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SHORT PAPER

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Behavior of an oppositely charged oil–water interface

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Abstract This paper virtually presents induced behavior of an oppositely charged oil–water interface with the use of a high-speed camera. The elevation behavior of an oil–water interface is demonstrated experimentally, using a transparent acrylic cylindrical container (176 mm in inner diameter, 450 mm in height) with the bottom half (100 mm) filled with deionized water and the top half (between 50 and150 mm) with an immiscible oil (viscosity 1 or 5 cSt). Copper fragments are inserted into each liquid (at top and bottom) to serve as electrodes, i.e., the oil layer is negatively charged, and the water layer is positively charged. A high-DC-voltage power supply provides potential difference of the order between about 1 and 30 kV. As a result, three kinds of behavior are observed, i.e.: (1) rotary motion on the interface in lower electric field supplied about $E = 0.013$ kV/mm; (2) fluctuation on the interface in medium electric field supplied about $E = 0.021$ kV/mm; (3) elevation of the interface in higher electric field supplied between $E = 0.04$ and 0.65 kV/mm (which depends on the depth of the oil layer).

Keywords Oil–water interface · Oppositely charged two liquids · Visualization

1 Introduction

Electric fields induce motion of charged particles or liquids (see e.g., de Gennes et al. 2008; Ristenpart et al. 2009) and it is utilized in practical fields such as chemical engineering. Likewise, in steel-refining process, an interface motion due to electrophoretic forces between two immiscible liquids is an intriguing subject to promote a chemical reaction. This paper virtually presents induced behavior of an oppositely charged oil–water interface with the use of a high-speed camera.

2 Experimental setup and visualization procedure

The elevation behavior of an oil–water interface is demonstrated experimentally, using a transparent acrylic cylindrical container (176 mm in inner diameter, 450 mm in height) with the bottom half

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(h_{water} = 100 mm) filled with deionized (DI) water and the top half ($50 \le h_{oil} \le 150$ mm) with an immiscible oil (viscosity 1 or 5 cSt). Copper fragments are inserted into each liquid (at top and bottom) to serve as electrodes, i.e., the oil layer is negatively charged, and the water layer is positively charged. A high-DC-voltage power supply provides potential difference of the order between about 1 and 30 kV. The induced behavior of the charged interface is recorded with a high-speed camera whose frame rate is 7,200 fps with the shutter speed 133 μs for the resolution 640 × 480 pixels. The cylindrical container is surrounded by a larger acrylic rectangular tank. Water is immersed in not only the cylindrical container, but also the rectangular tank so that distortion of images due to light refraction can be reduced in a photograph.

3 Results and discussion

After application of the electric field (see the previous section), the oppositely charged oil–water interface cannot be still. Electrophoretic forces cause the interface to rotate, fluctuate or attract towards the minus electrode. Indeed, three kinds of behavior are observed, as shown in Fig. 1, i.e., (1) rotary motion on the

