Air-Stable Droplet Interface Bilayers

Andy Sarles,[1] Jonathan Boreyko,[2] Chris Richards,[3] Pat Collier[4]

[1]*Department of Mechanical, Aerospace, and Biomedical Engineering, University of Tennessee, Knoxville, Tennessee 37996*

[2]*Department of Biomedical Engineering and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061*

[3]*Department of Chemistry, University of Kentucky, Lexington, KY 40506*

[4]*Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, TN 37831*

Droplet interface bilayers (DIBs) are versatile model membranes useful for synthetic biology and biosensing; however, to date they have been for the most part confined to fluid reservoirs. Here, we demonstrate that when two or more water droplets meet on an oil-infused nanostructured substrate, they exhibit noncoalescence due to the formation of a thin oil film that gets squeezed between the droplets from the bottom up. We show that when phospholipids are included in the water droplets, an air-stable droplet interface bilayer ("air-DIB") forms between the noncoalescing water droplets. As with traditional oil-submerged droplet interface bilayers, we were able to characterize ion channel transport by incorporating peptides into each droplet.

However, air-DIBs are subject to evaporation, which can, over time, destabilize them and reduce their useful lifetime compared to traditional DIBs that are fully submerged in oil. We show that the lifetimes of air-DIBs can be extended by an order of magnitude by maintaining the temperature just above the dew point (the temperature at which water vapor condenses into liquid water at the same rate that it evaporates). We find that increased evaporation rates from an air-DIB droplet above the dew point result in increased disorder in membrane structure related to the loss of water molecules of hydration from the polar head group regions of the bilayer. This disorder leads to disruption of the electric double layer at the membrane, and a higher permeability of the bilayer to hydrated ions. This primarily affects the electrical conductivity of the membrane, while the membrane capacitance, which is dominated by the capacitance of the non-polar hydrocarbon chain regions of the bilayer, is not significantly affected. Temperature and relative humidity are attractive parameters for controlling the stability and composition of air-DIBs membranes, and will be important if these membranes ultimately prove to be useful model systems for ambient sensing and synthetic biology.

Finally, we demonstrate the ability of these air-stable droplet interface bilayers (airDIBs) to incorporate gated ion channels via fusion of microsomes, which enables the biosensing of airborne matter.

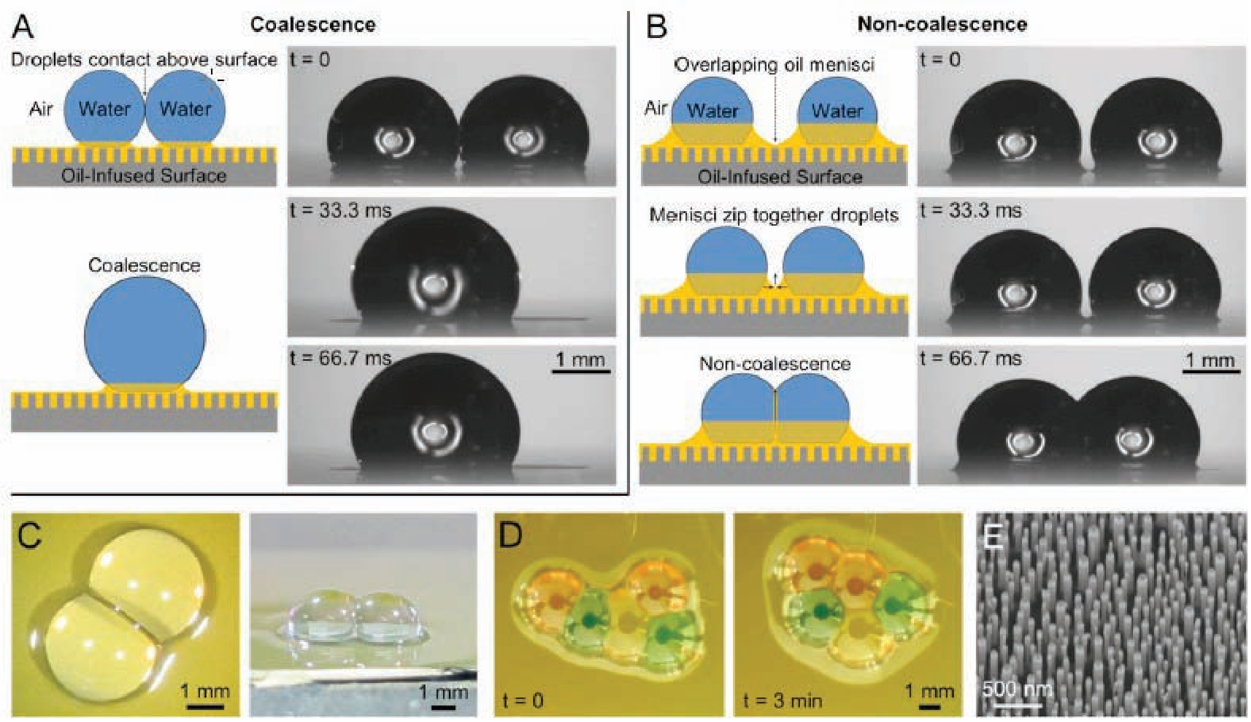

Figure 1 Interactive behavior of water droplets on an oil-infused nanostructured surface. (A) Droplets colliding at the liquid–air interfaces exhibited coalescence. (B) When the oil menisci of two droplets overlapped, an oil film formed between the droplets to enable noncoalescence. (C) Top-down and isometric photographs of noncoalescing droplets. (D) Multiple droplets could be connected into a network; due to the negligible hysteresis, these networks spontaneously rearranged over time to minimize their surface energy. (E) SEM of nanopillared substrate. [Boreyko, et al., *Proc. Natl. Acad. Sci. USA*, **111**, 7588-7593 (2014).