Ferrofluid: A Brief Overview

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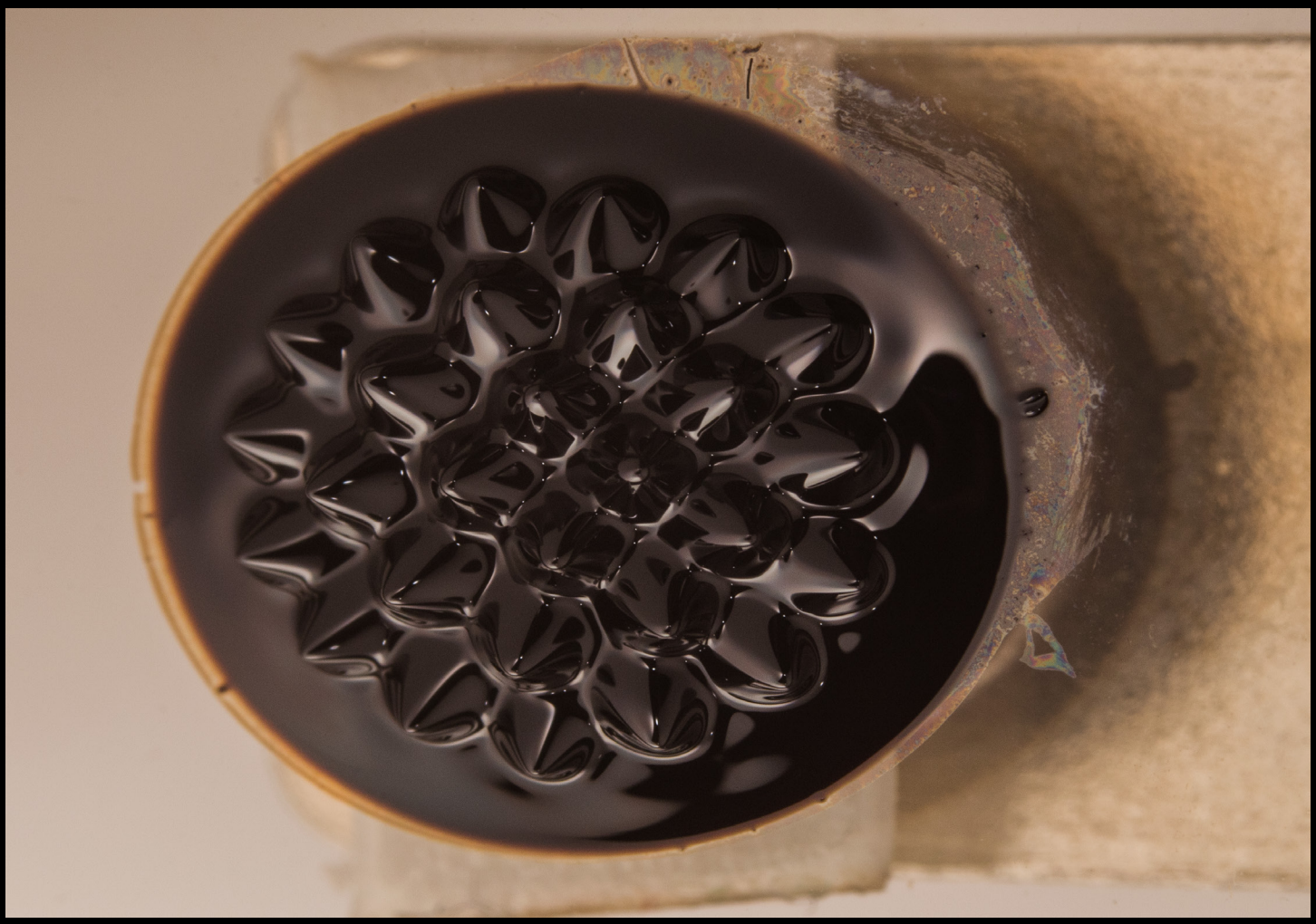
Where It All Started

Ferrofluids were first discovered in the 1960's while NASA was researching for a way to control liquids in zero gravity. When NASA set aside the idea of using ferrofluids in favor of another method, two scientists (Dr. Ronald Moskowitz and Dr. Ronald Rosensweig) got a license for the NASA technology. Moskowitz and Rosensweig saw how much potential ferrofluids had and founded what is currently known as Ferrotec. Ferrotec is a company that has found many applications for ferrofluid and continues to find more.

