A Holistic Review of Wetting of Droplets

Poster · June 2018

DOI: 10.13140/RG.2.2.28495.79525

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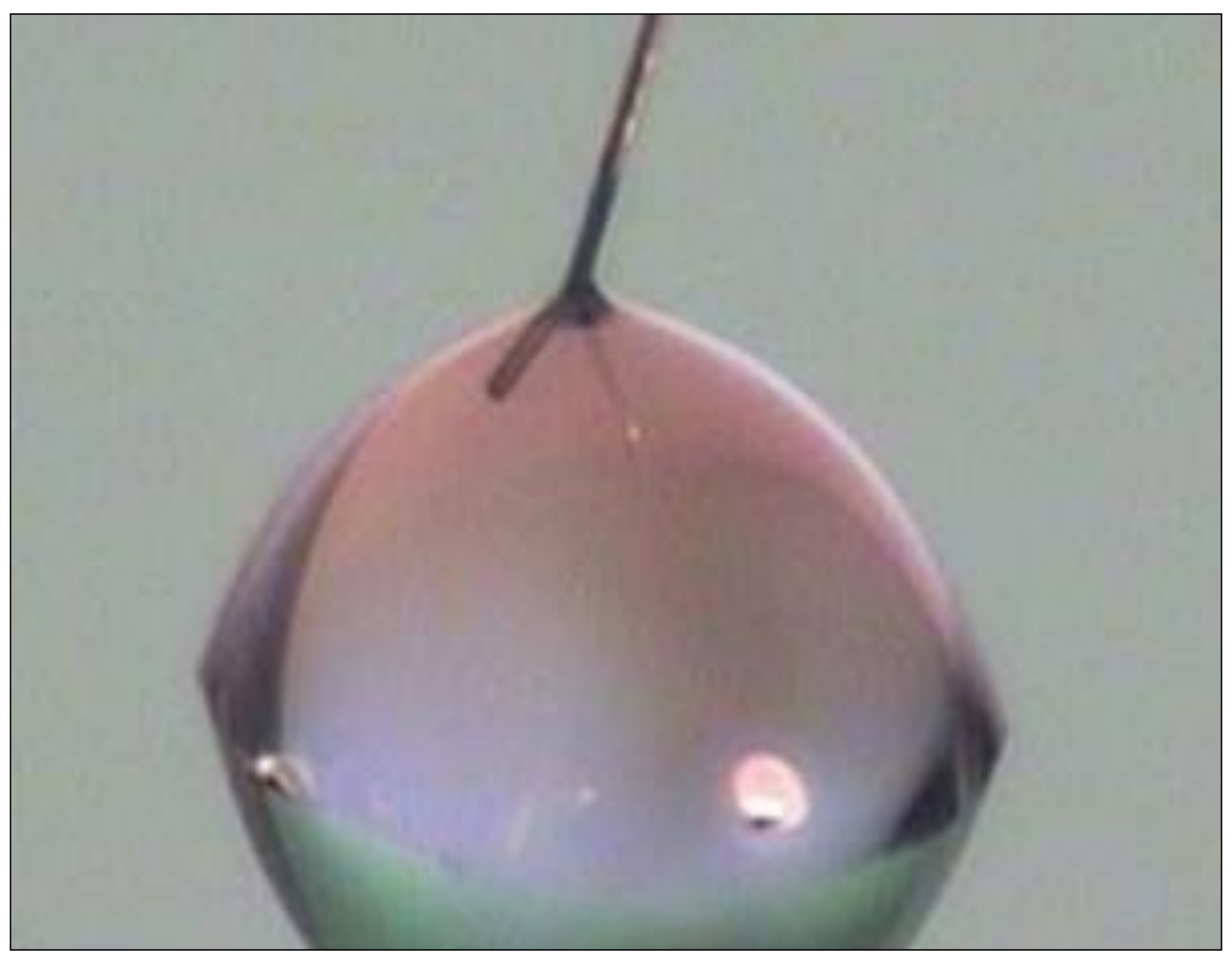
