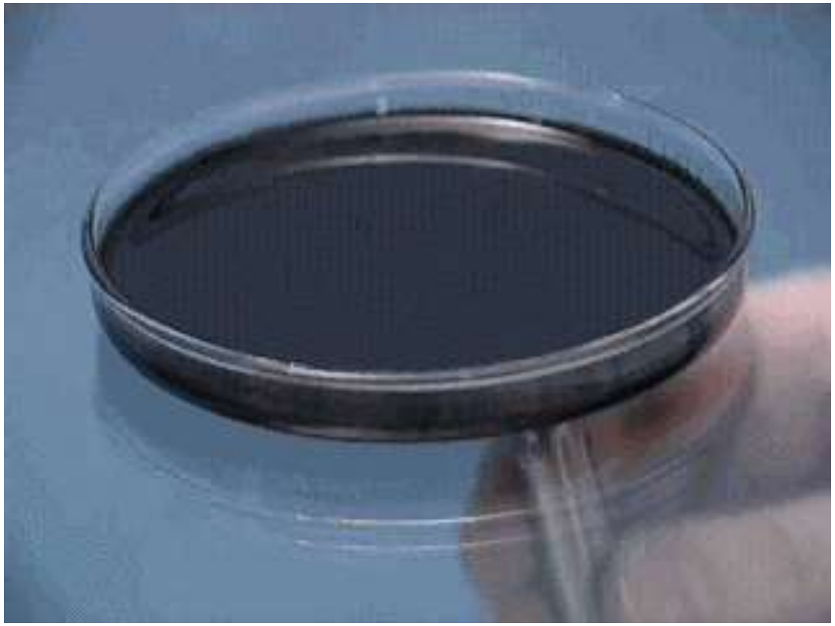
Ferrofluid

: Ferrofluid-impregnated surfaces for active manipulation of droplets



2015311481

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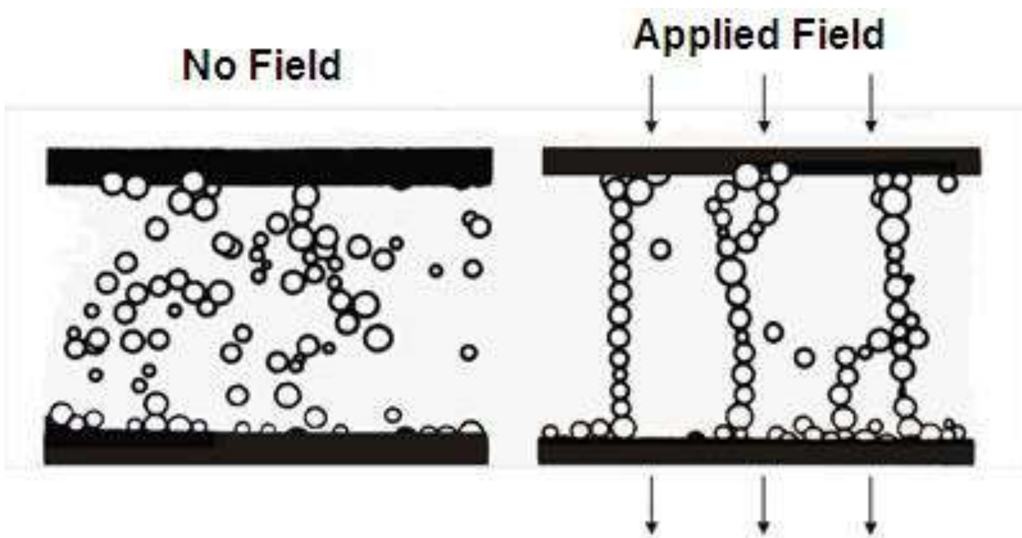
Contents

1.History

Ferrofluid as a liquid rocket fuel

Ferrofluid could be drawn toward a pump inlet in a weightless environment by applying a magnetic field.



