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On the way to physically correct indentation analyses

Common indentation analyses (ISO and ASTM standardized) suffer from iterations, polynomials and approximations. However, correct physics on the basis of elementary mathematics avoids iterations and violations of the energy law for hardness and modulus. The new physically founded laws $F_N=0.8\ k\ h^{3/2}$ and $W_{applied}/W_{indent}=5/4$ apply to nano, micro and macro depth sensing indentations. Importantly, they detect phase changes under load and allow for the arithmetic treatment for single or successive phase transformations, surface layer effects and correct adsorption energies. Thus, the first physical hardness H, stiffness/indentation moduli (these are not "Young's moduli"), indentation works, activation energies and phase transformation energies are directly obtained, simply by application of the basic physically founded equations that avoid the unfortunate common energy law violations. Non-steadiness kinks (in the linear $h^{3/2}$ plots) and any deviations from the precise 5/4 ratio (integration of the smooth appearing loading curves over one or more phase transition onsets is not allowed) prove phase change (s) under load. For example, five successive phase changes to reveal six different polymorphs of NaCl up to 50 N load (corresponding to HV5) from depth-sensing indentations will be presented and analysed. In addition to fcc and bcc, theoretical predictions published three new polymorph structures and there is the possibility of twins and amorphous phases. The undeniable half-page physical deductions of the two basic formulas will be presented and discussed as the derived formulas for the mentioned and further mechanical applications. This is not only of academic interest, but materials' properties must be correctly and reliably described, and technical materials must withstand pressure upon use without failing. The latter are at risk when phase change onset pressures remain undetected, because of the formed interfaces between different polymorphs as sites for nucleation of cracks. Highly resolved (5000X) 3D-microscopy reveals details of crack nucleation. The non-detection of of phase changes is the main objection against the reliability of non-depth-sensing Vickers, Brinell, Rockwell, etc. hardness characterizations of daily life technical materials (not withstanding their always similar standard plates that equally undergo the undetected phase changes). The neglecting of always several undetected phase changes misses the most relevant properties with creation of high common risks. Furthermore, indentation measurements gain enormously in precision, because invalid single measurements can be directly excluded when they do not concur with the undeniable physical $F_N \propto h^{3/2}$ law's linear correlation with >3 or >4 nines, due to local imperfections, or skew, or too close to interface or to borderline indentations. The safety issues also for all the numerous applications that derive from ISO H and E_r are evident and largely unexplored.

Biograpy

Gerd Kaupp has completed his PhD at Würzburg University and Postdoctoral studies from Iowa State University, Lausanne University and Freiburg University. He held a Full-Professorship till 2005 in Oldenburg, Germany and he privately continues his research on wasteless solid-state chemistry temperature-controlled with 100% yield since 1984, AFM on rough surfaces since 1988, the non-stochastic but versatile and better resolving sub-diffraction limit microscopy for unstained non-fluorescing materials of all types (resolution <10 nm, since 1995), and (nano) indentations (since 2000). In the latter field, he is still urging ISO (NIST) to correct their 50 years old standards for conformity with physics. He has published more than 300 papers in renowned journals and has been serving as an Editorial Board Member of several scientific journals.

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