Cover Image: Ferrofluid photographed at 1x and focus stacked

Below : Ferrofluid



The Nitty Gritty

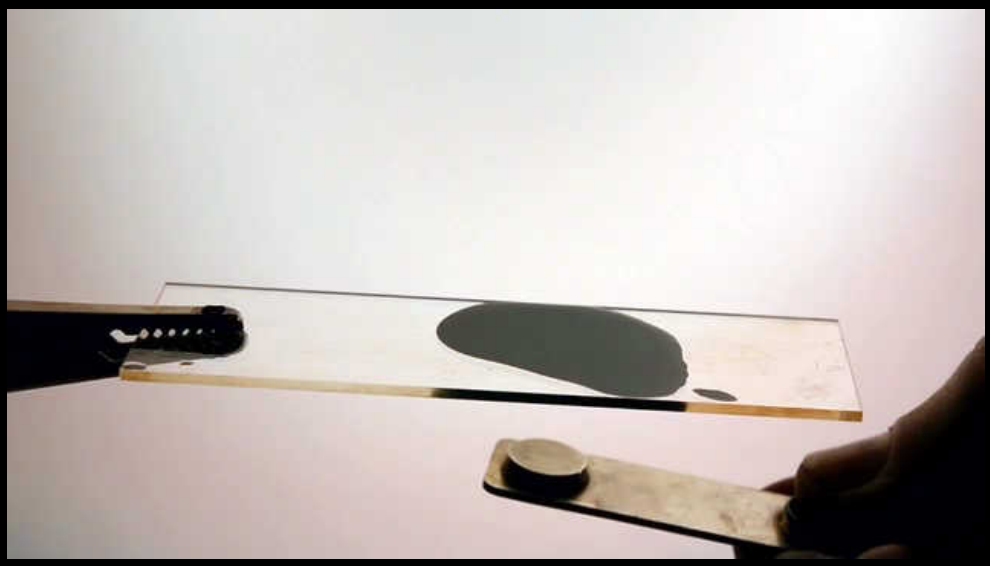
Ferrofluids are colloidal liquids made up of nanoscale particles coated in a surfactant and suspended in a carrier fluid. The composition is generally 5% magnetic solid, 10% surfactant and 85% carrier fluid. The carrier fluid is usually oil or water based.

The surfactant coating on the nanoscale particles is used to inhibit clumping. It accomplishes this by lowering the surface tension between the particles and the carrier fluid. Surfactants often used in carrier fluids are oleic acid, citric acid, soy lecithin and tetramethylammonium hydroxide. The surfactant used generally depends on what the purpose of the ferrofluid is.

The nanoscale particles used in ferrofluids are ferromagnetic and have a diameter of ten nanometers (1.0 x 10^-8 meters). The diameter is so small because it is necessary for the particles to be dispersed evenly in the carrier fluid. These particles are suspended by brownian motion. Brownian motion is the random motion of particles resulting from their collision with the faster moving molecules of the liquid they're suspended in. This motion allows them to resist gravitational settling over time. The particles are often a compound containing iron. An iron oxide such as magnetite is commonly used.