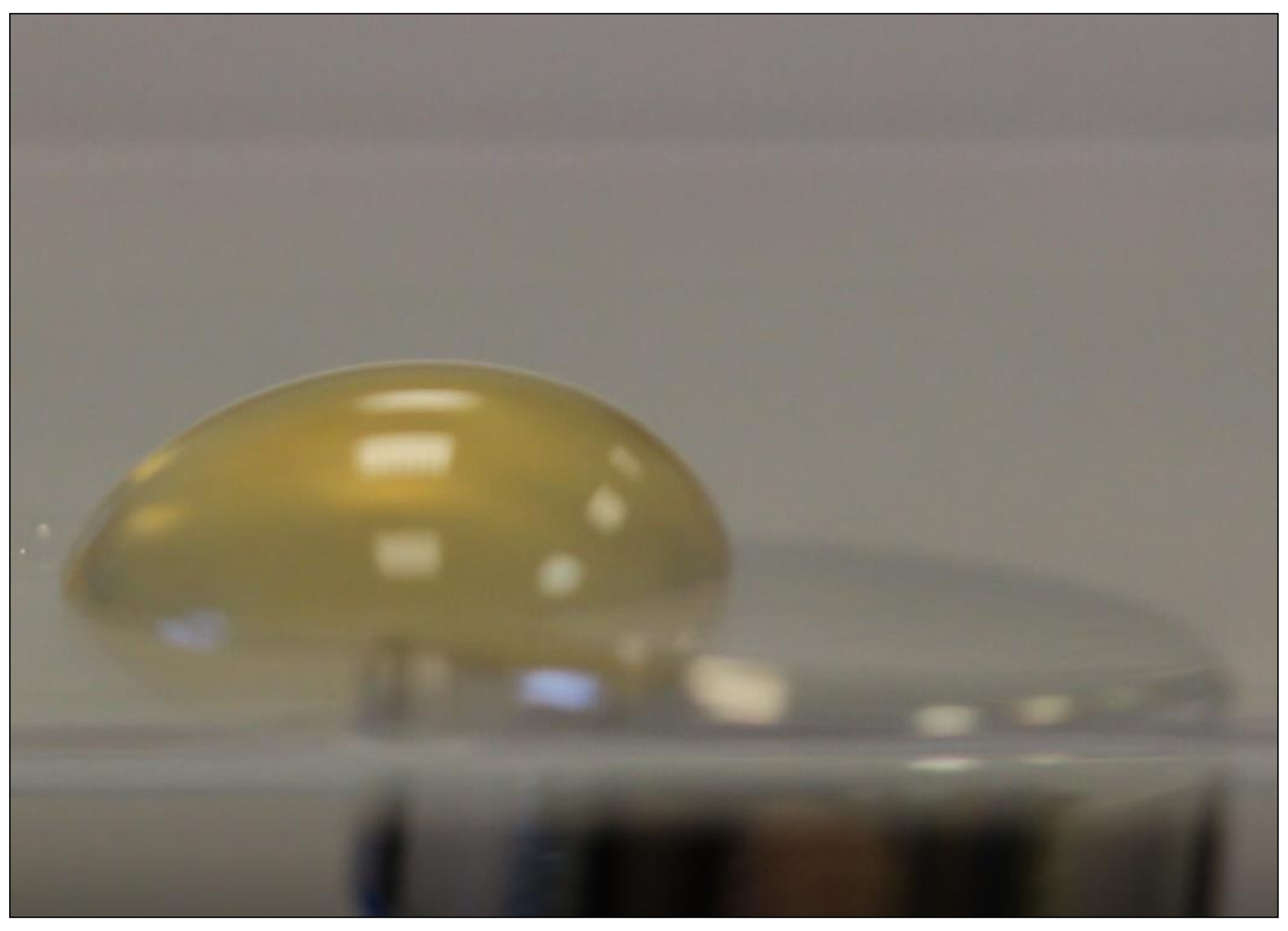
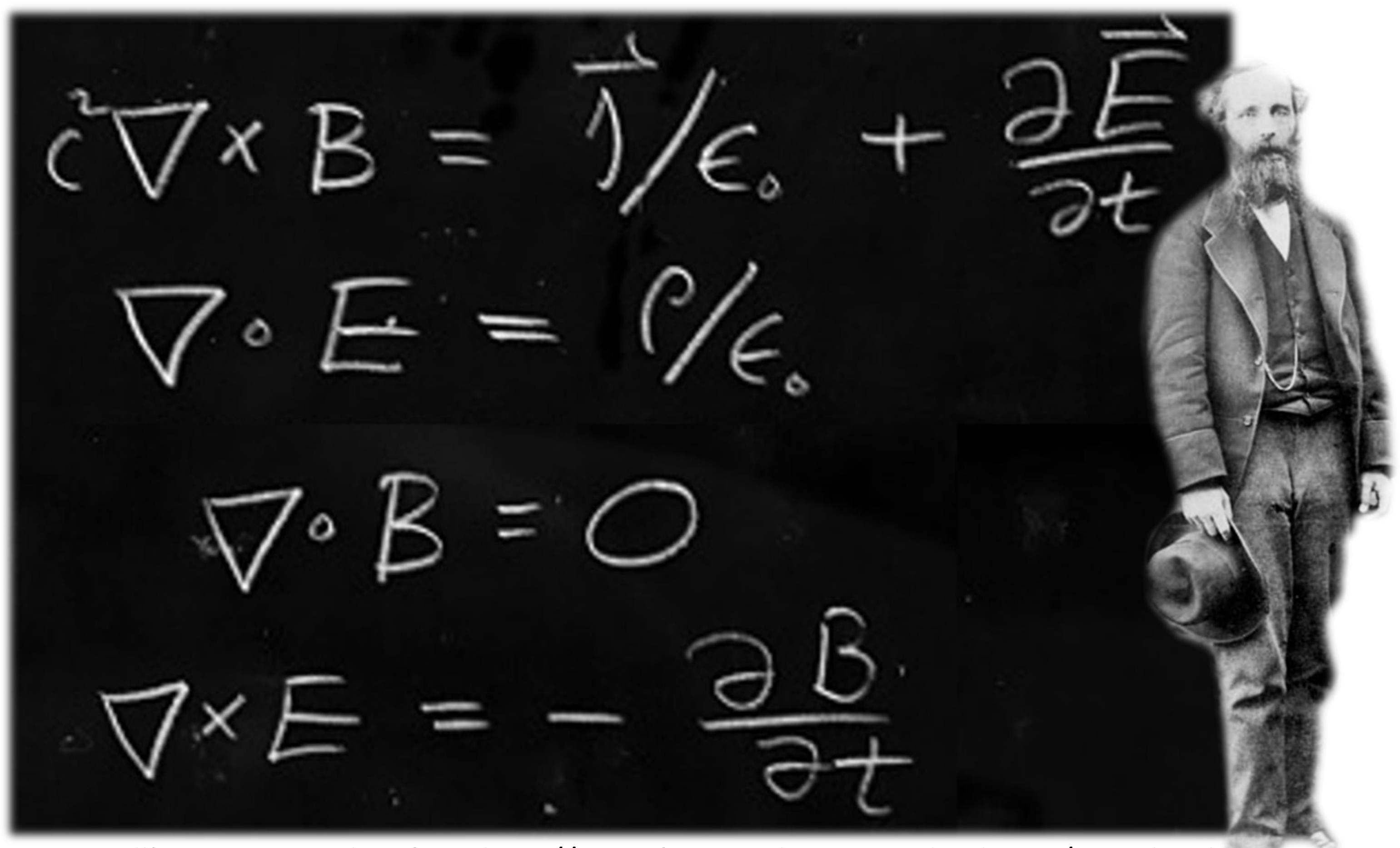


