1 | Annex A: Technical data sheet from Bayer

As it was mentioned several times during the main text, obtaining information about how different oils behave at the low temperatures of the cold laboratory was a challenge. On this aim, a catalogue by Bayer from many years ago was found (Bayer, n.d.). It was a key in order as it was the only technical data sheet with detailed information of how dimethicones of many different viscosities react to a change in temperature. The information provided by different dimethicone producers is trustworthy because it is a pure substance and the only variable is the size of the polymer molecule. But, if the viscosity is the same at 25 °C, the size of the molecules is also the same, as these two properties are strongly related. Therefore, the information of Bayer´s dimethicone can be extrapolated to the DOW´s dimethicones as a first approximation.

This document can not be found online, so it is included in the annexes in order to provide the reader an information that was useful to choose which dimethicone oil will be more suitable for developing our technique. In the Figure 1 a table is shown, that clearly describes the evolution of the viscosity with the temperature.

Baysilone-Öl M	Viskosität in mm² · s⁻¹ (cSt) bei											
	−80 °C	−60 °C	−40 °C	−20 °C	0 °C	25 °C	40 °C	60 °C	80 °C	100 °C	120 °C	140 °C
3	70	28	13	7	4,6	3	2,4	1,8	1,5			
5	132	50	23	14	7,8	5	4,0	3,1	2,6	2,2		
10		120	52	27	16	10	7,9	6,0	4,9	4,0	3,1	2,7
20		270	100	57	34	20	15,2	11,8	9,2	7,2	6,0	5,0
50				150	85	50	40	28	20	16	13	10
100				290	170	100	75	55	41	32	27	21
350				1 000	620	350	290	200	150	125	95	75
500				1 300	850	500	400	290	210	165	140	110
1 000				2 900	1 850	1 000	750	520	400	300	230	190
5 000					8 500	5 000	3 800	2 800	2 000	1 600	1 200	1 000
12 500					20 000	12 500	9 800	7 000	5 100	4 000	3 000	2 400
30 000					50 000	30 000	22 000	16 500	11 500	8 500	7 000	5 000
60 000					100 000	60 000	42 000	30 000	20 000	15 500	11 000	9 000
100 000					180 000	100 000	75 000	55 000	40 000	30 000	22 000	17 000
300 000					500 000	300 000	200 000	175 000	133 000	100 000	78 000	62 000
1 000 000					2 000 000	1 000 000	750 000	520 000	390 000	280 000	210 000	160 000

Figure 1: The table shows evolution of the viscosity in mm^2/s (cSt) for ("Viskosität in $mm^2 \cdot s^{-1}$ (cSt) bei") different temperatures(Bayer, n.d.).

As the aim was to achieve, at the temperature of the cold laboratory (around -23 °C), a viscosity similar to the viscosity that the Leica Type N immersion liquid has at 23 °C, this table was really useful to predict the evolution of several dimethicones at low temperatures. The Leica Type N immersion liquid has a viscosity of 825 cSt at 23 °C (DOW, 2017). So, clearly the best candidate is the 350 cSt dimethicone, which should reach a viscosity of 1000 cSt at -20 °C.

2 | Annex B: Obtaining the formula of the viscosity for the emptying of a syringe

On the main work a brief version of this sections is given at the section 2.1.1., but how the formula of the kinematic viscosity is obtained is described in deeper detail here.

Once the aim of this section has been explained, we can go on analyzing the variables that we are directly going to measure and how they relate to the viscosity. The emptying of a syringe shaped and steady container is characterised by a pressure only depending in the vertical position (x). Therefore, the equilibrium equation, taking into account the shear stresses (τ) at the mantle surface (dependant on the radial position), the pressure forces (p) at the front and rear areas and the gravity force, is the following:

$$-\frac{dp}{dx} + \frac{2}{r}\tau + \rho g = 0 \tag{1}$$

where g is the acceleration of gravity, ρ is the density of the oil and the shear stress (τ) can be defined by the Newton´s viscosity law in terms of the velocity of the fluid $u(r)$ and the dynamic viscosity η:

$$\tau(r) = \eta \frac{du(r)}{dr} \tag{2}$$

where $u(r)$ is the velocity of the fluid.