Above : Ferrofluid photographed at 2x

Introducing A Magnetic Field



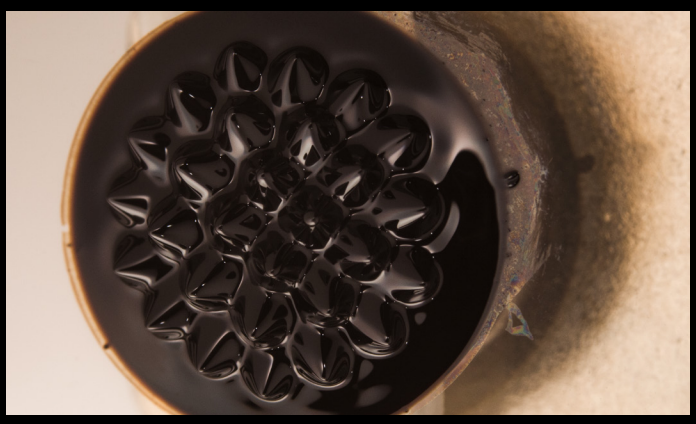
Above : Video of the effect a magnetic field has on ferrofluid

As seen in the images and video clip when introduced to a magnetic field a ferrofluid will form peaks and valleys. The peaks form along the magnetic field lines and show the contours of the magnetic field. This is similar to effects seen with iron filings and a magnet. The formation of the peaks is due to normal-field instability. Normal-field instability occurs when the force of the magnetic field outweighs the stabilizing effects of the surface tension and gravitational forces. This is seen in the video clip at the point where the magnet is close enough to the ferrofluid to form a single peak.

Above : Ferrofluid photographed at 3x and focus stacked

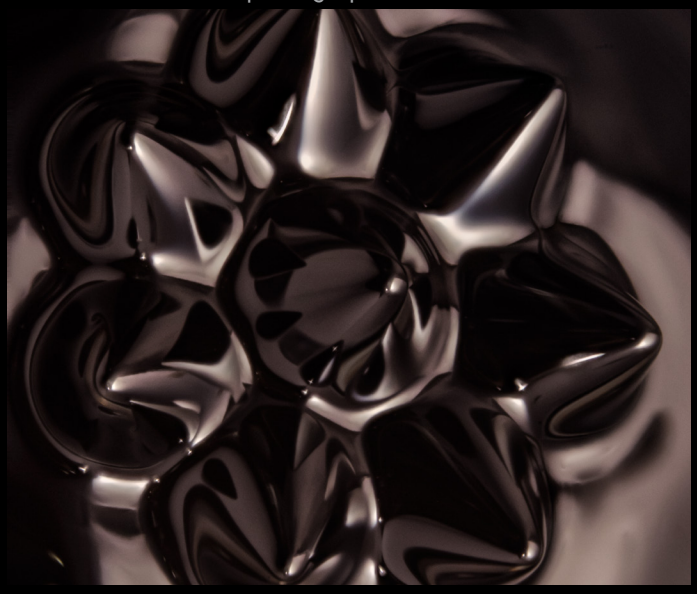
In What Ways Is It Used?

A ferrofluid's ability to change shape and retain properties of a liquid when a magnetic field is applied allows them to be utilized in a wide range of applications. The first and most popular is its use in loudspeaker technology. It allows for better power handling and audio response. Another way in which ferrofluids are utilized is creating seals in electronics. By using magnets to keep the ferrofluid in place, it can keep dust and debris from entering the device. Also, due to ferrofluids friction reducing properties when used with neodymium magnets, it is often used in mechanical engineering. There are several other applications in which ferrofluids are utilized but there has been recent research into using ferrofluid for telescope mirrors.



