Comment on "Nanoadhesion between Rough Surfaces"

In a recent Letter [1] Chow has studied the adhesion between solids with rough surfaces. He assumed that the surface roughness is self-affine fractal, but nevertheless treated the surface asperities as spherical bumps of *identical* radius R. This is similar to the classic paper by Fuller and Tabor [2], where it was shown that already a relative small surface roughness can completely remove the adhesion. However, self-affine fractal surfaces have roughness on many different length scales, and when this is taken into account a qualitatively new picture emerges (see below), where, e.g., the adhesion force may even vanish (or at least be strongly reduced), if the fractal dimension $D_{\mathrm{f}} > 2.5$. Thus the theory of Chow [1] overlooks the perhaps most important aspects of real surfaces—the existence of a wide distribution of length scales. Here I present some simple arguments which illustrate the profound importance of not excluding any surface roughness length scale in the analysis [3].

Fuller and Tabor have shown that for elastic solids with surface roughness on a *single length scale* λ, the competition between adhesion and elastic deformation is characterized by the parameter $\theta = Eh^2/\lambda\Delta\gamma$, where h is the amplitude of the surface roughness. (Chow instead introduced the parameter $\beta \sim \theta^{2/3}$, but in the present context θ is a more convenient quantity.) The parameter θ is the ratio between the elastic energy and the surface energy stored at the interface, assuming that complete contact occurs. When $\theta \gg 1$ only partial contact occurs, where the elastic solids make contact only close to the top of the highest asperities, while complete contact occurs when $\theta \ll 1$.

Surfaces of real solids have roughness on a wide distribution of length scales. Assume, for example, a self-affine fractal surface. In this case the statistical properties of the surface are invariant under the transformation

$$\mathbf{x} \rightarrow \mathbf{x}\zeta, \qquad z \rightarrow z\zeta^{\alpha},$$

where $\mathbf{x} = (x, y)$ is the 2D position vector in the surface plane, and where $0 < \alpha < 1$. This implies that if h_{a} is the amplitude of the surface roughness on the length scale λ_{a}, then the amplitude h of the surface roughness on the length scale λ will be of order

$$h \approx h_{\mathrm{a}}(\lambda/\lambda_{\mathrm{a}})^{\alpha}.$$

Thus we get

$$\theta_{\mathrm{a}} = \theta(\lambda_{\mathrm{a}}/\lambda)^{2\alpha-1},$$

where $\theta_{\mathrm{a}} = Eh_{\mathrm{a}}^2/\lambda_{\mathrm{a}}\Delta\gamma$. Hence, when we study the system on shorter and shorter length scale $\lambda_{\mathrm{a}} < \lambda$, θ_{a} will decrease or increase depending on whether $\alpha > 1/2$ or $\alpha < 1/2$, respectively. In the former case, if $\theta < 1$ the adhesion will be important on any length scale $\lambda_{\mathrm{a}} < \lambda$. In particular, if λ is the long-distance cutoff length λ_0 in the self-affine fractal distribution, then *complete contact will occur at the interface*. In the latter case, even if $\theta < 1$ so that the adhesion may seem important on the length scale λ, at short enough length scale $\theta_{\mathrm{a}} > 1$. Thus, without a short-distance cutoff, *adhesion and the area of real contact will vanish*. In reality, a finite short-distance cutoff will always occur, but this case requires a more detailed study (see Ref. [3]). Finally, I suggest that the present problem may be studied by a renormalization group type of approach, where during the process of eliminating short-wavelength roughness components, the effective interfacial energy $\Delta\gamma_{\mathrm{eff}}(\lambda)$ depends on the wavelength λ of observation.

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Received 25 July 2001; published 11 March 2002
DOI: 10.1103/PhysRevLett.88.129601
PACS numbers: 68.35.Gy, 05.40.–a, 68.35.Ct

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