From our readers

HARDER THAN DIAMOND? JUST FICTION

To the editor — In a recent correspondence on hardness[1], several assertions were made, some of which are incorrect and some are misleading.

First, the title "What does 'harder than diamond' mean?", suggests that some materials can be harder than diamond. In fact, so far, no natural or synthesized material has been found to be harder than natural diamond. Moreover, it appears quite unlikely[2,3] that a material harder than natural diamond can be synthesized.

Second, the authors state "But for materials approaching the hardness of diamond — measured at 60–120 GPa — indentation is no longer controlled by plastic deformation alone, and issues such as brittle cracking and deformation of the indenting tip come into play." In fact, the formation of a permanent indentation in a material, irrespective of its hardness, is by plasticity alone. If the load on the indenter is above a critical value for the brittle solid, only then will cracking follow plasticity.

Third, the authors have suggested that for brittle materials involving cracking around indentations, the hardness decreases with increasing indenter load because of the degree of cracking, which increases with increasing indenter load. In fact, such a variation of indentation hardness occurs for most ductile and brittle materials even if there is no cracking around indentations. Sometimes this behaviour is referred to as indentation size effect.

Fourth, the authors recommend that indentation hardness values "higher than 120 GPa should not be called 'hardness' to avoid confusion". This is a misleading suggestion. According to a very well accepted definition[4], the indentation hardness of an elastic-plastic solid is given by the indenter load divided by the projected area of the permanent indentation formed. In the literature[5], the indentation hardness of single crystals of natural diamond has been reported to be 143 ± 6 GPa (Berkovich diamond indenter under a load of 2 N). Therefore, it is perfectly appropriate to state that the indentation hardness of a particular solid is 120 GPa.

To re-emphasize, there is no material harder than natural diamond and, therefore, it is proper to determine the indentation hardness of other hard solids using pyramidal indenters made of natural diamond single crystals, and to quote the hardness values in the normal way, that is, indenter load divided by the projected contact area of the indentation formed. In order to determine the projected contact areas of micro- and nanoindentations it is more appropriate to image the indentations using a well-calibrated atomic force microscope than to use the unloading curves obtained from the nanoindentation machine[6]. It should also be stated that in this way of measuring the projected contact area of an indentation, there is little danger of any errors introduced due to any elastic relaxation, as it is generally accepted that during indenter unloading, the size of the indentation diagonals, even for indentations in hard materials, does not show any significant change[7]. Finally, as a precaution, the maximum indenter load should be chosen carefully so that there is no cracking around the indentation formed.

References

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