Due to the pressure only depending on the vertical axis and the shear stress on the radial axis, we can solve this differential equation by separation of variables.

$$\frac{dp}{dx} - \rho g = \frac{2\eta}{r}\frac{du(r)}{dr} = C \tag{3}$$

Establishing the boundary conditions of the pressure as:

$$p(0) = p_0 + \rho g h \tag{4}$$
$$p(l) = p_0 \tag{5}$$

where p_0 is the atmospheric pressure.

So, we get the following expression of the pressure in terms of the vertical position:

$$p(x) = p_0 + \rho g h \left(1 - \frac{x}{l}\right) \tag{6}$$

If we go back to equation 3, we get that the constant is:

$$C = \frac{dp}{dx} - \rho g = -\rho g \left(1 + \frac{h}{l}\right) \tag{7}$$

But also:

$$C = \frac{2\eta}{r}\frac{du(r)}{dr} = -\rho g \left(1 + \frac{h}{l}\right) \tag{8}$$

So:

$$\frac{du(r)}{dr} = -\frac{r}{2\eta}\rho g\left(1+\frac{h}{l}\right) \tag{9}$$

Once we integrate it and fix the constant with the boundary condition $u(r_0) = 0$:

$$u(r) = \frac{\rho g(l+h)}{4\eta l}(r_0^2 - r^2) \tag{10}$$

Finally, from the velocity we can get the volumetric flux with the following integral:

$$Q = \int_{S_0} u\, dS = \int_0^{r_0} 2\pi\, r\, u\, dr \tag{11}$$

The resolution of the integral leads to this result (Hutter and Wang, 2016):

$$Q = \pi\, \frac{\rho\, g\, (l+h)}{8\, \eta\, l}\, r_0^4 \tag{12}$$

The volumetric flux (Q) can be experimentally calculated by timing the emptying of the syringe, as the volumetric flux is the relation between the volume of the container and the emptying time (t):

$$Q = \frac{V}{t} = \frac{h_e\, \pi\, \left(\frac{D}{2}\right)^2}{t} \tag{13}$$

So, rearranging the equation, we can show the dynamic viscosity (η) in terms of the time (t) and a number of parameters that are already known. Therefore, the aim of the experiment is to measure the emptying time of the syringe, in order to estimate the viscosity of the oil:

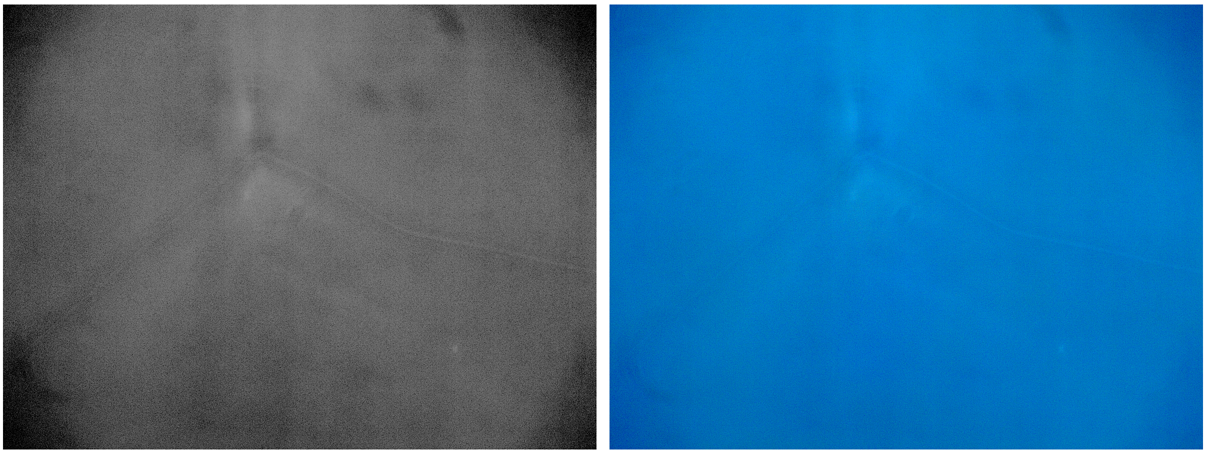
$$\eta = \pi \frac{\rho\, g\, (l+h)\, t}{8\;\, l\, (h_e\, \pi\, \left(\frac{D}{2}\right)^2)} r_0^4 \tag{14}$$

