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Shape of polystyrene droplets on soft PDMS: Exploring the gap between theory and experiment at the three-phase contact line

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The shapes of liquid polystyrene (PS) droplets on viscoelastic polydimethylsiloxane (PDMS) substrates are investigated experimentally using atomic force microscopy for a range of droplet sizes and substrate elasticities. These shapes, which comprise the PS-air, PS-PDMS, and PDMS-air interfaces as well as the three-phase contact line, are compared to theoretical predictions using axisymmetric sharp-interface models derived through energy minimization. We find that the polystyrene droplets are cloaked by a thin layer of uncrosslinked molecules migrating from the PDMS substrate. By incorporating the effects of cloaking into the surface energies in our theoretical model, we show that the global features of the experimental droplet shapes are in excellent quantitative agreement for all droplet sizes and substrate elasticities. However, our comparisons also reveal systematic discrepancies between the experimental results and the theoretical
predictions in the vicinity of the three-phase contact line. Moreover, the relative importance of these discrepancies systematically increases for softer substrates and smaller droplets. We demonstrate that global variations in system parameters, such as surface tension and elastic shear moduli, cannot explain these differences but instead point to a locally larger elastocapillary length, whose possible origin is discussed thoroughly.

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