§66. Application of Micro-Indentation Technique to Characterization of Heavy-Ion-Induced Hardening

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Irradiation of metallic ions in the MeV energy range with or without co-implantation of helium ions is an effective, powerful and relatively quick experimental method to simulate the high-energy neutron damages in materials and the synergistic effect with transmutant helium. However, the use of ion irradiation of this kind has mostly been limited to the studies on microstructural evolution and swelling, because the induced damage occurs only within a surface layer of typically one micrometer thick. This study is intended to establish a simple and quick method to characterize the plastic deformation properties of such thin damaged layer by mean of ion beam irradiation and a low load hardness measurement technique. The present work focuses on the development of experimental techniques and considerations specific to analyzing the measured data from specimens which possess perpendicularly uneven hardness property. For this purpose, metals and alloys of different classes, namely a model austenitic alloy, pure iron and pure vanadium, were irradiated with nickel ions of different energy with and without co-implantation of helium ions and then subjected to an low-load instrumented indentation tests. The load - displacement property obtained from the experiment was then analyzed in order to extract the amount of the net hardening due to irradiation.

As a conclusion, it was demonstrated that the hardening of metallic materials induced by heavy ion irradiation in an MeV energy range can be quantitatively evaluated by the instrumented low-load indentation technique. A depth-profile measurement of the apparent indentation hardness and the elastic work analysis appeared to be effective for this purpose. A higher-load indentation test may be employed to determine the hardening in a thin layer at a reasonable accuracy, provided (1) damaged layer thickness is know, (2) indentation depth is larger than the layer thickness and (3) the amount of relative hardening is large enough (approximately larger than 50%). It was also shown that the depth-dependent $B'=d^2P/dz^2$ analysis is not applicable for hardening evaluation for the current testing system but it provides the upper limit of indentation depth to give the real hardness of the damaged layer.

Acknowledgment

The authors gratefully acknowledge Mr. Hiroyasu Tanigawa at Kyoto University and Dr. Hideo Watanabe at Kyushu University for their help in the specimen preparation, Dr. Shinji Sato and Mr. Kenichiro Watanabe both at University of Tokyo for their assistance in the indentation tests and Dr. Hiromi Shibata at University of Tokyo and Messrs. Makoto Narui and Takao Omata at ATOX Inc. for their assistance in conducting the ion irradiation.

Reference

1) Katoh,Y., Muroga,T., Iwai,T., and Motojima, O., "Application of Micro-Indentation Technique to Characterization of Heavy-Ion-Induced Hardening", Proceedings of the JUPITER / IEA Joint Symposium on Small Specimen Test Technologies for Fusion (in printing).