The classification of the oil is based on the kinematic viscosity, which can be related to the dynamic viscosity on the following way:

$$\nu = \frac{\eta}{\rho} = \pi \frac{g\, (l+h)\, t}{8\;\, l\, (h_e\, \pi\, \left(\frac{D}{2}\right)^2)} r_0^4 \tag{15}$$

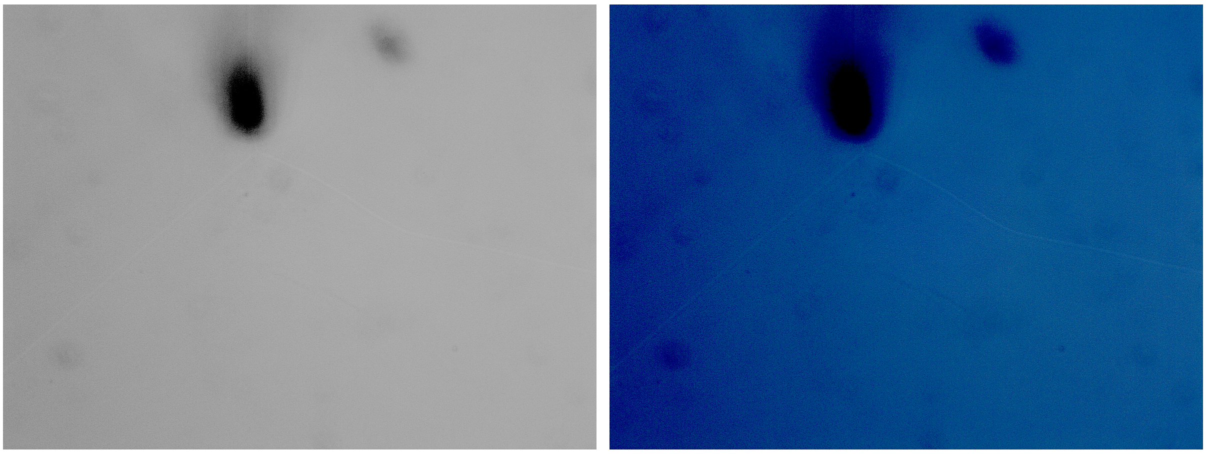
3 | Annex C: Comparison of colour images and black and white images

It was rapidly stated at the beginning of the results that the difference between colour images and black and white images was purely aesthetic. In this section several colour images of the work appear compared to their black and white analogs and vice versa. In every pair, the image on the left is the one appearing on the main text.



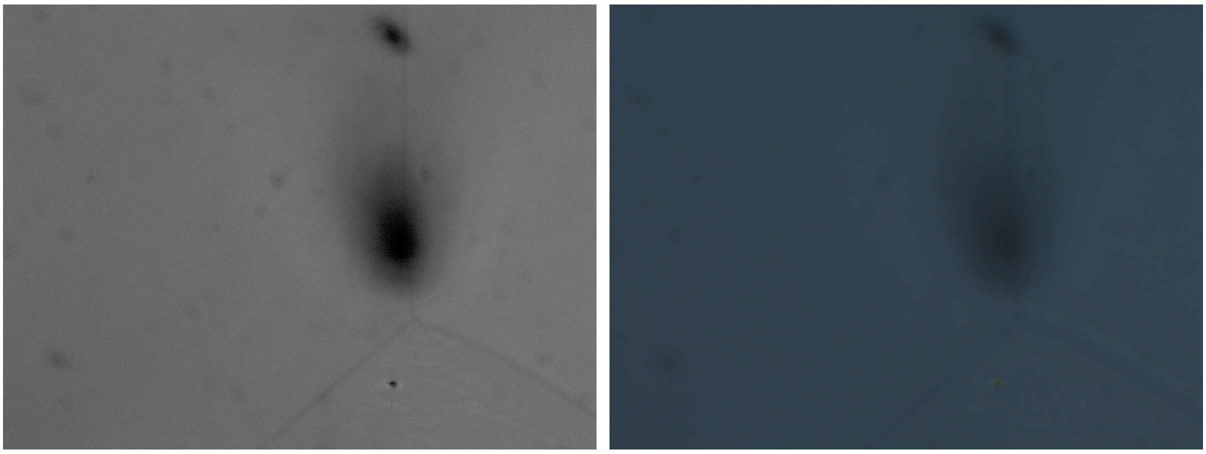
(a) Black and white. **(b)** Colour.