Above : Ferrofluid

Below : Ferrofluid photographed at 1.5x and focus stacked

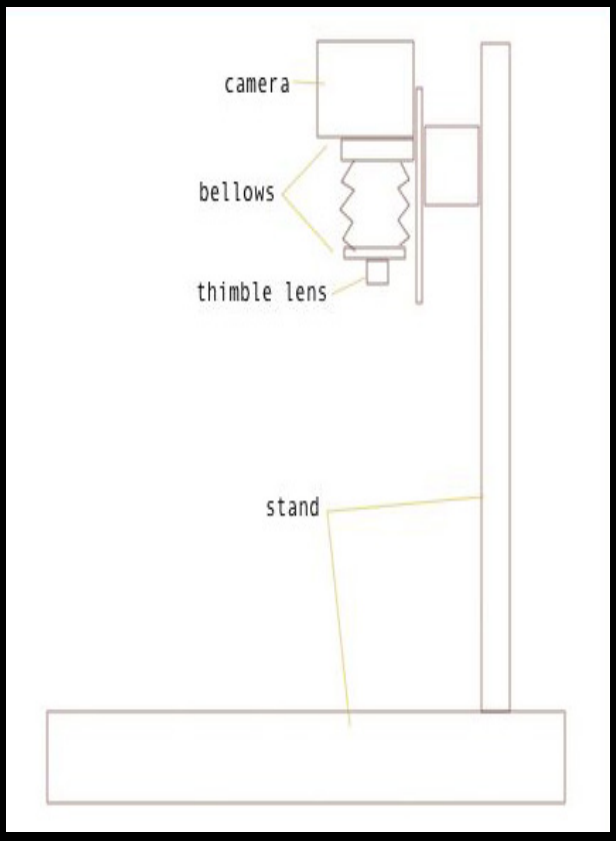


There has been a lot of research going into Magnetic Fluid Deformable Mirrors over the last couple of years. This is because liquid mirrors allow for atmospheric corrections and are cheaper to produce than solid mirrors. Currently there are some liquid mirrors employed by using mercury. Drawbacks to this are that mercury is toxic and can only be used on a horizontal plane. By using ferrofluid as the liquid base, it is possible to control the surface of the mirror by magnetic coils placed underneath it and use the mirror titled to differing angles. There is still a lot of research to be done but ferrofluids future in optics looks very promising.

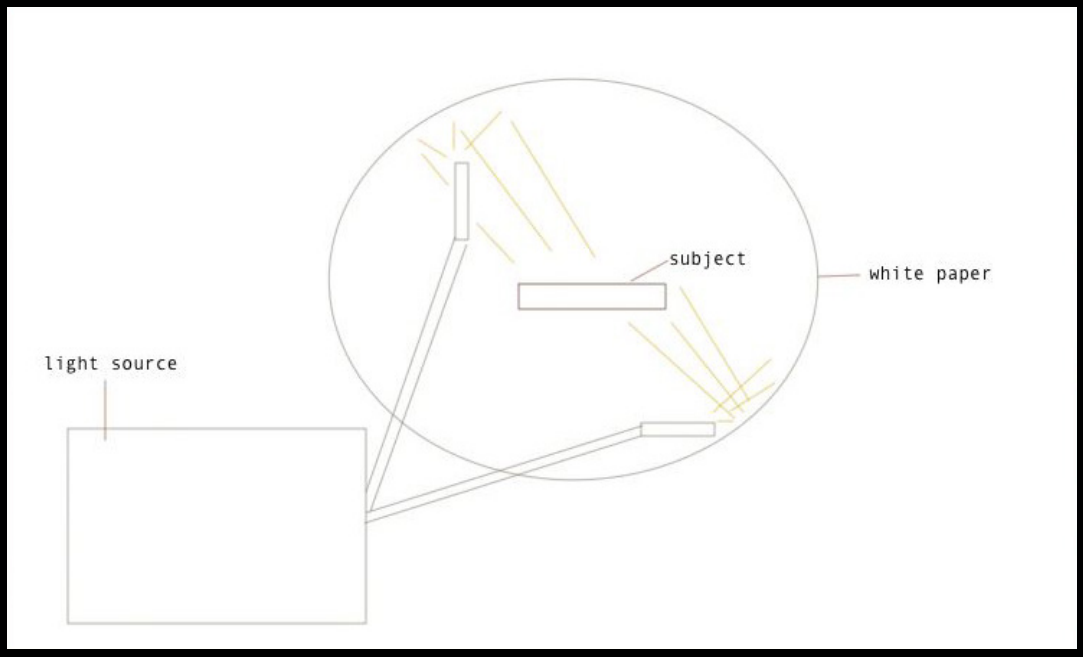
Photographing Ferrofluid

For the creation of the images used in this article I used a Nikon D5100, various thimble lenses and bellows on a stand. I mostly used a Bausch& Lomb 32 mm and Nikon 63 mm thimble lens.