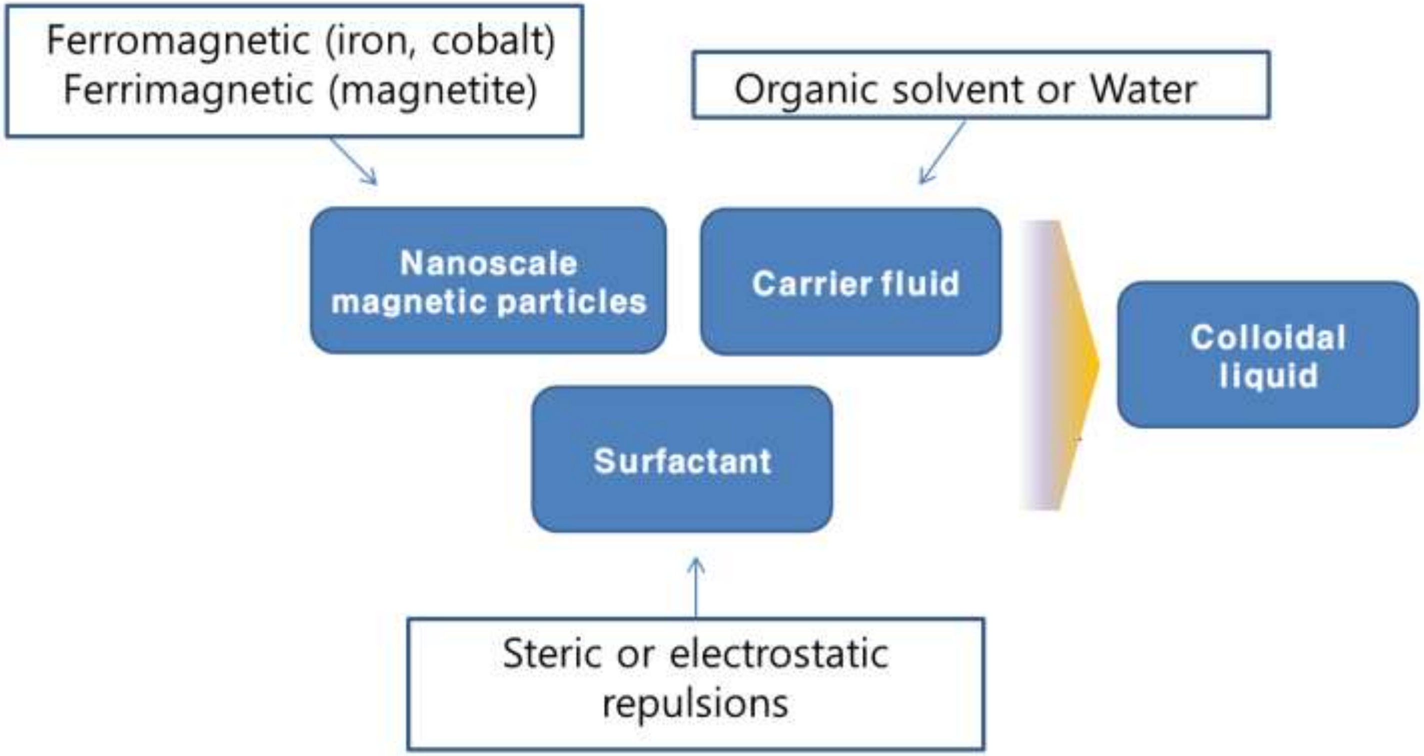
Disorientation

Orientation

in 1963 by NASA's Steve Papell

2.Ferrofluid

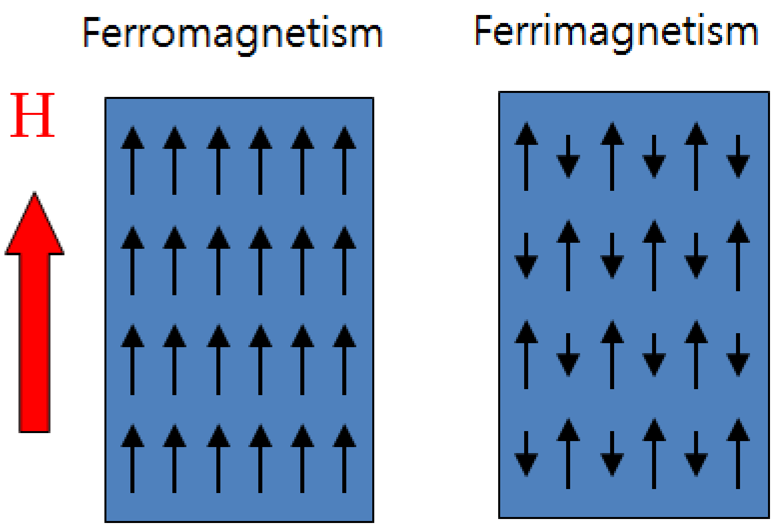
1. colloidal liquid

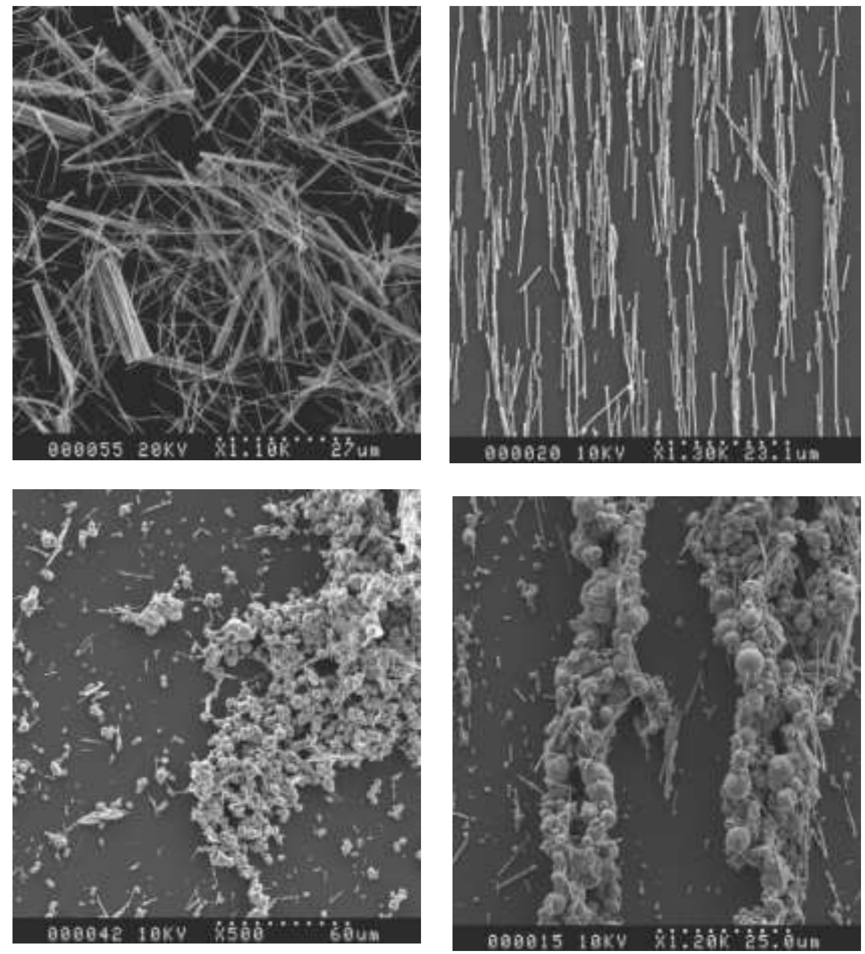


2.Ferrofluid

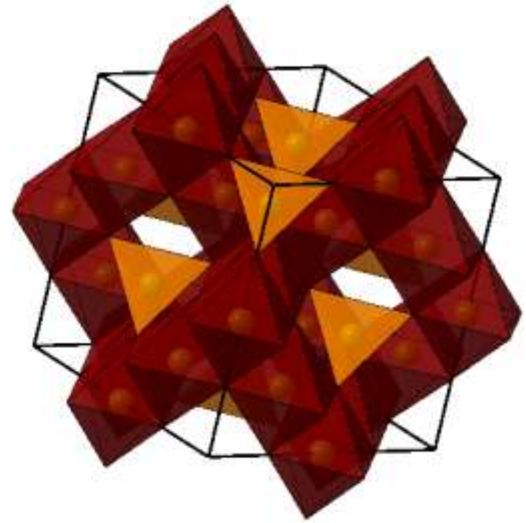
The location of the fluid could be precisely controlled through the application of a magnetic field.

The ferromagnetic particles are strongly magnetized in the presence of a magnetic field





