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Deformation and Contact Between Self-Affine Surfaces[1]

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Molecular interactions at contacts between surfaces determine the strength of adhesion and friction forces. The total area of contact and the spatial distribution of forces are determined by a complex interplay between surface topography and elastic and plastic deformation far below the surface. The situation is further complicated by the fact that many real surfaces have roughness on a wide range of lengths that can be described by self-affine scaling. The talk will provide a detailed analysis of contact between such self-affine surfaces. First continuum mechanics results for elastic and plastic solids will be contrasted. In both cases the contact area increases linearly with the applied normal load, implying that the mean pressure in the contacts <p> is constant. For elastic surfaces <p> increases linearly with the root mean squared slope of the surface, Δ. For plastic surfaces, <p> is bounded by about six times the yield stress σ_y, but over the typical range of σ_y, <p> rises roughly as $\sigma_y^{2/3}$. The morphology of the contacts is complex. Individual contacts have fractal area and perimeters, and plastic deformation increases the fractal dimension. There is a power law probability distribution $P(a)$ of cluster areas a: $P(a) \sim a^{-\tau}$. The value of τ is larger than 2 for elastic surfaces, and $\tau \approx 2$ for plastic surfaces. The above continuum results are next tested against MD simulations of 2D and 3D solids with self-affine surfaces. We find that the contact area is still linearly related to the load, but the slope can differ from continuum predictions. For elastic surfaces this arises from the failure of the continuum assumption that surfaces are smooth and differentiable at small scales. For plastic surfaces the discrepancies reflect unusual modes of plastic deformation at the interface. These changes are correlated to frictional forces in the simulations.

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