Figure 2: Corresponding to Figure 13a of the main text. Triple junction observed with the 63x objective lens. Incident illumination.



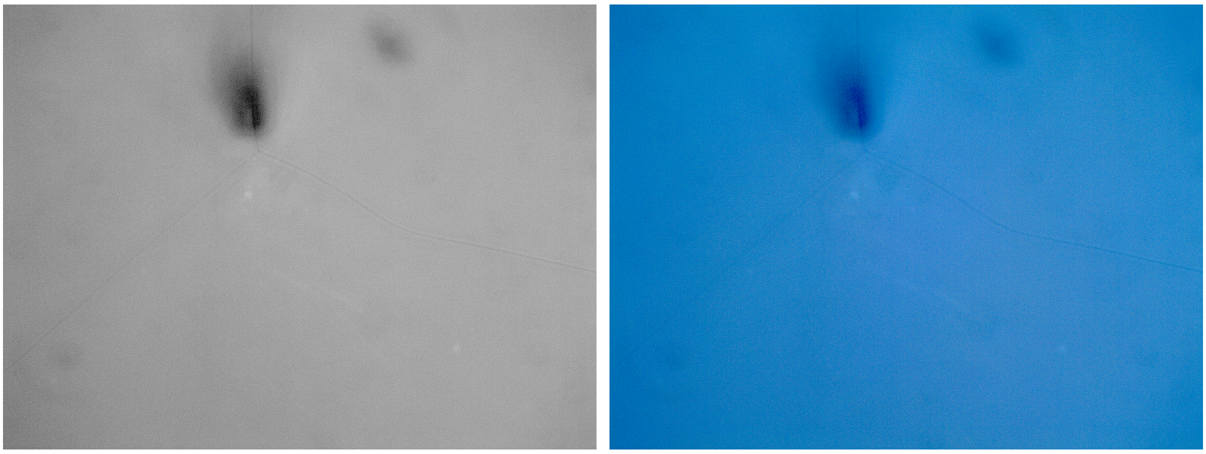
(a) Black and white. **(b)** Colour.

Figure 3: Corresponding to Figure 13b of the main text. Triple junction observed with the 63x objective lens. Transmitted illumination.



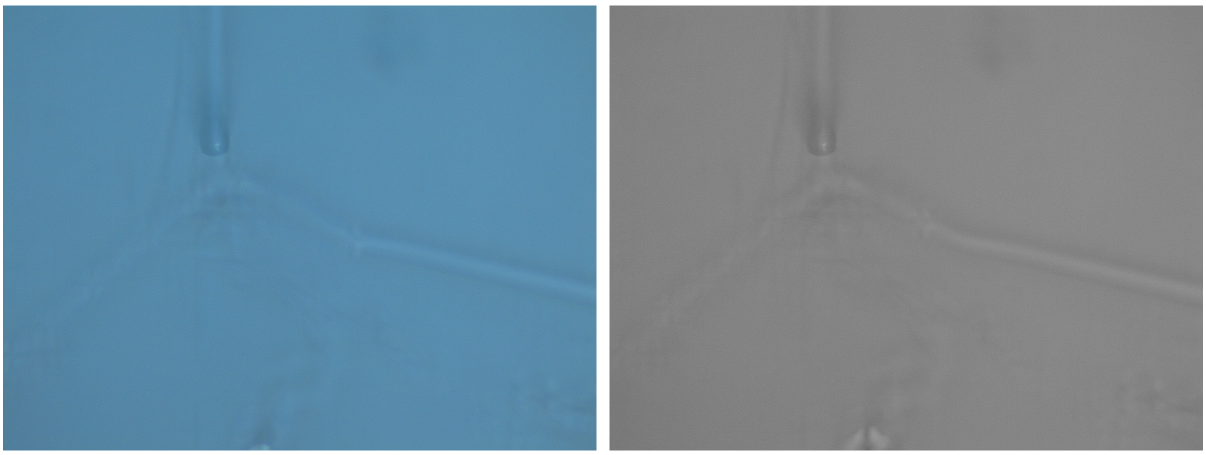
(a) Black and white. **(b)** Colour.

Figure 4: Corresponding to Figure 14b of the main text. Triple junction observed with the 100x objective lens. Transmitted illumination.