Magnetite



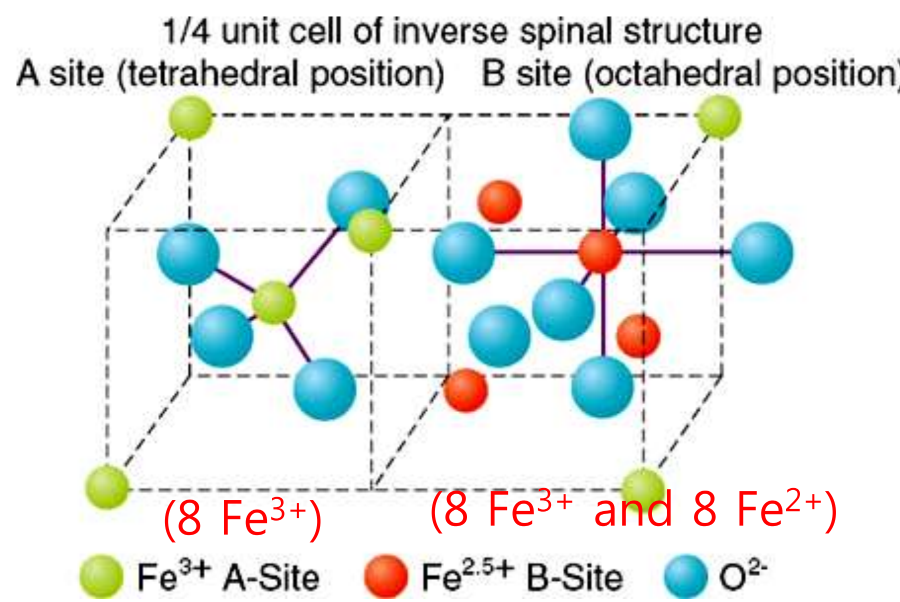
Fe_3O_4

- Spinel group

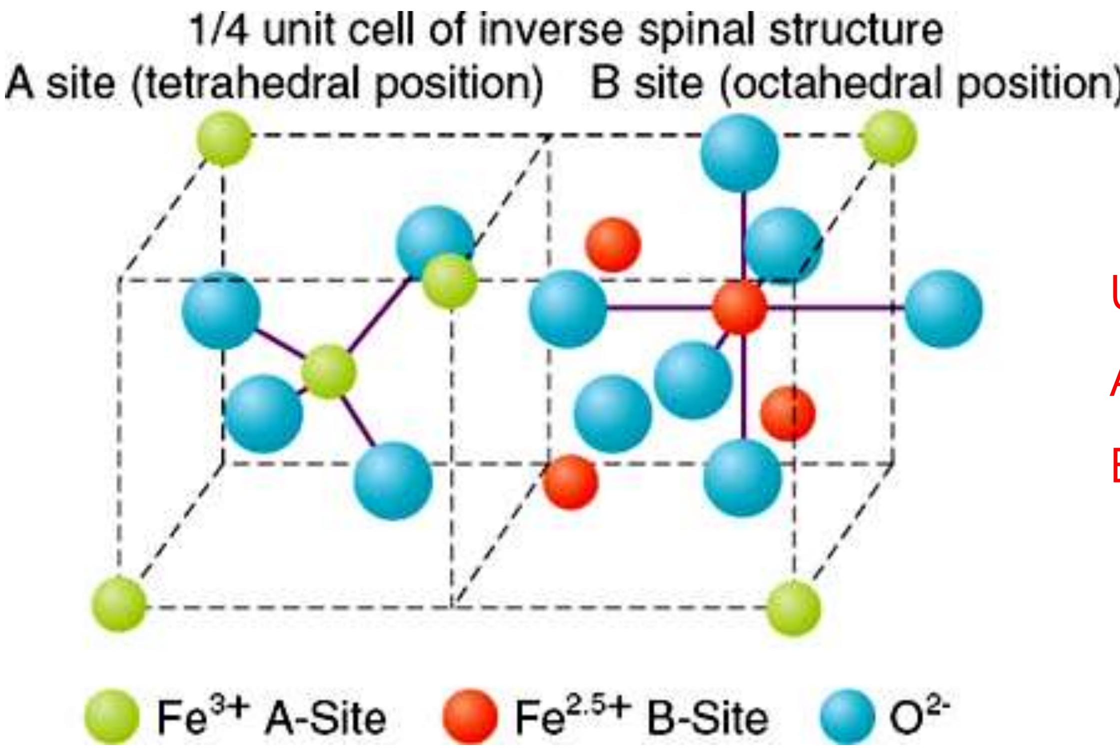
- General spinel formula: AB_2O_4
  A = 2+ metal, B = 3+ metal
  $Fe_3O_4 \Rightarrow Fe^{2+} + 2\ Fe^{3+}$

- Inverse spinel strucutre.
  spinel structures are usually cubic close-packed oxides with one octahedral and two tetrahedral sites per formula unit.

