Supporting Information

A.1 Drag and lift forces

For a liquid drop in contact with a plane under linear shear flow,[1] the drag force is[2]

$$F_d = 1.7[6\pi\eta R(U^* - V^*)], \tag{S.1}$$

where η is fluid viscosity, R is droplet radius, U^* is fluid velocity evaluated at droplet center and V^* is droplet velocity evaluated at its centroid. For quasi-2D case, the net surface tension force, sometimes known as the retentive force, is

$$F_r = 2R\sigma sin\theta_e(cos\,\theta_r - cos\,\theta_a), \tag{S.2}$$

where θ_e, θ_a and θ_r are the equilibrium, advancing and receding contact angles respectively and σ is the surface tension of the droplet. Balancing the drag and retentive forces for a sliding drop yields an estimate for the relative velocity

$$(U^* - V^*) = 0.0624\left(\frac{\sigma}{\eta}\right) sin\theta_e(cos\,\theta_r - cos\,\theta_a), \tag{S.3}$$

which expresses the relative velocity $U^* - V^*$ in terms of observed contact angles. This can be solved iteratively.[3]

The hydrodynamic lift force acting on drop in shear flow is[4]

$$F_l = 6.4R^2\sqrt{\dot{\gamma}\rho\eta}(U^* - V^*), \tag{S.4}$$

where $\dot{\gamma}$ is the fluid shear rate and ρ is the fluid density.

For quasi-2D case, the adhesion force is

$$F_a = \sigma L_z(\sin\theta_r + \sin\theta_a), \tag{S.5}$$

where L_z is the out-of-plane width (in z direction). If we approximate shear rate as $\dot{\gamma} \sim V^*/2R$, a balance of the lift and adhesion forces yields

$$\frac{F_l}{F_a} \sim 0.1\left(\frac{2R}{L_z}\right)\sqrt{Re}\,\psi(\theta_e,\theta_r,\theta_a), \tag{S.6}$$

where

$$Re = \frac{2\rho V^* R}{\eta}, \tag{S.6a}$$

$$\psi(\theta_e,\theta_r,\theta_a) = \frac{\sin\theta_e(\cos\theta_r - \cos\theta_a)}{\sin\ {}_r + \sin\theta_a}, \tag{S.6b}$$

which is the same result obtained by Das et al.,[5] but for quasi-2D case.

A.2 Characterization of interfacial tension

The interfacial tension between oil and solvent phases σ can be calculated using the Irving-Kirkwood approach,[6] which for interfaces parallel to x–z plane, is expressed as,

$$\sigma = \frac{L_y}{2}\left[\langle p_{yy}\rangle - \frac{1}{2}\left(\langle p_{xx}\rangle + \langle p_{zz}\rangle\right)\right], \tag{S.7}$$

where L_y is the height of the simulated box in y direction. p_{xx}, p_{yy} and p_{zz} are the negative diagonal components (angular brackets $\langle\cdots\rangle$ denotes ensemble average) of the stress tensor $\mathrm{S}_{\alpha\beta}$, expressed as,

$$\mathrm{S}_{\alpha\beta} = -\frac{1}{V}\langle \sum_i^N m u_{i\alpha} u_{i\beta} + \sum_i^N \sum_{j>i}^N r_{ij\alpha} F_{ij\beta} \rangle, \tag{S.8}$$

where is the number of particles, $u_{i\alpha}$ and $u_{i\beta}$ are the peculiar velocity components of particle i, defined as $u_{i\alpha} = v_{i\alpha} - \bar{v}_\alpha(\boldsymbol{x})$, where $v_{i\alpha}$ is the velocity component of i and $\bar{v}_\alpha(\boldsymbol{x})$ is the stream velocity at position $\boldsymbol{x}$. $F_{ij\beta}$ is the inter-particle force components between particles i and j.

Fig. A1 shows surface tension as a function of oil-solvent repulsion a_{OS} estimated using the Irving-Kirkwood method.

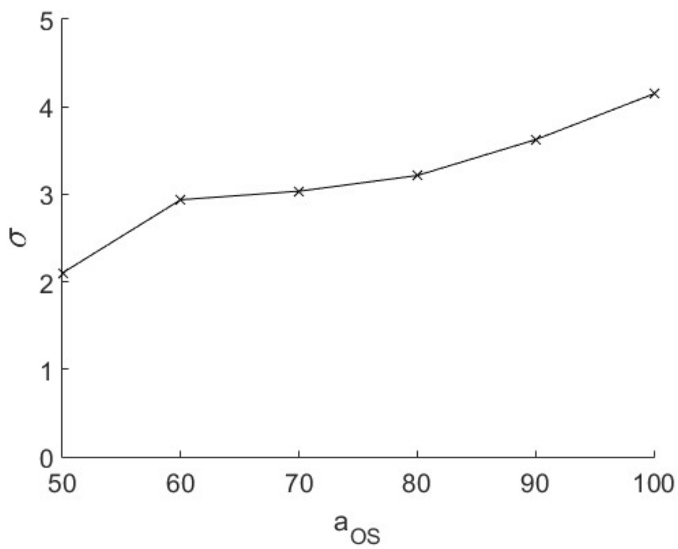

Fig. A1. Plot of surface tension σ against oil-solvent repulsion a_{OS} estimated using the Irving-Kirkwood method.

A.3 Dynamic oil absorption ratios

Under low oil-polymer repulsion a_{OP}, the oil droplet can penetrate and seep into the polymer brush layer. For $a_{OP} = 20$, a droplet of radius $R = 10$ is fully submerged and unaffected by surface flows, whereas for larger partially submerged droplets, the absorbed volume fraction η_p decreases linearly with U^* (Fig. A2). For surface droplets, η_p is relatively insensitive to U^* at low values of U^*, but decreases as the droplet approach its critical lift-off velocity U_{cl}^*.

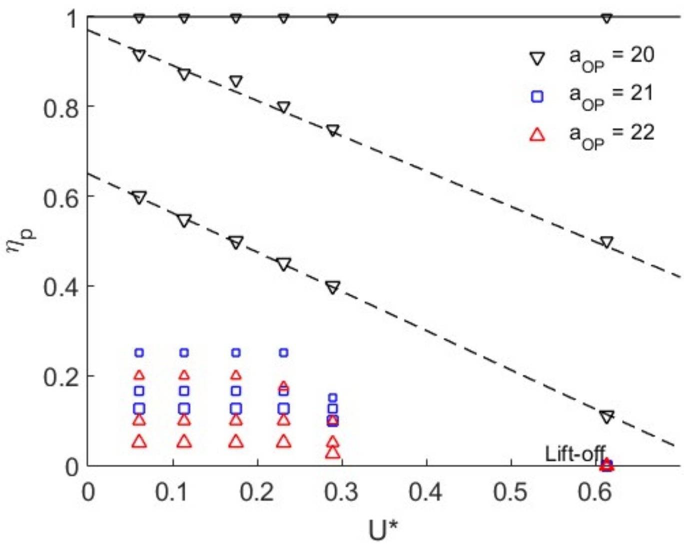

Fig. A2. Plot of absorbed volume fraction η_p against flow velocity U^* evaluated at droplet center for various a_{OP}. Relative symbol sizes denote droplet sizes $R = \{10, 15, 20\}$. For $a_{OP} = 20$, the absorbed volume fraction η_p of a partially submerged droplet decreases linearly with U^* (dashed lines). For surface droplets, η_p is relatively insensitive to U^* at low values of U^*, but decreases as the droplet approach its critical lift-off velocity U_{cl}^*.

References

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