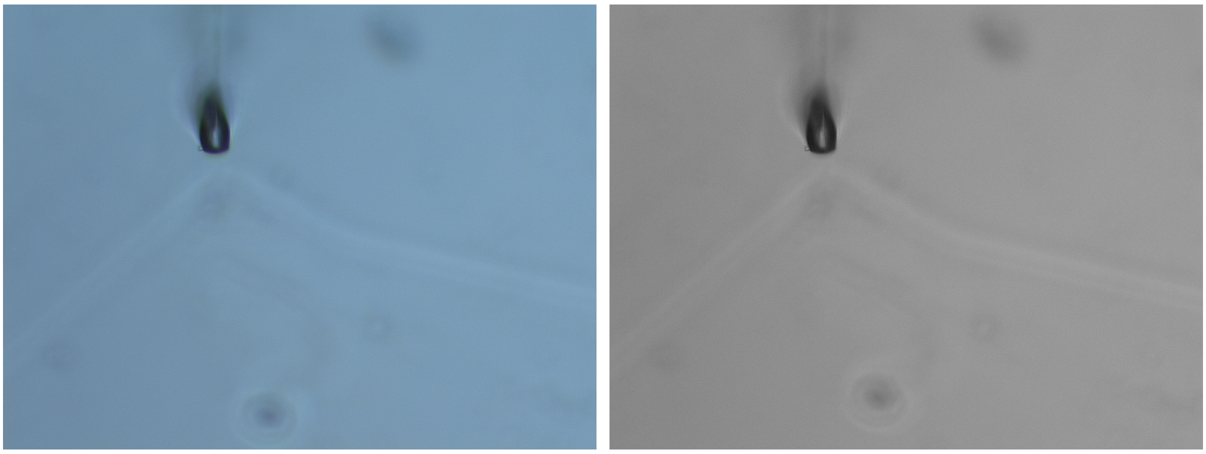
(a) Black and white. **(b)** Colour.

Figure 5: Corresponding to Figure 16 of the main text. Triple junction observed with the 63x objective lens. Combination of transmitted and incident illumination.



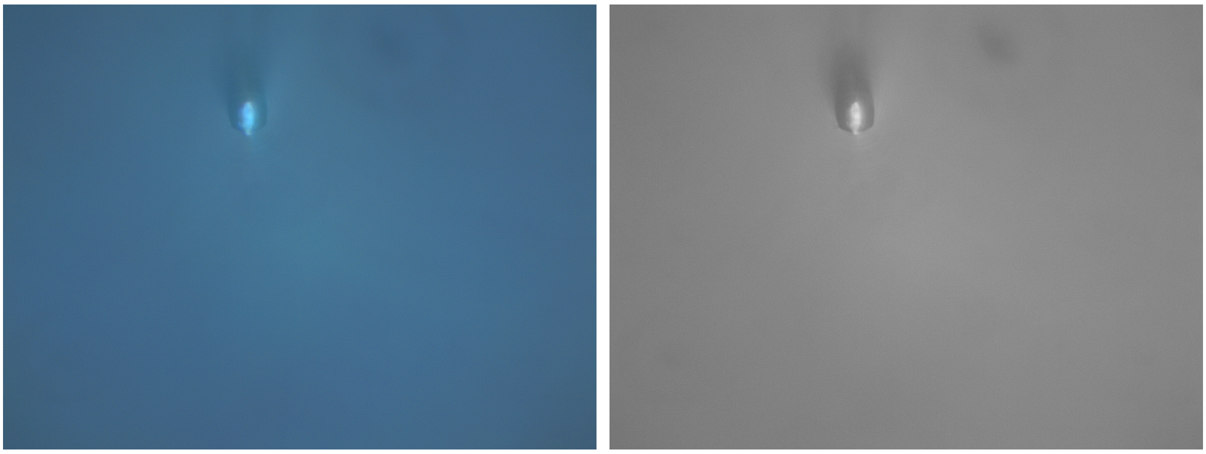
(a) Colour. **(b)** Black and white.

Figure 6: Corresponding to Figure 20a of the main text. Bubble observed with the 50x objective lens. Incident illumination.