  All of the Fe^{2+}ions and half of the Fe^{3+}ions occupy octahedral sites, while the other half of the Fe^{3+}ions occupy tetrahedral sites.



Magnetite



Unit cell:

A-sites (8 Fe^{3+})

B-sites (8 Fe^{3+} and 8 Fe^{2+})

Inverse Spinel (Fe_3O_4)

A		B	
Fe^{3+} ↓ $5\mu_B$	↑ $5\mu_B$	Fe^{3+}	Fe^{2+} ↑ $4\mu_B$

=> **Ferrimagnetism**

3. suspension

magnetic and van der Waals interactions must be overcome. ↔ aggromerating

Particle size effect

Einstein equation

$$D = \frac{kT}{3\pi\mu d_\mathrm{p}}$$

D = the Brownian diffusion coefficient
d_p = Diameter of particles
k = Boltzmann constant
T = Absolute temperature of the fluid
μ = Dynamic viscosity of the fluid

$$\langle s^2 \rangle = 2D\Delta t$$

$$V\left(= \sqrt{\langle s^2 \rangle / \Delta t^2}\right)$$

mean square particle displacement equation

the cluster size ↑ ,V ↓ , Particle size ↑

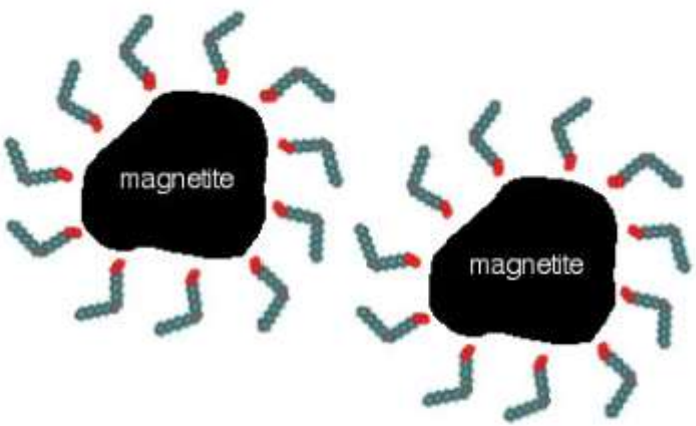
Particle size ↑, Brownian motion ↓

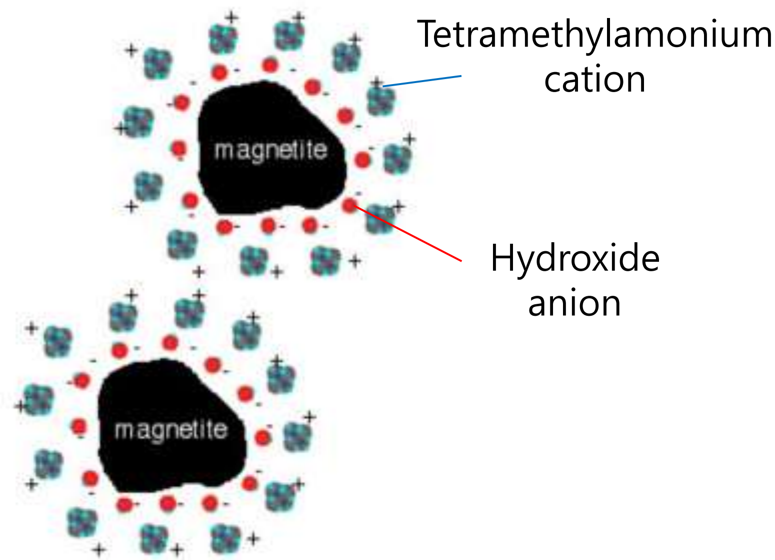
$$\boxed{d_\mathrm{p} = \frac{2kT}{3\pi\mu V^2 \Delta t}}$$

3.suspension

Surfactant

Steric repulsion	Electrostatic repulsions
Long-chain hydrocarbon	Ionic surfactants

