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Comment on "Influence of random roughness on cantilever curvature sensitivity" [Appl. Phys. Lett. 96, 041912 (2010)]

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In Ref. 1 (referred to as **I** for brevity), Ergincan *et al.* combine the treatment of the impact of surface roughness on the sensitivity of cantilevers by Weissmüller and Duan[2] (referred to as **II**) with a statistical parameterization of the roughness. The analysis of the underlying mechanics problem in **II** points at suitable moments of the distribution of the surface misorientation angle, θ, as the relevant microstructural variables. Ergincan *et al.* adopt the results of **II** and express $\langle \theta^2 \rangle$ (where the brackets denote average over the surface) in terms of parameters that can be derived from the height–height correlation function of the surface. These parameters are the roughness exponent, H, and characteristic values for the amplitude (w) and lateral extension (ξ) of the surface corrugation (cf. **I**). In spite of the straightforward nature of the modification, **I** arrives at significantly different conclusions on the impact of roughness for the sensitivity than **II**. In **I**, the sensitivity of Si cantilevers drops to zero for some configurations, whereas **II** explains that vanishing sensitivity cannot be expected for that material due to its small Poisson ratio, ν. The contradiction can be traced to the use, in **I**, of unphysically large misorientation angles.

For isotropic and uniform surface stress, the sensitivity ratio, T/T_0, of a cantilever subject to changes in its surface stress is given by[2]

$$\frac{T}{T_0} = \frac{1}{2}\left\langle \frac{1+\nu}{1-\nu}\cos\theta + \frac{1-3\nu}{1-\nu}\sec\theta \right\rangle. \quad (1)$$

The Taylor expansion of Eq. (1) is $T/T_0 = 1 - A_2\langle\theta^2\rangle - A_4\langle\theta^4\rangle + O[\langle\theta^6\rangle]$, where $A_2 = \nu/(1-\nu)$ and $A_4 = (7\nu - 3)/[24(1-\nu)]$. For sufficiently small θ one then has

$$\frac{T}{T_0} \approx 1 - \frac{\nu}{1-\nu}\langle\theta^2\rangle. \quad (2)$$

I introduces a root-mean-square local slope, $\rho_{\rm rms}$, which satisfies $\rho_{\rm rms}^2 \approx \langle\theta^2\rangle$ in the limit of "weak roughness," $\langle\theta^2\rangle \ll 1$ and which can be expressed as a function of w, ξ, and H. Plots of T/T_0 versus w/ξ for Si in **I** suggest that the sensitivity can be reduced all the way to zero for w/ξ between 0.5 and 1.

We have plotted, in Fig. 1, the T/T_0-values from Eqs. (1) and (2) for the entire range of θ, assuming a facetted surface with a single value of θ (cf. **II**). We used the two ν values (0.18 and 0.28) for Si surfaces from **I** and added a plot with $\nu=0.44$ for Au. It is noted that for Au the approximate T/T_0 agrees well with the exact value in the whole range of θ since the large ν entails small A_4. Two observations are remarkable for the Si data in Fig. 1. First, there is a significant deviation between the exact and approximate result when $\theta \gtrsim 45°$. This is because A_4 is large for the small ν of the Si surfaces. Caution is therefore required when using Eq. (2) in conjunction with finite misorientation. Second, for Si none of the graphs goes to zero at any angle. The finding of $T/T_0 = 0$ in **I** therefore leads us to suspect that the conversion from w/ξ to θ used in **I** may produce unphysically large misorientation values, $\theta > 90°$. Such retrograde angles are inconsistent with the derivation of Eqs. (1) and (2), and they are also not consistent with a description of the surface where the local height is a function of the position.

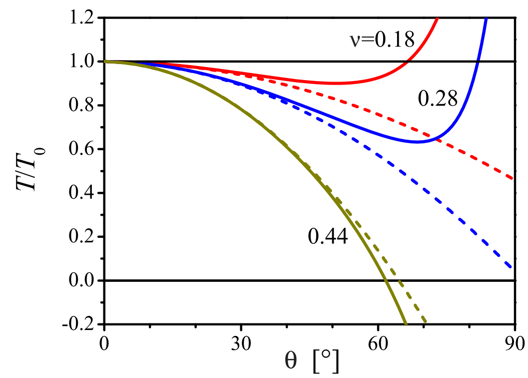

FIG. 1. (Color online) Variation in cantilever sensitivity, T/T_0, with inclination angle, θ, of the surface facets for surfaces with different Poisson ratios, ν. Solid line: exact value, Eq. (1); dashed line: approximate value, Eq. (2). Note that sensitivity for the smaller ν is positive through the entire angle range. This is in conflict with results in **I**.

We conclude that the results of **I** should be re-examined to verify (i) the consistency between the statistical roughness parameters and the mean-square misorientation angle and (ii) the requirement $\langle\theta^2\rangle \ll 1$.

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