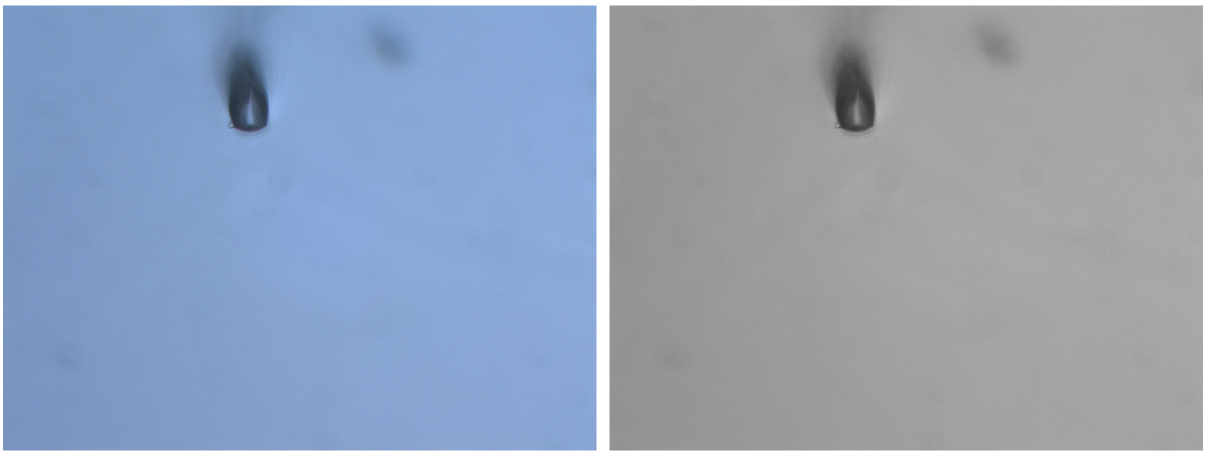
(a) Colour. **(b)** Black and white.

Figure 7: Corresponding to Figure 20b of the main text. Bubble observed with the 50x objective lens. Transmitted illumination.



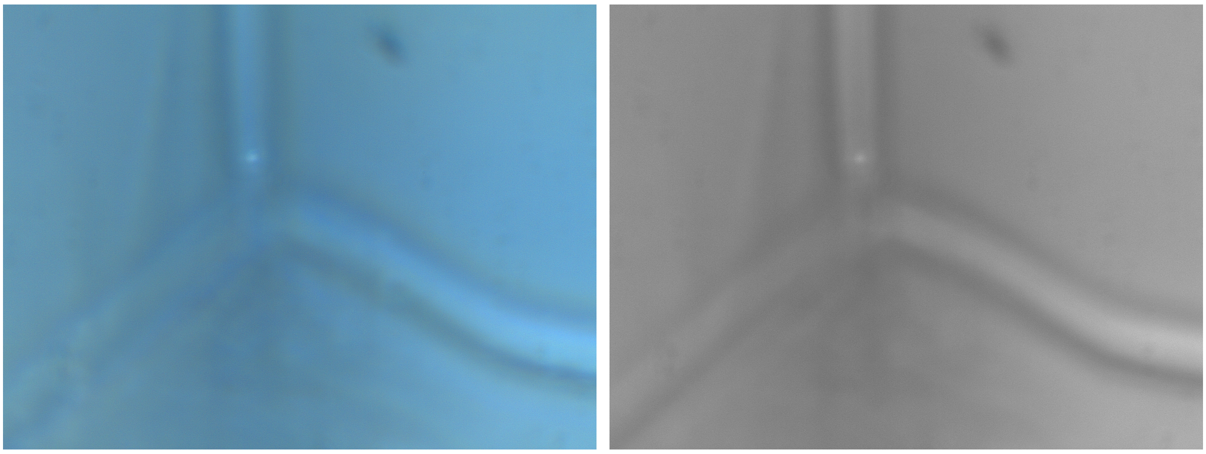
(a) Colour. **(b)** Black and white.

Figure 8: Corresponding to Figure 21a of the main text. Bubble observed with the 63x objective lens. Incident illumination.