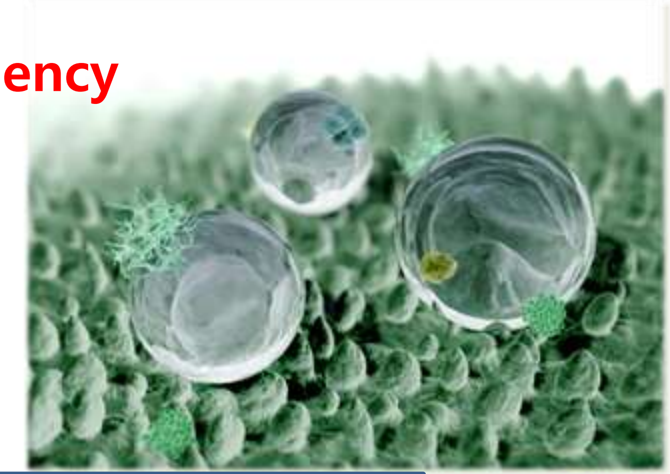




cis- oleic acid for oil-based ferrofluids

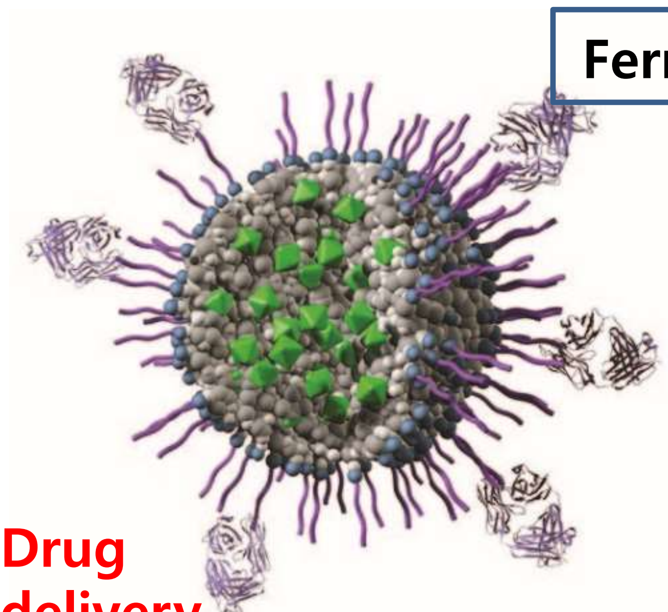
tetramethylammonium hydroxide For aqueous ferrofluid.

Liquid repellency



Droplet mobility and manipulation on non-wetting surfaces

Ferro fluid & Magnetic field

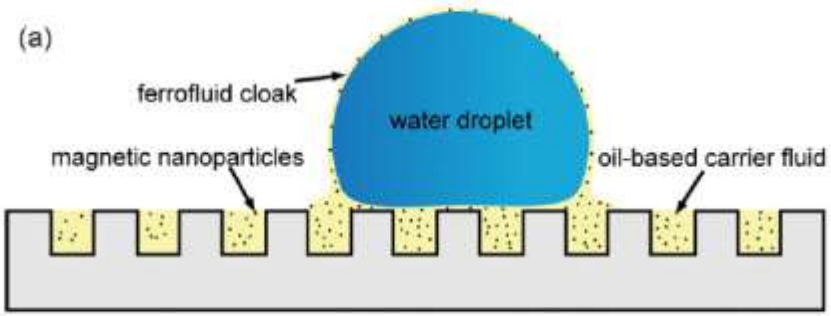


Drug delivery

Anti-icing

4. Active surfaces

Ferrofluid-impregnated surfaces for active manipulation of droplets



- Lubricant(ferrofluid)-impregnated surface

The lubricant will impregnate a textured surface if $\boxed{\Theta os <= \Theta c.}$

Θos = contact angle of ferrofluid to solid surface

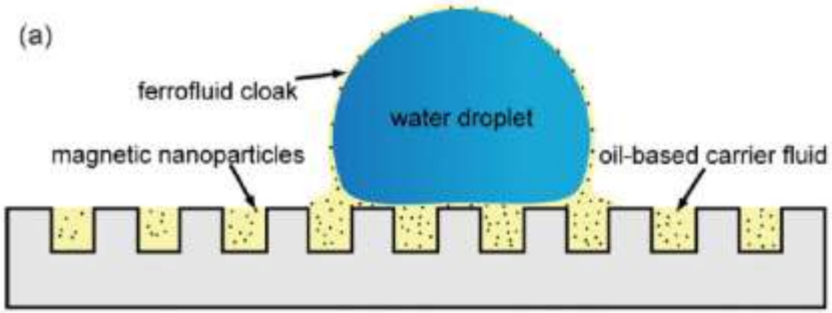
$\theta_c = \cos^{-1}[(1-\phi)/(r-\phi)]$. the critical angle

Ø = the fraction of the projected area of the textured surface.

r = the ratio of total surface area of the textured surface to its projected area.

