, L.L. Zhu, J. Lu, Numerical investigation of fracture behavior of nanostructured Cu with bimodal grain size distribution, *Acta Mech*., 2014, vol. 225, pp. 1093–1106.
[9] L. Lu, X. Chen, X Huang, K. Lu, Revealing the maximum strength in nanotwinned copper, *Science*, 2009, vol. 323, no. 5914, pp. 607–610.
[10] I.A. Ovid'ko, N.V. Skiba, A.G. Sheinerman, Plastic deformation modes in ultrafine-grained metals with nanotwinned structures, *Rev. Adv. Mater. Sci.*, 2015, vol. 41, no. 1, pp. 93–98.
[11] S. Zhang, P. Huang, F. Wang, Graphene-boundary strengthening mechanism in Cu/graphene nanocomposites: A molecular dynamics simulation, *Mater. Des.*, 2020, vol. 190, art. no. 108555.
[12] Y. Jiang, R. Xu, Z. Tan, G. Ji, G. Fan, Z. Li, D.-B. Xiong, Q. Guo, Z. Li, D. Zhang, Interface induced strain hardening of graphene nanosheet/aluminum composites, *Carbon*, 2019, vol. 146, pp. 17–27.
[13] M. Khoshghadam-Pireyousefan, R. Rahmanifard, L. Orovcik, P. Švec, V. Klemm, Application of a novel method for fabrication of graphene reinforced aluminum matrix nanocomposites: Synthesis, microstructure, and mechanical properties, *Mater. Sci. Eng. A*, 2020, vol. 772, art. no. 138820.
[14] O. Guler, N. Bagci, A short review on mechanical properties of graphene reinforced metal matrix composites, *J. Mater. Res. Technol.*, 2020, vol. 9, no. 3, pp. 6808–6833.
[15] L.R. Safina, J.A. Baimova, K.A. Krylova, R.T. Murzaev, R.R. Mulyukov, Simulation of metal-graphene composites by molecular dynamics: a review, *Letters on Materials*, 2020, vol. 10, no. 3, pp. 351–360.
[16] K. Lu, L. Lu, S. Suresh, Strengthening Materials by Engineering Coherent Internal Boundaries at the Nanoscale, *Science*, 2009, vol. 324, no. 5925, pp. 349–352.
[17] N.V. Morozov, I.A. Ovid'ko, N.V. Skiba, Plastic flow through widening of nanoscale twins in ultrafine-grained metallic materials with nanotwinned structures, *Rev. Adv. Mater. Sci.*, 2014, vol. 37, no. 1/2, pp. 29–36.
[18] Z. Liu, S. Zhang, J. Yang, J.Z. Liu, Y. Yang, Q. Zheng, Interlayer shear strength of single crystalline graphite, *Acta Mech. Sin.*, 2012, vol. 28, pp. 978–982.
[19] N.V. Skiba, Mechanism of fracture toughness enhancement in bimodal metal-graphene composites with nanotwinned structure, *Mater. Phys. Mech*., 2023, vol. 51, no. 2, pp. 58–64.
[20] N.F. Morozov, I.A. Ovid'ko, A.G. Sheinerman, N.V. Skiba, Formation of deformation twins through ideal nanoshear events near crack tips in deformed nanocrystalline materials, *Rev. Adv. Mater. Sci.*, 2012, vol. 32, no. 1, pp. 75–81.
[21] Y.C. Wang, Y.B. Zhu, Z.Z. He, H.A. Wu, Multiscale investigations into the fracture toughness of SiC/graphene composites: Atomistic simulations and crack-bridging model, *Ceram. Int.* 2020, vol. 46, no. 18, part A, pp. 29101–29110.