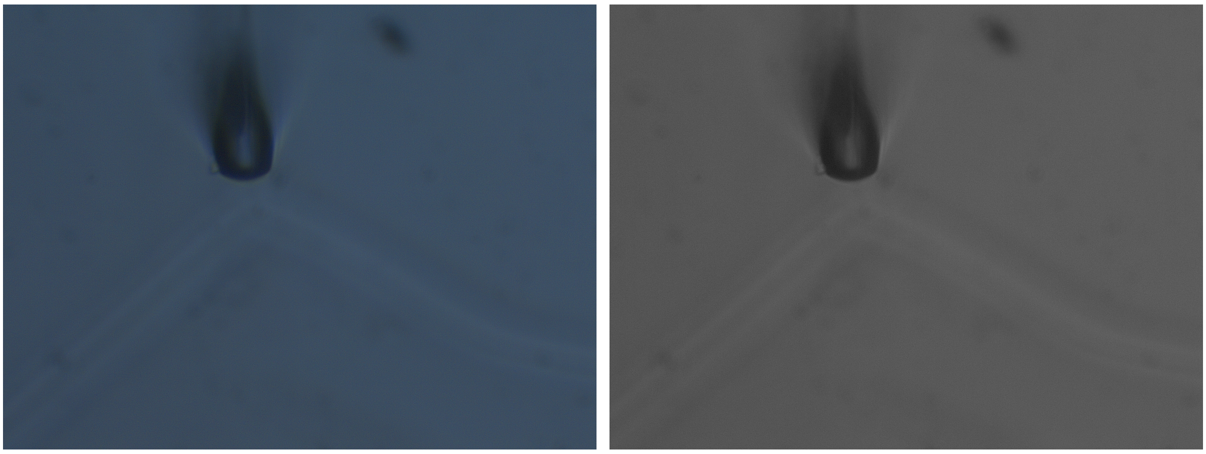
(a) Colour. **(b)** Black and white.

Figure 9: Corresponding to Figure 21b of the main text. Bubble observed with the 63x objective lens. Transmitted illumination.



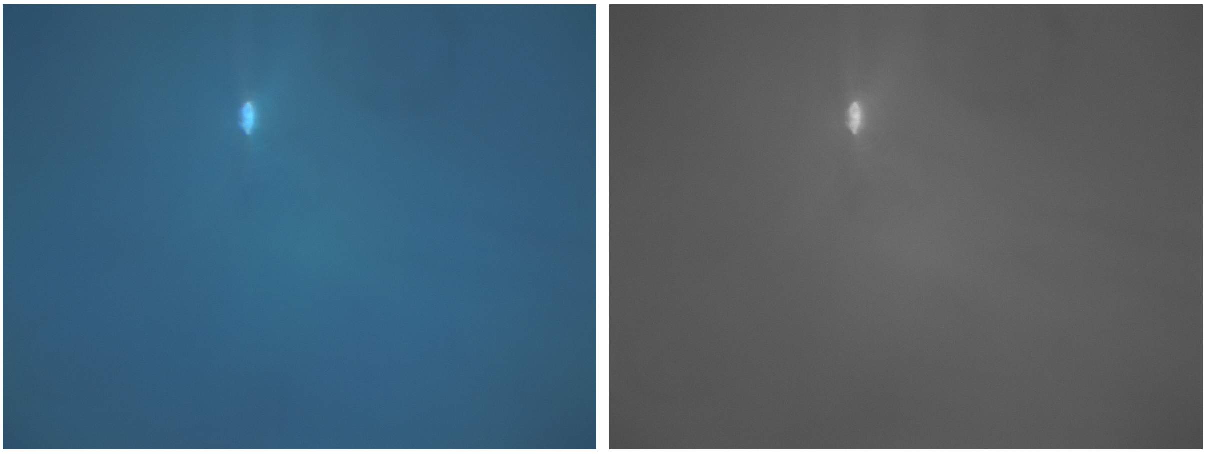
(a) Colour. **(b)** Black and white.

Figure 10: Corresponding to Figure 22a of the main text. Bubble observed with the 100x objective lens. Incident illumination.



(a) Colour. **(b)** Black and white.

Figure 11: Corresponding to Figure 22b of the main text. Bubble observed with the 100x objective lens. Transmitted illumination.



(a) Colour. **(b)** Black and white.

Figure 12: Corresponding to Figure 23 of the main text. Bubble observed with the 63x objective lens. Combination of transmitted and incident illumination.

References

Bayer. Bayer silicone baysilone Öle m, n.d. (unpublished). 1

DOW. Technical data sheet: Xiameter® pmx-200 silicone fluid, 50-1,000 cs, 2017. https://www.dow.com/documents/en-us/productdatasheet/95/95-5/95-516-xiameter-pmx-200-si-fluid.pdf. 1

K. Hutter and Y. Wang. *Fluid and thermodynamics Volume 1: Basic fluid mechanics*, pages 589–592. Springer, 2016. 3