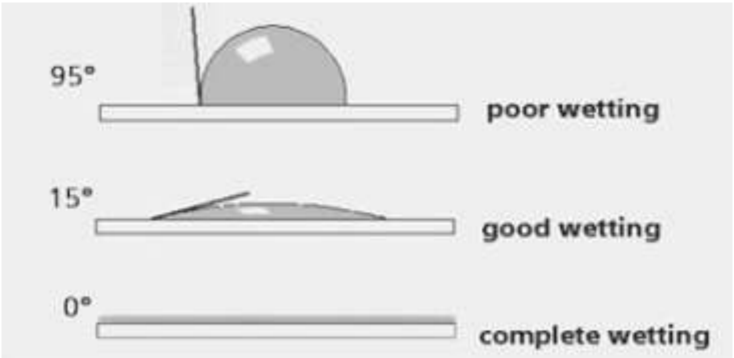
4. Active surfaces

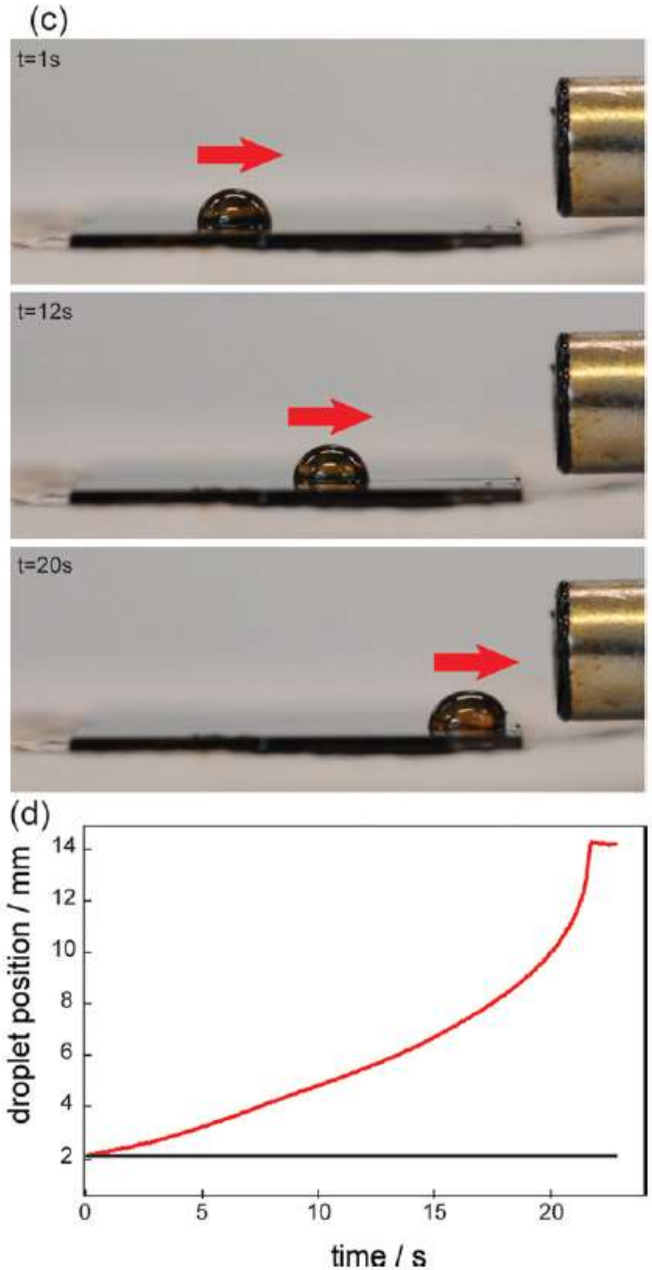
Ferrofluid-impregnated surfaces for active manipulation of droplets



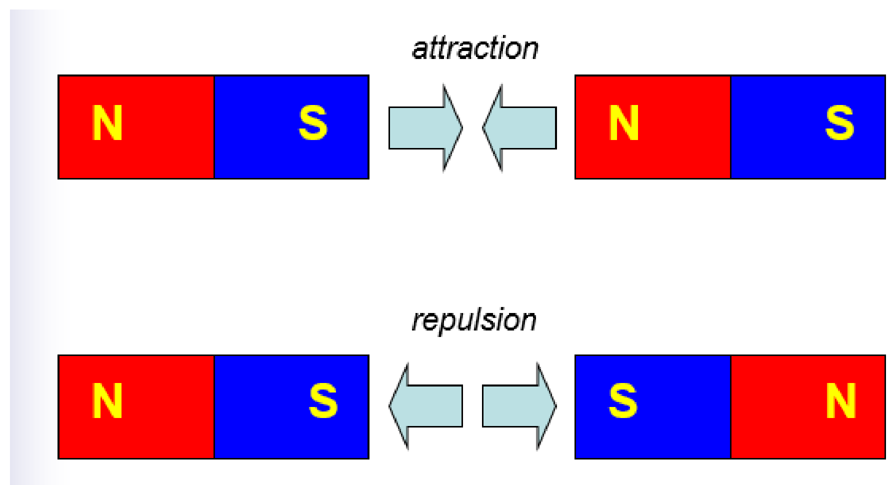
- a thin layer of ferrofluid-lubricant surrounds the water droplet.

> ➢ The oil based ferrofluid is immiscible with water droplet.
>
> ➢ The *spreading parameter S*, $S = \gamma_{SG} - (\gamma_{SL} + \gamma_{LG})$
> When $S > 0$, complete wetting
> When $S < 0$, partial wetting occurs.
>
> $$S_{os(w)} \geq 0, \quad S_{ow(v)} \geq 0.$$
>
> $S_{os(w)}$, S of Ferrofluid to the solid
>
> $S_{ow(v)}$, S of Ferrofluid to the water

