6th International Conference on Nanotechnologies and Biomedical Engineering Proceedings of ICNBME-2023, September 20–23, 2023, Chisinau, Moldova - Volume 1: Nanotechnologies and Nano-biomaterials for Applications in Medicine

General Nature of Serration Effect in Crystals and Other Materials Under Indentation

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https://doi.org/10.1007/978-3-031-42775-6_11

Abstract

The nature of the manifestation of the “serration effect” (SE) during nano-microindentation of materials of various types was studied in this work: ionic and covalent crystals (LiF, MgO, Si), coated systems (CSs) of the film/substrate type, metals (Cu, austenitic steel AISI 316L) and laser phosphate glasses doped with rare earth elements (SP-R). The serration effect on the nano-microindentation P(h) curves was revealed both at the loading and unloading stages. It has been established that serration effect is a property of all studied materials. General regularities were revealed: SE is most pronounced in single crystals and CSs, less in metals, and the weakest in glasses. With an increase in the load on the indenter and an increase in the loading rate, the amplitude and step of oscillations decrease. The characteristic dependences obtained in the paper correlate with the literature data, which also confirm the wavelike nature of indentation for various materials. It has been suggested that the effect may be associated with the elastic-plastic recovery (relaxation) of the material, which takes place throughout the entire indentation process. The fluctuations revealed on the load-displacement curves may indicate the wave nature of the indentation process and the universal character of the oscillatory effect in the process of depth-sensing indentation.

Keywords: serration effect, model single crystals, composite systems, metals, glasses, nano-microindentations

References

1. Lorenz, D., Zeckzer, A., Hilpert, U., Grau, P., Johnson, H., Leipner, H.S.: Pop-in effect as homogeneous nucleation of dislocations during nanoindentation. Phys. Rev. B **67**, 172101-1–172101–4 (2003). doi:https://doi.org/10.1103/PhysRevB.67.172101

2. Tromas, C., Gaillard, Y., Woirgard, J.: Nucleation of dislocations during nanoindentation in MgO. Phil. Mag. **86**(33–35), 5595–5606 (2006). https://doi.org/10.1080/14786430600690499

3. Ohmura, T., Wakeda, M.: Pop-in phenomenon as a fundamental plasticity probed by nanoindentation technique. Materials **6**, 4259–4267 (2013). https://doi.org/10.3390/ma6094259

4. Dey, A., Chakraborty, R., Mukhopadhyay, A.K.: Enhancement in nanohardness of soda– lime–silica glass. J. Non-Cryst. Sol. **357**, 2934–2940 (2011). https://doi.org/10.1016/j.jnoncrysol.2011.03.036

5. Gouldstone, A., Chollacoop, N., Dao, M., Li, J., Minor, A.M., Shen, Y.-L.: Indentation across size scales and disciplines:Recent developments in experimentation and modeling. Acta Mater. **55**, 4015–4039 (2007)

6. Grabco, D.Z., Harea, E.E., Shikimaka, O.A., Sherban, D.A.: Elastoplastic response of TCO/SiCSs to local loading. In: Horisons inWorld Physics, Ed. Albert Reimer, vol. 277, pp. 111–130 (2012)

7. Grabco, D.Z., Pyrtsac, K.M., Ghimpu, L.Z., Volodina, G.F.: Mechanical properties of the coating/substrate composite system: nanostructured copper films on a LiF substrate. Surf. Eng. Appl. Electrochem. **52**(4), 319–333 (2016). https://doi.org/10.3103/S1068375516040074

8. Zuev, L.B., Barannikova, S.A., Zarikovskaya, N.B., Zykov, I.: Phenomenology of wave processes of localized plastic flow. PSS **43**(8), 1423–1428 (2001)

9. Oliver, W.C., Pharr, G.M.: An improved technique for determining hardness and elastic modulus using load and displacement sensing indentation experiments. J. Mater. Res. **7**(6), 1564–1583 (1992). https://doi.org/10.1557/JMR.1992.1564