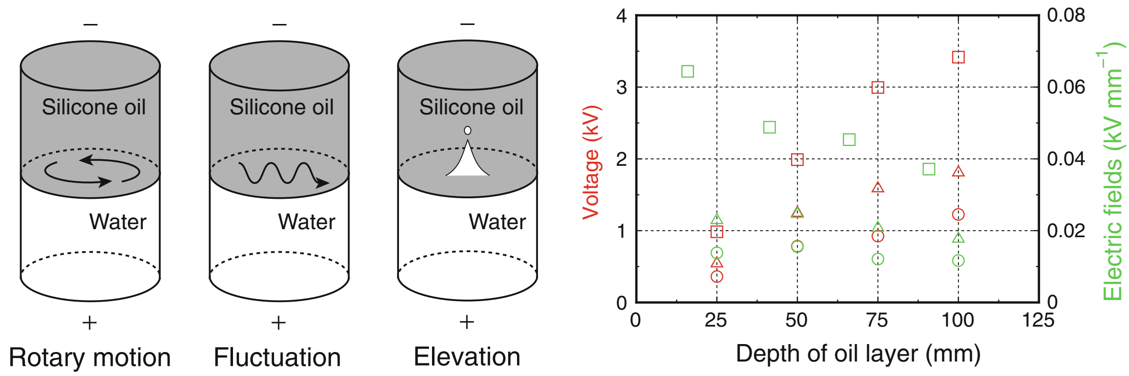

Fig. 1 Three kinds of patterns observed of an oppositely charged oil–water interface for 1 cSt viscosity. *Circle* Rotary motion, *triangle* fluctuation, *square* elevation

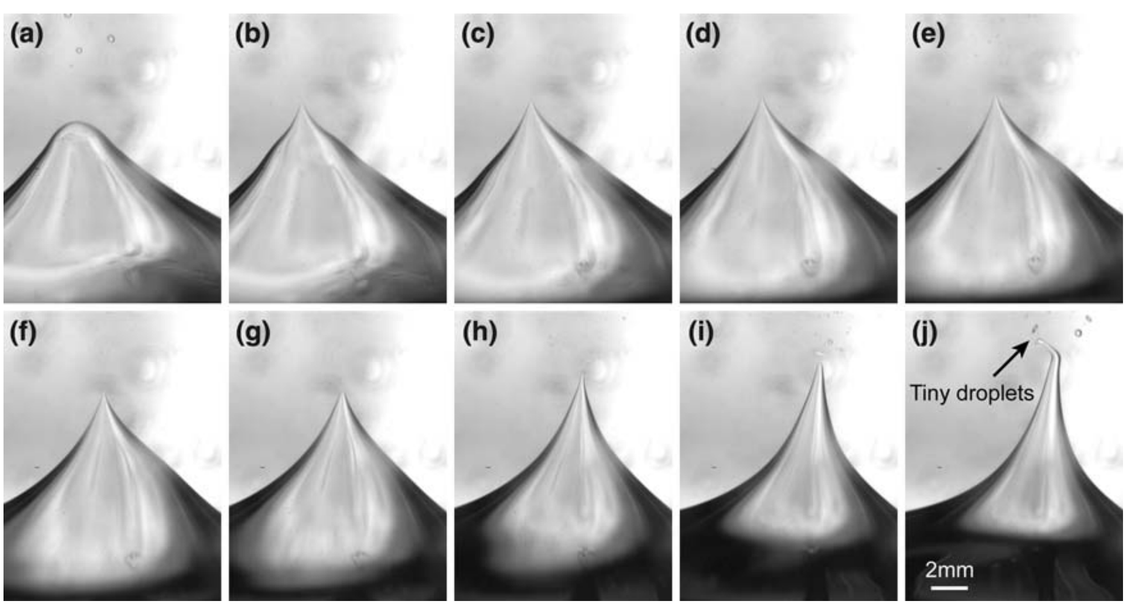

Fig. 2 Selected snapshots of an elevated oil–water interface with 33 kV voltage supplied for h_{oil} = 100 mm and 5 cSt viscosity. Time interval is 57/7,200 s each

interface in lower electric field supplied about $E = 0.013$ kV/mm; (2) fluctuation on the interface in medium electric field supplied about $E = 0.021$ kV/mm; (3) elevation of the interface in higher electric field supplied between $E = 0.04$ and 0.65 kV/mm (which depends on the depth of the oil layer). Here, the voltage V exhibited in the right of Fig. 1 is arranged using the electric field $E = V/d$ (d is defined as the distance between the minus electrode and the peak point of the interface). Figure 2 shows selected snapshots of the attracted interface [i.e., pattern (3)] under 33 kV voltage supplied for the 5 cSt viscosity. The attracted interface increases the swell and sharpens with the progress of time, which ends up being torn at the peak point of the elevated interface and producing tiny droplets about the order of micrometer (see the last of Fig. 2).

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