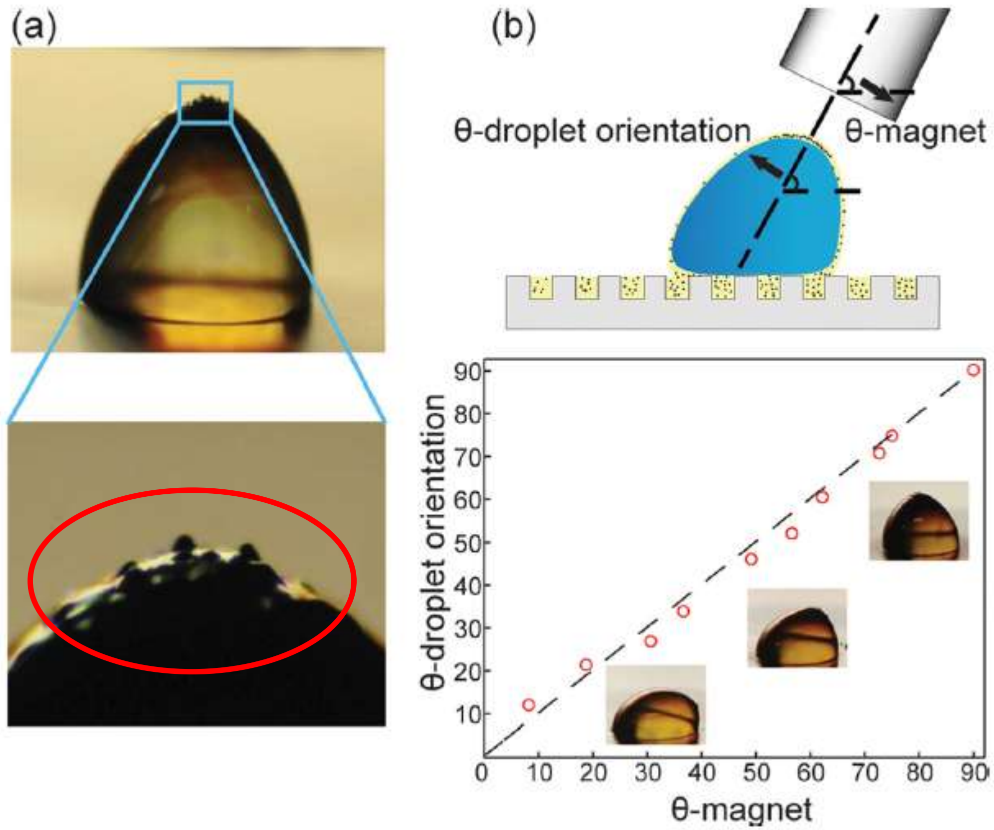




Approaching a permanent magnet to the droplet :
The droplet accelerates towards the magnet

