Spreading of Emulsions on Solid Substrate

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Introduction:

Emulsion is a mixture of two or more liquids that are normally immiscible. In an emulsion composed of two liquids, one liquid (dispersed phase) is dispersed into the other liquid (continuous phase). The wettability and stability of emulsions are important parameters with explicit influence on an extensive variety of industrial applications ranging from the petroleum industry to the manufacturing industry. Surprisingly, there is no comprehensive study of emulsion spreading to date; this is mostly due to the complexity of the structure of the emulsions and non-homogeneity of the dispersed phase bubbles in size and their distribution through the emulsion.

We investigated the spreading and wettability of emulsions on solid substrates. Emulsions were prepared with varying weight percentages of water, silicone oil, and small amounts of surfactant [1]. Single drops of emulsions with different weight percentages were placed on glass substrates. Rheology of these drops was also characterized in the lab using a rheometer (AR-2000, TA Instruments). The evolution of contact angle, base diameter, contact line, maximum height, and the spreading rate of the drops as a function of time were also investigated in this research. The phenomenon of coarsening of emulsions near the contact line was also characterized.

Experimental Setup and Materials:

Experiments were carried out using water, silicon oil and soap as a surfactant. Drop deposition experiments were conducted with Drop Shape Analyzer (DSA 100) manufactured by Krüss. Glass slides with dimensions of 50×24×0.15 mm^3 (VWR microcover glass) were rinsed successively in acetone, methanol and DI water. The glass slide was plasma cleaned with Plasma Cleaner PDC-32g for almost 5 minutes, and then placed into a Krüss drop shape analyzer chamber, which was at room temperature. Glass windows covered three sides of the chamber and provided the observation porthole for illumination source. The main stage, on which the glass substrate was situated, can be precisely positioned in x, y and z directions. The deposition of emulsion droplet on the glass substrate was conducted manually in two steps by the metal syringe plunger, which has a rubber attached and was placed inside the syringe a 2 mL syringe. In the first step, the emulsion was extracted from the storage bottle into the syringe using the metal syringe plunger; the syringe was then placed in the syringe holder of the DSA 100 in the downward direction. In the second step, an emulsion droplet was deposited on the glass substrate manually by pushing through the syringe with same plunger and through 0.5mm diameter injection needles. The injection syringe was situated on a syringe revolver brought down manually/automatically and entered a hole at the top of the chamber, near the glass cover glass. Single droplet dispensing of an emulsion drop was performed when the needle was slowly taken close to the solid substrate. A high-speed CCD camera capable of recording 90 fps was used as a visualization technique to study droplet evolution during spreading. The base diameter and contact angle of the emulsion drop were measured at each frame by the Krüss analyzer using the Laplace-Young method. This method fitted profile of the sessile drop in the region of the baseline to the Young-Laplace equation. Using the fitted parameters, the slope of the three-phase contact point at the baseline was determined and then used to find the contact angle. Moreover, base diameter is defined as a distance between two contact points.

Results and Discussion:

The emulsion drops were deposited onto a glass substrate and took on a spherical cap form; initially the drops spread very slowly before they reach a point at which sudden fast spreading was observed. This behavior occurred for all emulsion droplets in a matter of several seconds. This behavior is due to the coalescence of the dispersed water bubbles close to the leading edge of the droplet, which causes the sudden fast spreading. We also observed that the spreading on the left contact point and right contact point of the droplet are not the same: one side is much faster than the other. This is due to the non-homogeneity of the distribution of the dispersed phase water bubbles inside the water-silicon oil emulsion; therefore, the left and right contact lines have a substantial difference in spreading rate. In the experiments, we noticed non-homogeneity size of the water bubbles; this non-uniformity influenced the spreading rates of the contact points of the right and left sides. The behavior of the spreading of the emulsion drops on the glass substrates are due to the coarsening of the emulsions.

Reference:

[1] Jonathan E. Forester, Jorge M. Sunkel, John C. Berg, J. Appl. Polymer Sci., 81, 1817-1825 (2001).