Electrowetting of a water droplet on a hydrophobic surface. [5]

Electrowetting is used in many technological applications such as lab-on-chip [1] and display technologies [2]. Its efficacy is limited by contact angle hysteresis and contact angle saturation [3]. The classical model of electrowetting, derived from the energy-minimization approach, lacks a full explanation of these issues. We use magnetic fields to control the wetting of droplets. This phenomenon is called **Magnetowetting**. We derive and experimentally verify a relationship between the change in contact angle of a droplet and the magnetic flux density through the droplet using the **Maxwell Stress Tensor** [4].



Magnetowetting of an aqueous solution of Manganese Chloride on a hydrophobic surface.



Maxwell's Equations taken from http://www.feynmanlectures.caltech.edu/II_18.html

Maxwell Stress Tensor

$$\vec{F} = \oint_s \overleftrightarrow{T} \cdot d\vec{a} - \epsilon_0\mu_0 \frac{\delta}{\delta t}\int_v \vec{S}\, d\tau$$

$$T_{ij} \equiv \underbrace{\epsilon_0\left(E_iE_j - \frac{1}{2}\delta_{ij}E^2\right)}_{\text{Electric}} + \underbrace{\frac{1}{\mu_0}\left(B_iB_j - \frac{1}{2}\delta_{ij}B^2\right)}_{\text{Magnetic}}$$

Wetting in a uniform magnetic field

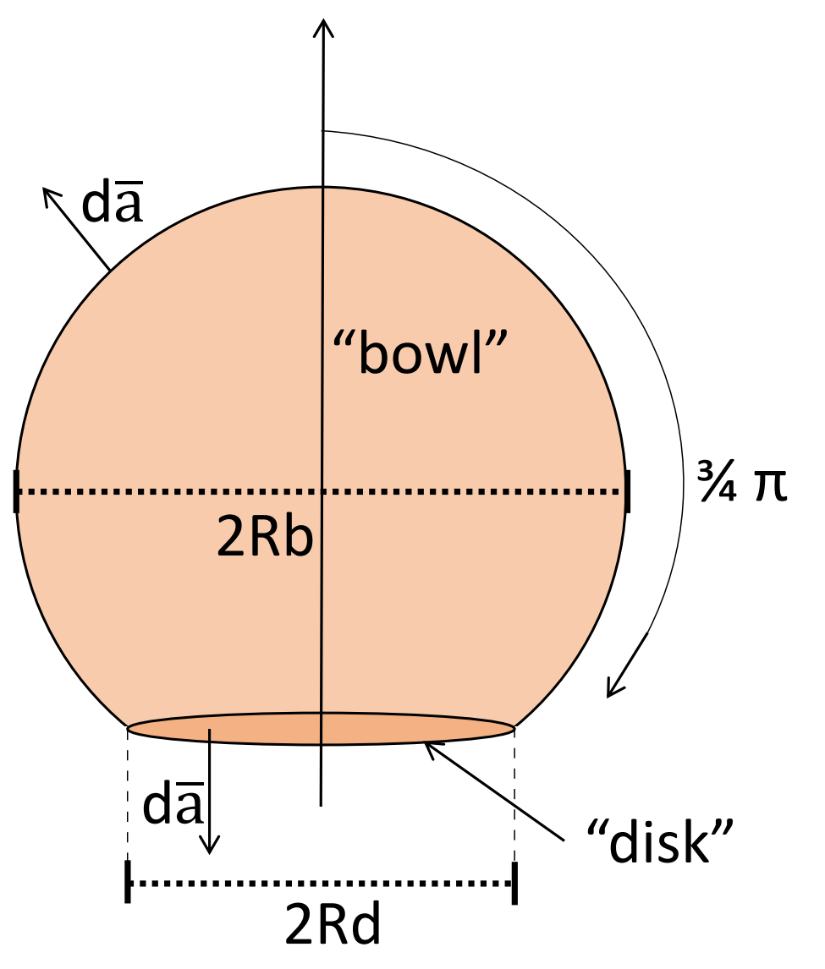
We approximate the surface over which we integrate the Maxwell Stress Tensor as a capped-off sphere (or bowl) and use a pair of Helmholtz coils to produce a uniform magnetic field. The resulting force on the droplet disturbs the equilibrium of the surface tensions $\sigma_{lv, vs, ls}$, which leads to a change in the contact angle.