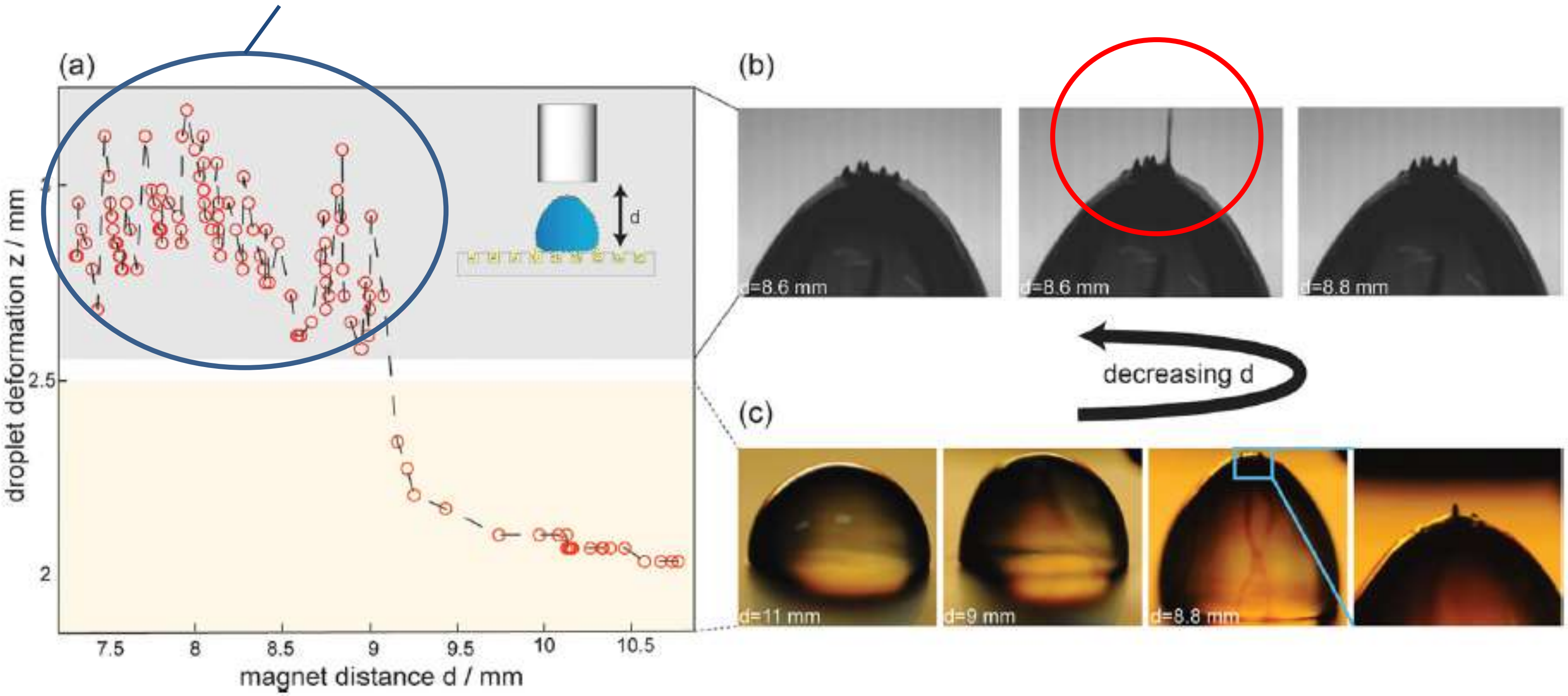


Symmetric magnet configuration **Asymmetric magnet configuration**



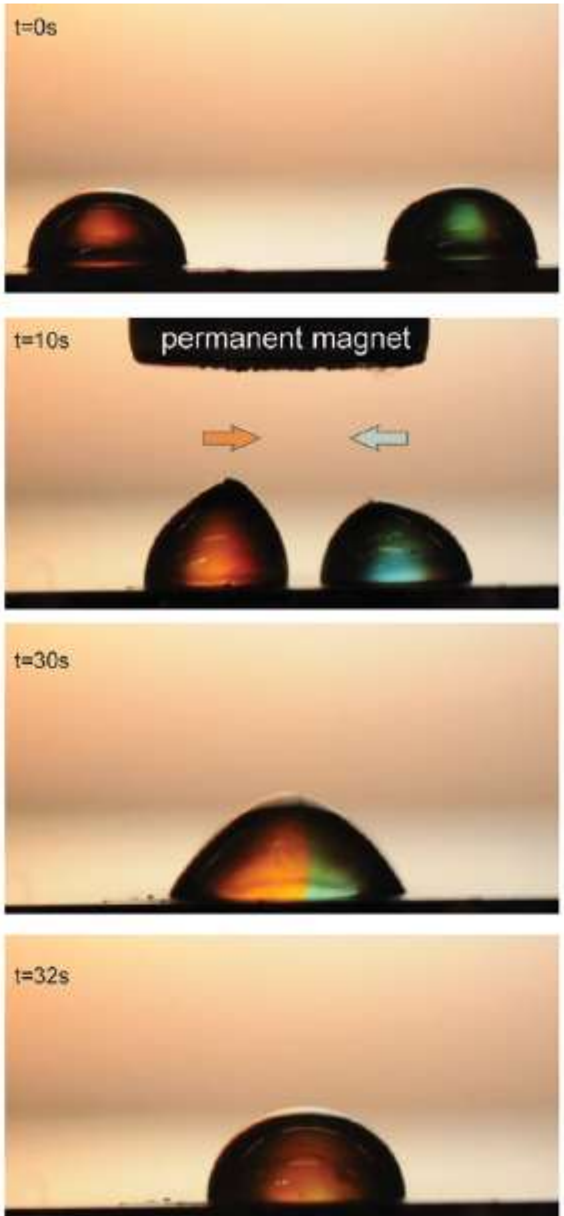
- Deform towards the magnet
- local cone-like structures
- Balance of the magnetic attractive force with interfacial forces that act to hold these particles in the ferrofluid film.
- In an asymmetric configuration, the droplet distort towards the region of higher magnetic field.

Jetting transition

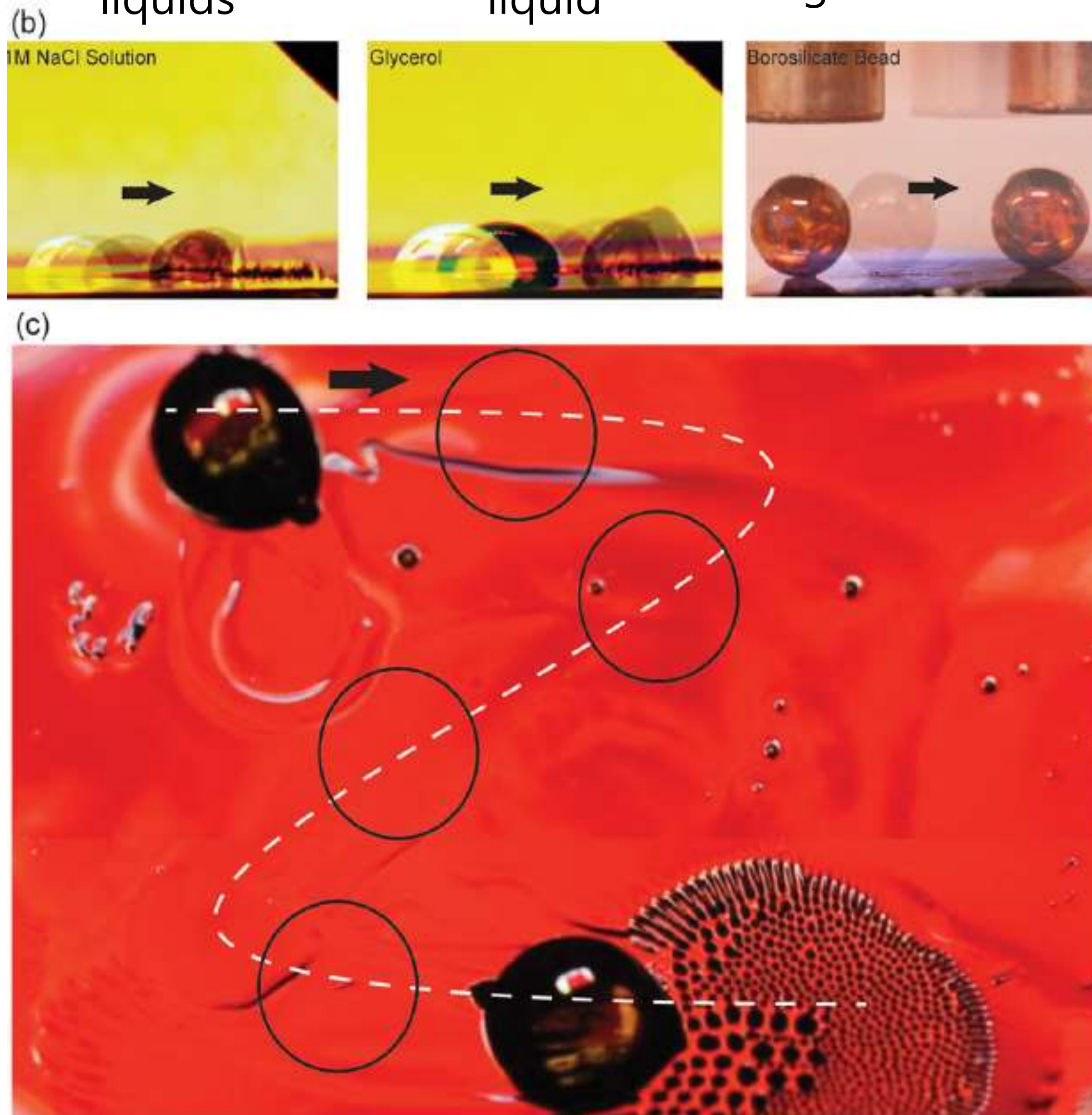


Droplet deformation versus magnet distance.
Magnet distance↓ Droplet height ↑
Jetting transition : The particles physically detach from the film.
The magnetic attractive force of the particles is greater than the interfacial forces that are stabilizing them in the cloak.

Coalescence of two droplets



conductive liquids | Viscous dielectric liquid | glass bead




THANK
YOU