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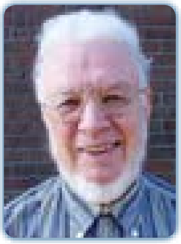

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Basic physics disproves the obligatory ISO-14577 standards: A dilemma for all indentation mechanics

Most mechanical properties of materials are deduced from indentation with pyramidal/conical diamond tips. The obligatory ISO-14577 standard iterates hardness (H_{ISO}) and elastic modulus ($E_{r\text{-}ISO}$) with triple violation of basic physics (energy law violation, wrong exponent on h, and denying phase transitions under load). Very high-load indentation techniques (Vickers, Knoop, Brinell, Rockwell, etc. hardness) are even more empiric and include the same violations. Thus, the normal force (F_N) is not proportional with h^2, but with $h^{3/2}$, as is physically founded[4] and experimentally confirmed. The wrong exponent 2 also prevents the detection of initial surface effects (that must be corrected for) and phase transitions under load. While the latter often occur within the 1000 µN range, some require the mN and up to >25 N range, where multiple phase transitions generally occur with the additional risk of macroscopic cracking (for example NaCl at 0.618 mN, 3.34 mN, 2.49 N, 9.12 N, 24.43 N, these without cracking[13]. The way for a physical treatment of indentations has been paved with "Kaupp-plots" ($F_N = k\,h^{3/2}$) since 1990. The material's penetration resistance k requires the energy-law correction factor of 0.8. But that is still not appreciated by the establishment. And pressure-formation requires work! Pressure has long been used for elastic modulus determinations though. It does not help that the very high-force techniques rely on the diameters of the impression surface such as Vickers, Knoop, Brinell (they are convertible into the depths), or that Rockwell and Shore measure the depth. Problems with cracks are not seen and reported (this does not mean cracks upon unloading for fracture toughness), but different load ranges have to be distinguished and empirical inter-conversion formulas are used. The physically valid H_{phys}=0.8k/tg^2 can now be obtained by linear regression of the loading curve's Kaupp-plot, excluding the three flaws. Indentation moduli $E_{r\text{-}phys}$ require energy correction and experimental stiffness dF_{max}/d_h, using simplest arithmetic. Indentation moduli are not the claimed "Young's moduli" and should be directly calculated but not iterated with up to 11 free parameters. All of that is valid for all types of materials and instrumented depth sensing techniques. The dilemma of the ISO standards against physics and thus the woldwide "enforced" iteration of further wrong mechanical properties is detrimental, producing very large size-dependend errors and increasing crack probabilities. Liability problems for disastrous material failures ensue. Textbooks and instrument software must be rewritten, the ISO-14577, a NIST tutorial, and the opposing publications retracted. The physical correctness must be installed for the sake of daily life security. Examples will be discussed. ISO appears slow in changing its standards for complying with physics. I continuously ask them to release an urgent caveat, telling that ISO-14577 will be subject to change for the physical reasons.

Recent Publications

1. Kaupp G, (2013) Penetration resistance: a new approach to the energetics of indentations. Scanning 35: 392-401.
2. Kaupp G (2013) Penetration Resistance and Penetrability in Pyramidal (Nano)Indentations. Scanning 35: 88-111

3. Kaupp G (2014) Activation energy of the low-load NaCl transition from nanoindentation loading curves. Scanning 36: 582-589.
4. Kaupp G (2016) The physical foundation of FN = kh3/2 for conical/pyramidal indentation loading curves. Scanning 38: 177- 179 (open access)
5. Kaupp G (2006) Dilemma zwischen ISO und Physik: Nanotechnologie decktauf. Nanobay, 3. May 2016.

Biography

Gerd Kaupp studied chemistry at the University of Würzburg, Germany, and was appointed full professorship at the University of Oldenburg in 1982. Since 2005 he is retired member at the University of Oldenburg. He served as guest professor and pursues his scientific interests also with consulting. His expertise is in chemical kinetics, laser photochemistry, waste-free benign productions, solid-state chemistry, reactive milling, mechanochemistry, atomic force microscopy, scanning near-field optical microscopy SNOM, nanoscratching, nanoindentation, bionics, and standardization of nanomechanics. He is keynote speaker in these fields, published numerous scientific papers and books and is inventor of patents in solid-state and environmental chemistry.

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