

When two bodies interact, energy is typically transferred. This transfer of energy is sometimes sought, as with energy generators and cooling systems, while other times the requirement is to avoid it, as with general energy storage or in processes requiring energy transfer efficiency.

An important mode of energy transfer, which we term energy dissipation, involves the loss of stored energy in the form of heat. This heat is dissipated to the surroundings with a corresponding increase in temperature. The mechanism for energy dissipation in the nanoscale is an important characteristic of materials and systems where energy concentration might cause malfunction, damage or poor efficiency. For example, integrated electronics [1], photosynthetic processes that occur in plants [2] and even the mechanisms involved in ductility, evolution of the damage and toughening of the bones [3] are greatly influenced by their ability and capacity to dissipate energy in the nanoscale.

Dissipative nanoscale processes might include any interplay of phenomena related to atom reorientation and dislocation, local rearrangement of atoms, disruption of chemical bonds, atom collisions, electron-phonon-photon interactions[1] and general thermal excitation (Figs. 1-2) [4]. Nevertheless, it is not only the magnitude of the energy dissipated in the interaction (Fig. 3) but also the spatial distribution of the dissipated energy that controls the effects of energy dissipation in a system (Figs. 4-5). That is, processes involving energy efficiency and energy conversion need to take into account the dispersion or localization of dissipative processes. Here, we analyse the four fundamental nanoscale energy dissipation processes. We discuss the level or degree of localization by calculating the effective area of interaction of a dynamic nanoscale system when interacting with its surroundings and how energy spreads out in the process. Understanding the localization of energy dissipation and energy transfer in nanoscale systems will lead to more efficient energy conservation, conversion, harvesting and to preservation, damage prevention and efficiency of systems which require rapid cooling.

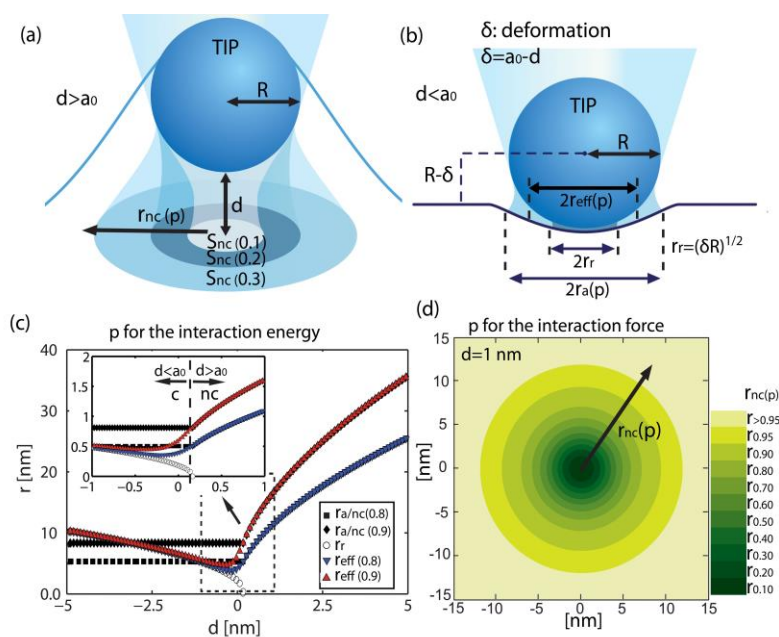


FIG. 1 Even though intermolecular forces are typically considered as short range, these still cover a finite area of interaction S with a radius r . A small nano-sphere of radius R interacting with a surface has several levels of localization (note the colour gradient) even in the (a) long range non-contact mode and when (b) both non-contact and contact occurs. Effective radius of interaction as a function of distance d for (c) the interaction energy and (d) the interaction force.