For lighting the ferrofluid, I settled on reflected light. I accomplished this by surrounding my subject with white paper and bouncing the light off of the paper. By using reflected light I minimized both the reflection of the lights in the ferrofluid and the reflections of the set-up.

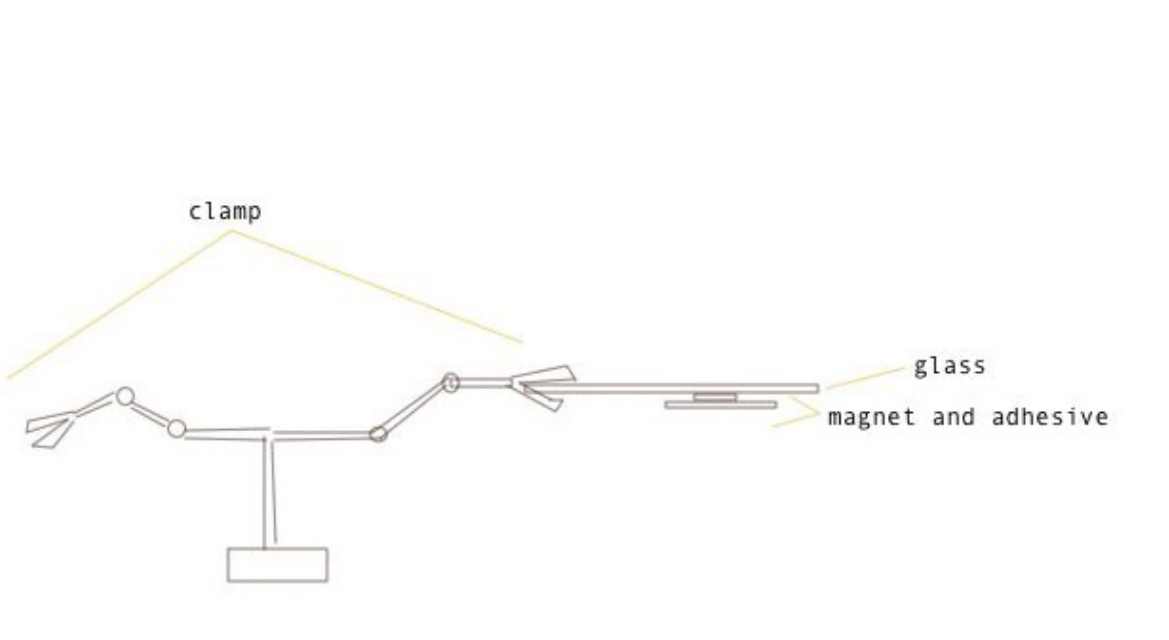


Above is a labeled diagram of my basic set-up



Above is a labeled diagram of my lighting set-up

Photographing Ferrofluid Con't



Below is a labeled diagram of the clamp I used to support the glass

I photographed the ferrofluid on various glass surfaces with a small adhesive keeping the magnet (a small neodymium) in place. To hold this all in place, I used a set of small clamps to either keep the set-up horizontal or at an angle. For the images that are stacked I used the program Zerene Stacker.

Difficulties I faced while creating these images were minimizing the reflections in the ferrofluid and keeping the images looking clean. This is because the ferrofluid is extremely reflective and incredibly messy.

Above : An Image of my final set-up (w/o camera)

Works Cited

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