Theory for Heterogeneous Water/Oil Separation

Roi Bar-On, Ofer Manor
Interdisciplinary Graduate Program for Applied Mathematics, Technion - IIT, Haifa, Israel
roi1812@campus.technion.ac.il

Oil-polluted water is produced in large quantities in both domestic and industry utilities, which necessitate the development of new functional materials for fast and cheap phase separation [1-2]. It was shown in laboratory that membranes designed as hydrophilic or hydrophobic may separate oil/water mixtures [3-4]. The membrane pores possess specific affinity to water or oil, so that to favor the passage of the same phase through the pores and repeal the opposite phase away from the membrane.

We employ classical density functional theory (DFT) to elucidate the physical mechanisms governing the phase separation of water/oil emulsion near a membrane surface which possesses specific affinity to oil, at near-equilibrium. We capture emulsion concentration variations near the membrane surface while accounting for the finite volume of oil droplets in the emulsion's bulk and surface forces of molecular origin, i.e., hydrophobic, Van Der Waals (VDW), and electrical double layer (EDL) interactions, between the emulsion droplets.

We establish a clear connection between the size of drops, the surface forces between drops in the suspension and the variation in the concentration of droplets next to the membrane. We observe an increase in the concentration of oil droplets next to the lipophilic membrane surface at approximately 10 drop radii. Hence, pores in the membrane will support phase separation if their diameter corresponds to the length scale where the concentration of oil droplets near the solid is appreciably greater than the one in the liquid bulk. Moreover, we observe that the contribution of surface forces to the oil film (wetting the surface) thickness becomes appreciable for droplets smaller than 1 micron. Energy barriers to droplet attachment, which originate in surface forces, appear to increase the dense oil region volume next to the membrane.

REFERENCES

[1] R. K. Gupta, G. J. Dunderdale, M. W. England, and A. Hozumi, “Oil/water separation techniques: a review of recent progresses and future directions,” Journal of Materials Chemistry A, vol. 5, no. 31, pp.16 025–16 058, 2017.

[2] Y.-T. Hung, H. H. Lo, L. K. Wang, J. R. Taricska, and K. H. Li, “Powdered activated carbon adsorption,” in Advanced physicochemical treatment processes. Springer, 2006, pp. 123–153.

[3] A. Cambiella, E. Ortea, G. Rios, J. M. Benito, C. Pazos, and J. Coca, “Treatment of oil-in-water emulsions: Performance of a sawdust bed filter,” Journal of Hazardous Materials, vol. 131, no. 1-3, pp.195–199, 2006.

[4] X. Huang and T.-T. Lim, “Performance and mechanism of a hydrophobic–oleophilic kapok filter for oil/water separation,” Desalination, vol. 190, no. 1-3, pp. 295–307, 2006.

FIGURES

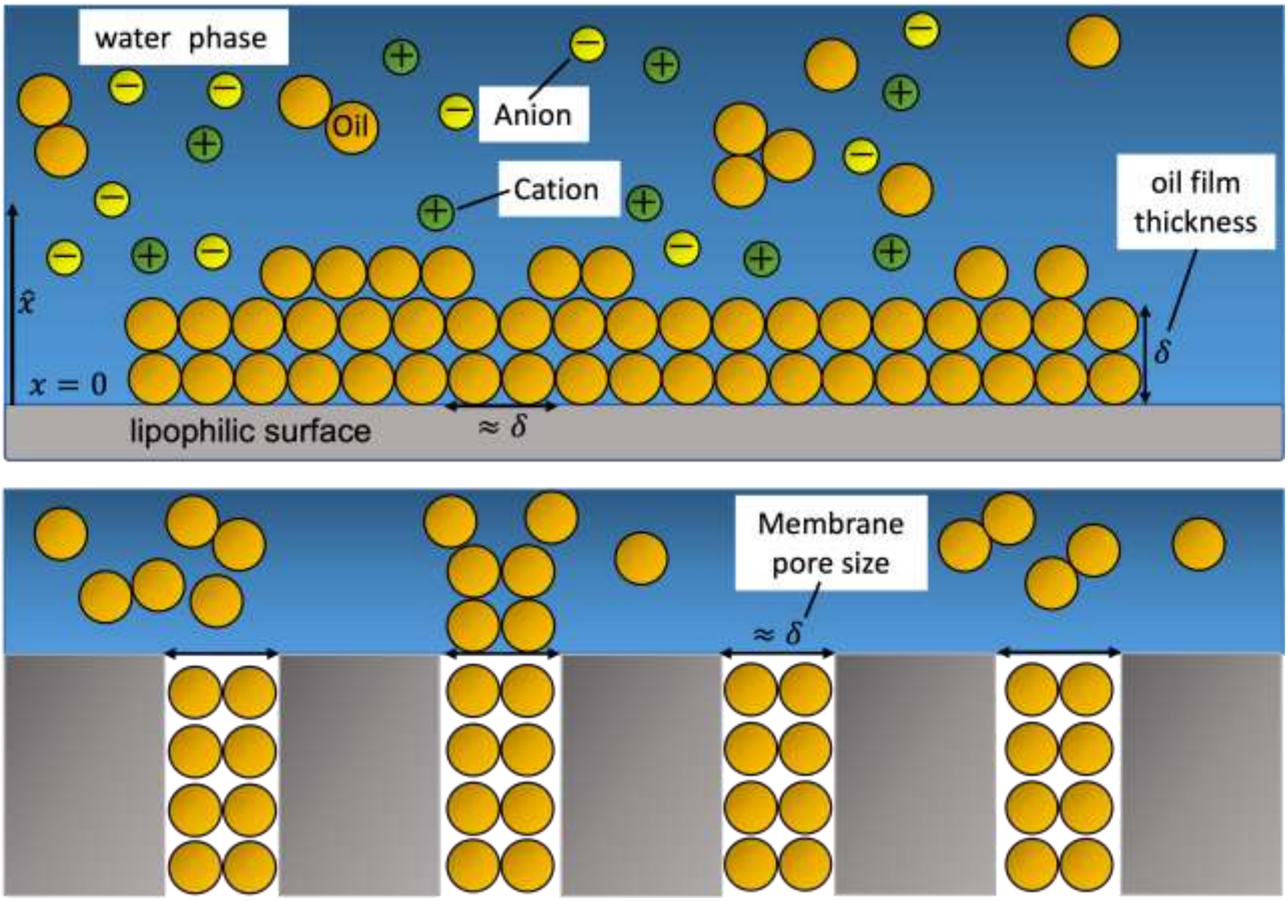

Figure 1: A semi-finite system with oil droplets (brown spheres) in water near a lipophilic solid surface (in gray). The oil droplets wet the membrane due to their chemical affinity to the lipophilic surface to form an oil film of thickness δ, which should be roughly equal to the pore size of a corresponding membrane to separate the mixture.