INSTRUMENTED INDENTATION

This special issue of the Journal of Materials Research contains articles that were accepted in response to an invitation for manuscripts.

Introduction

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Although studies of indentation hardness of solids have been carried out for more than a century, it is only during the last 30–40 years that researchers started to develop and use instrumented indentation machines with which both the indenter load and indenter displacement are recorded simultaneously and accurately. Since the availability of commercial instrumented indentation machines in the 1980s, their use has been extended to almost all branches of materials sciences and even some aspects of biological sciences. Mechanical properties of materials can now be measured from the macro-scale down to the nano-scale. These mechanical properties include hardness, Young's modulus, equivalent uni-axial yield stress, fracture toughness, elasticity of biological cells, viscoelasticity and residual stresses. The instrumented indentation machine has indeed become an essential aid to universal material characterization and modeling.

This focus issue is the fourth volume of the *Journal of Materials Research* (*JMR*) related to indentation. The first, entitled "Nanoindentation: From Ångstrom to Microns," appeared in 1999 [1] and the second, "Fundamentals and Applications of Instrumented Indentation in Multidisciplinary Research," in 2004 [2]; the third, "Indentation Methods in Advanced Materials Research" was issued in 2009 [3]. Much theoretical and practical research in expanded indentation methods has been done since 2009. Because *JMR* has led the discussion since its first volume on indentation and has continually been a center for sharing ideas and techniques, we are especially pleased at the publication of this fourth *JMR* focus issue. We believe that, as in the past, this focus issue will help guide trends in instrumented indentation and offer opportunities for future research.

In this focus issue, we see the extension of the indentation-derived properties from indentation hardness to various other mechanical properties, such as stress-strain relationship, fracture toughness, and adhesion. Multiscale computational simulation methods are being used to understand and correlate representative mechanical properties and indentation behaviors. Recent improvements of instrumented indentation machines and data analysis techniques are also captured, such as dynamic impact testing, high-temperature, atomic force microscope attachments, in situ facility for scanning electron microscopy (SEM) and transmission electron microscopy (TEM) studies, micro-pillar tests, and the availability of models in which neither the frame compliance nor the thermal drift contribute to the total indenter displacement, thus helping researchers considerably in advancing our understanding of the mechanical behavior of materials with high precision. This focus issue further demonstrates the maturity of instrumented indentation as a large number of applications to various materials and systems mentioned in the above, including biomaterials, nano-structured materials and composite materials, is reported.

We would like to express our deep appreciation to everyone who submitted papers and to all our reviewers. Their contributions are a critical step in the improvement and success of indentation techniques. This Focus Issue became possible through the cooperation of JMR staff. We, the Guest Editors, are very grateful to all of them. All the previous issues have been highly successful in enhancing our understanding of the fundamental mechanical properties of different types of material down to the nano-scale and we hope that this Focus Issue will be a valuable source of knowledge and inspiration.

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