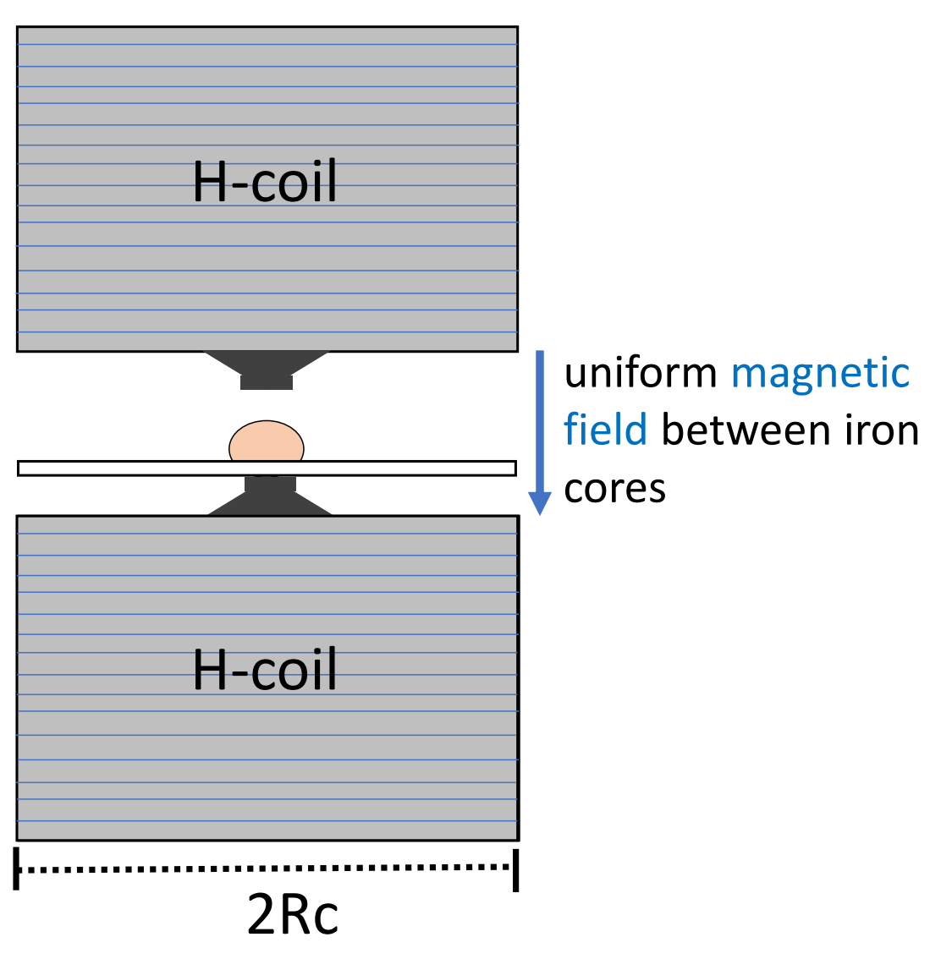
$$\cos(\alpha(I)) = \cos(\alpha(0)) - \frac{CI^2}{\sigma_{lv}}$$

Where C depends on the physical parameters of the droplet and magnet.

