

Solutions to Exercises

Chapter 2

- 2.1 They will significantly increase for a small N but level off for a large N (see Eq. 2.6).
- 2.2 The work function of the conductor should be such that the majority of the carriers can be spontaneously transferred to the appropriate polaronic level in the semiconductor.
- 2.3 A donor molecule that donates charge should be adsorbed, causing a potential step to form at the interface that downshifts the work function.
- 2.4 This is because localization occurs and activation is required for the carriers to be able to move.
- 2.5 Increased film order decreases the degree of localization of charges.
- 2.6 They are the mirror image of each other. There can be several vibronic levels at higher energies compared to the basic transition associated with each optical transition. Since both absorption and emission occur from the state with the lowest energy and to the vibronic levels, the absorption energy is increased and emission energy decreased for a specific vibronic level compared to the fundamental transition.

Chapter 3

- 3.1 Consider the flow velocity profile

$$\vec{v}(x, y, z) = \frac{1}{2\eta}(z^2 - 2h(x, y)z)\vec{\nabla}(\sigma\nabla^2 h(x, y) - p_{\text{vol}}) + \frac{z}{\eta}\vec{\nabla}\sigma$$

of the thin liquid film. At the liquid–substrate interface ($z = 0$) the velocity vanishes, $\vec{v}(x, y, 0) = 0$, and is thus continuous at the substrate surface, which is at rest. With this, one obtains viscous shear in the x direction as

$$\begin{aligned}\tau_{xz} &= \eta \left(\frac{\partial v_x}{\partial z} + \frac{\partial v_z}{\partial x} \right) \\ &= [(z-h) \partial_x (\sigma \nabla^2 h(x, y) - p_{\text{vol}}) + \partial_x \sigma] + \eta \frac{\partial v_z}{\partial h} \frac{\partial h}{\partial x}\end{aligned}$$

where we may omit the last term according to our assumptions, as it is proportional to dh/dx . At the liquid–gas interface, that is, at $z = h(x, y)$, the first term in square brackets cancels out and one thus obtains

$$\tau_{xz}(x, y, h) = \partial_x \sigma(x, y)$$

This is the Marangoni drag at the interface: the tangential viscous stress at the free surface of the liquid is identical with the gradient of the surface tension σ .

The same calculation holds for the y component. For the z component, one finds that $\tau_{zz}(x, y, z) = 0$ everywhere.

Finally, we have to show that the Stokes equation is satisfied. For this purpose we derive the velocity profile twice with respect to z and obtain

$$\eta \frac{\partial^2 \vec{v}(x, y, z)}{\partial z^2} = \vec{\nabla} (\sigma \nabla^2 h(x, y) - p_{\text{vol}})$$

which is the Stokes equation for a stationary flow ($dv/dt = 0$), driven by a hydrostatic pressure

$$p = -\sigma \nabla^2 h(x, y) + p_{\text{vol}}$$

which is composed of the Laplace pressure $-\sigma \nabla^2 h(x, y)$ associated with the curvature $1/R = -\nabla^2 h(x, y)$ of the liquid–gas interface and an additional volume-related pressures p_{vol} , for example, gravity.

- 3.2 This is a fairly easy exercise if one makes use of the incompressibility of the liquid, which says that