process at the final solution composition, it can be expected that nucleation would proceed within the mixing region before mixing is completed and local composition heterogeneity in the mixing region would significantly influence resulting nucleation outcome.[11,16,17] On the other hand, if the mixing process is much faster than nucleation, it can be expected that nucleation would only proceed once mixing is complete and local concentration gradients would not be significant. The significance of mixing can thus be assessed by comparison of characteristic times of mixing τ_m[18–20] and of nucleation τ_n and by analogy with chemical reactions, we can define a dimensional ratio of the two timescales τ_m/τ_n, similar to the Damköhler number.[21,22] While mixing time scales have been investigated and quantified across a range of mixing conditions,[23–25] it is less straightforward to quantify nucleation time scales (*e.g.*, inverse of induction time couples both nucleation and growth time scales and is dependent on relevant volume where nucleation occurs as well as observation method).

1.2.1.2 Shear

Heterogeneity of flow environment is inherent in vessels, pipes and pumps. Uniform flow field can be achieved in some idealized rheometry environments such as Couette (in the gap between two cylinders with inner cylinder rotating[26] or cone-and-plate cells). In pressure driven laminar flow in pipes the shear rate varies from zero in the center to the maximum value at the pipe wall. Ranges of shear rates experienced by fluids can vary widely depending on the nature of agitation, agitator shape, size and movement, vessel geometry and resulting flow regimes (*e.g.*, stirred tanks, Taylor–Couette flows, oscillatory flows).[27,28]

The effect of local flow environment on nucleation has been repeatedly noted in previous literature but in early reports it was unclear whether effects were due to primary or secondary nucleation (Figures 1.1 and 1.2).[29–33]

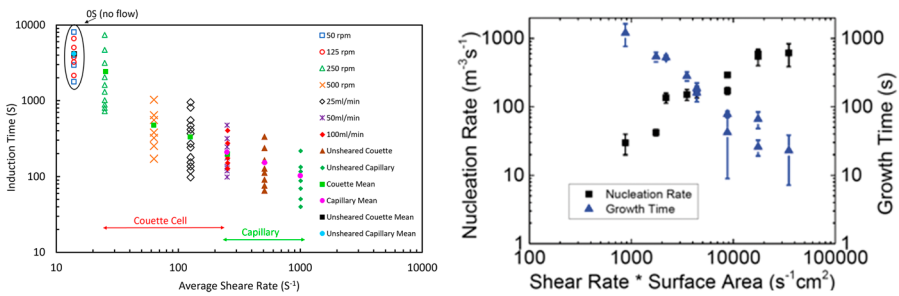

Figure 1.1 Induction time (s), nucleation rates J, and growth times t_g estimated from a model fit as a function of the product of the average shear rate and surface area. Adapted from ref. 34 with permission from American Chemical Society, Copyright 2015, and ref. 35, https://pubs.acs.org/doi/abs/10.1021/acs.cgd.5b01042, with permission from American Chemical Society, Copyright 2016.