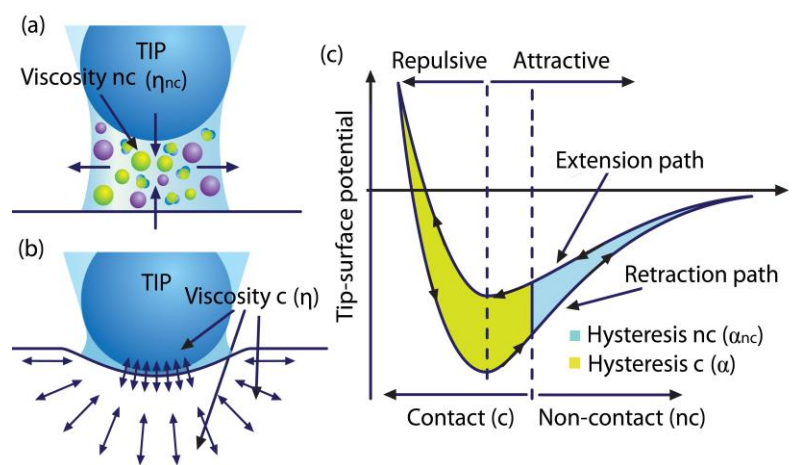


FIG. 2 Schemes depicting the origins of viscosity in (a) the nc region and (b) the c region. (c) Hysteresis processes are characterized by an increment in force, or potential energy as depicted, on retraction, as the tip moves away from the surface, as compared to extension. The scheme of the extension/retraction path is indicated by arrows.

Fundamental nanoscale dissipative forces

	non-contact	mechanical contact
$d > a_0$	$F_{\eta_{nc}} = -\eta_{nc} r_{nc} \dot{z}$ $F_{\alpha_{nc}} = -\alpha_{nc} \frac{RH}{6d^2}$	$F_{\eta} = -\eta (R\delta)^{1/2} \dot{z}$ $F_{\alpha} = -\alpha \frac{RH}{6a_0^2}$
$d < a_0$		

Energy density

$$\langle \rho \rangle = \langle E \rangle / \langle S \rangle$$

Localization

$$\langle M \rangle = \frac{\langle \rho \rangle}{\langle S \rangle}$$

Energy dissipation

$$\langle E \rangle = \frac{\pi k A_0 A}{Q} \left[\sin(\phi) - \frac{A}{A_0} \right]$$

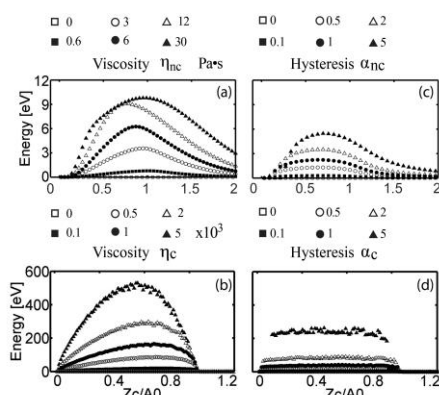


FIG. 3 Simulations of the mean energy dissipated per cycle for each of the four processes discussed in Fig. 2.

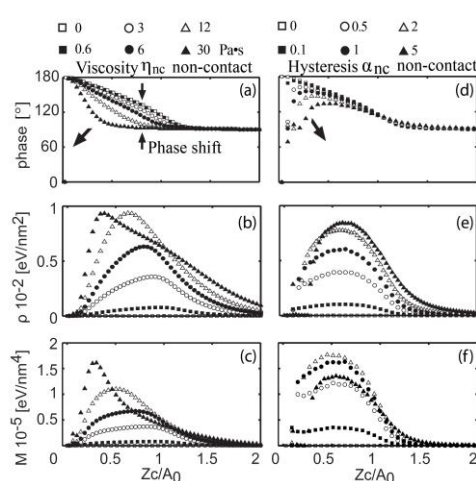


FIG. 4 Simulations of the response of the phase shift, energy density $\langle \rho \rangle$ and $\langle M \rangle$ as a function of normalized separation z_c/A_0 with increasing dissipative non-contact coefficients η_{nc} and α_{nc} .

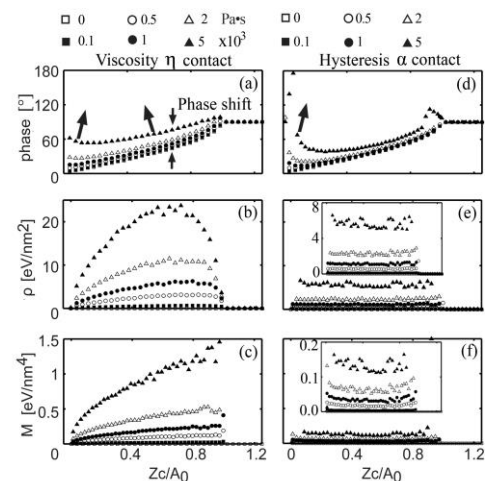


FIG. 5 Simulations of the response of the phase shift, energy density ρ and $\langle M \rangle$ as a function of normalized separation z_c/A_0 and increasing contact coefficients η and α .

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