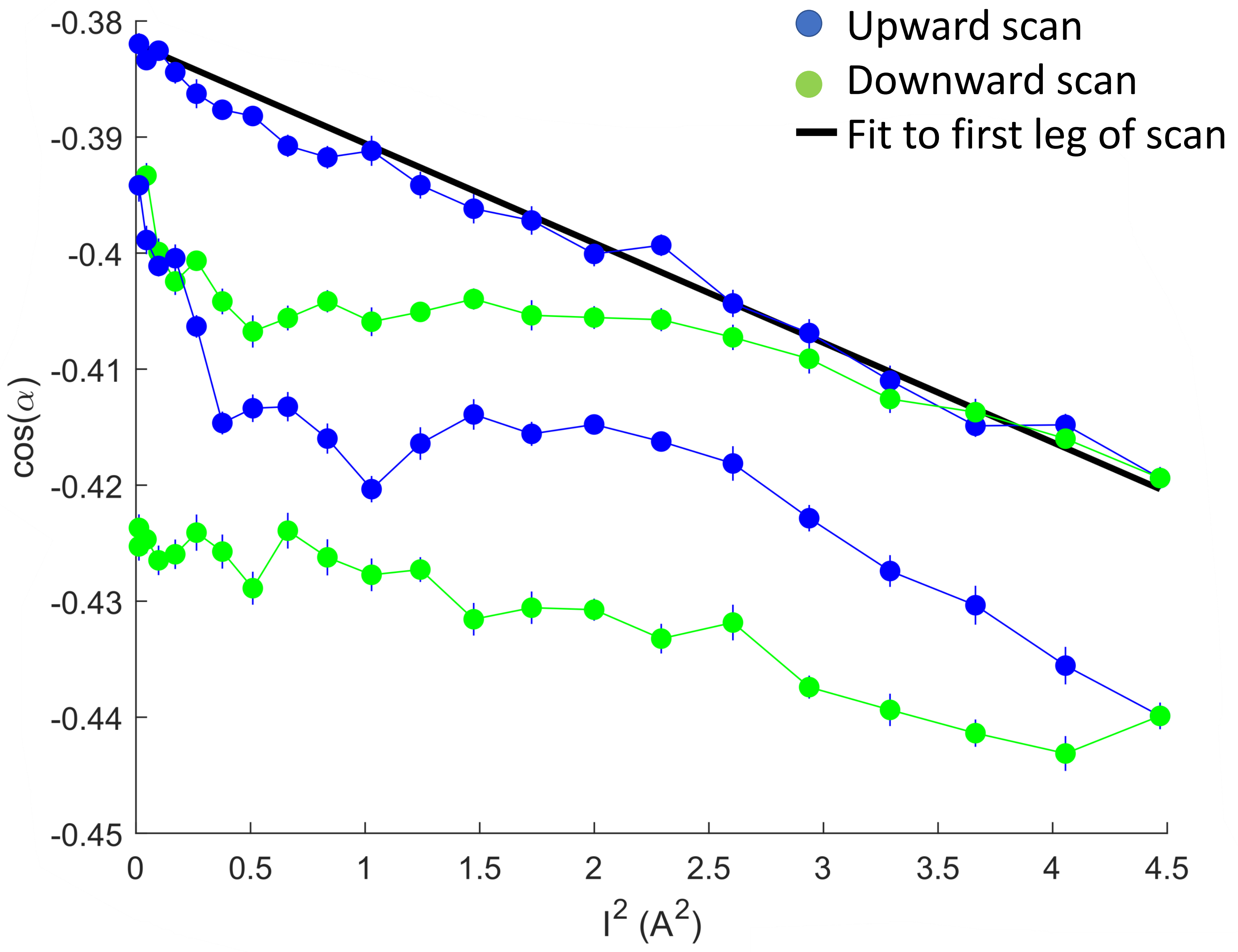
$$C = \frac{\mu\pi}{2}\left(\frac{{R_b}^2}{4} - {R_d}^2\right)\left(\frac{8N}{\sqrt{125}R_c}\right)$$

We experimentally verify this equation through measurement of the contact angle of a 10 μl droplet (aqueous solution of Manganese Chloride) in a pair of Helmholtz coils.





Preliminary Results & Conclusions



We find a linear relationship between a droplet's contact angle and the square of the magnetic field applied. This demonstrates the symmetry between electric and magnetic wetting phenomena. We propose that further investigations into this symmetry will pave the way for the development of novel experimental platforms.

References
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Acknowledgements
This work was supported by the EPSRC CDT in Intelligent Sensing and Measurement, Grant Number EP/L016753/1. The author's attendance at Electrowetting 2018 is supported by the Institute of Physics (IOP) C R Barber Trust Fund.

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