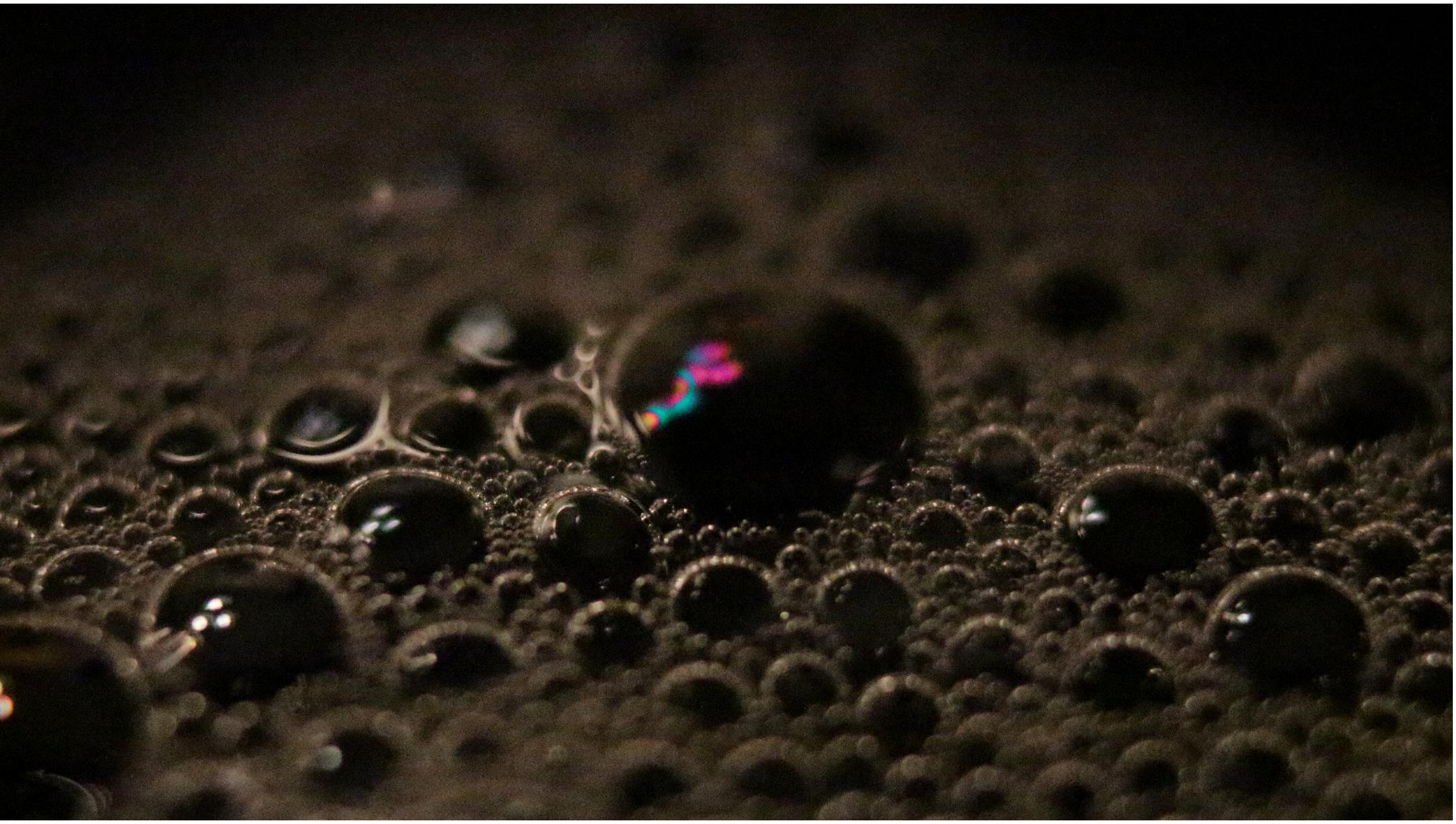

Get Wet 2016

BLEACH BUBBLES DISPLAY THIN FILM INTERFERENCE AND BUBBLE SCALING

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Introduction

The image I submitted for the Get Wet assignment is of soap(bleach) bubbles on a glass surface. The intent of the image was to test a new macro tube extension that I had recently acquired on a new lens. While trying to find interesting subjects to capture, I sprayed some Lysol surface cleaner onto my iPhone screen and tried to capture it as close as possible using the macro tube. The submitted image is actually only the fifth photo I ever took with the macro extension. When reviewing the images, I noticed a blotch of color in one of the photos that I had not noticed before, and which was not obvious to the naked eye. Fortunately, the extremely narrow depth of field used captured the colored section of the image. After trying to capture many more flows and fluid dynamics, I still found this image to be the most interesting and striking.

FLOW ANALYSIS

The apparatus used here is extremely simple, and used only common household materials. The process involved spraying the Lysol onto an iPhone screen, and observing the various sized bubbles as they pop and change places. Because soap bubbles only last a few seconds, the bubble matrix changes each time an image is captured. The main soap bubble with the colorful splotch is about 0.75 cm across, and the smallest soap bubble captured is less than 0.2 mm across, which gives an extreme range in scales, part of which makes this image so interesting. The distance from the far right edge to the far left edge of the image is less than 4 cm, making this a true macro photo.

The flow phenomenon that is captured is a group of soap bubbles, concentrated to the point that it can be considered a soap foam. There are two interesting phenomenon captured in this image: thin film interference (the colorful spot) and a demonstration of how Plateau's laws create a foam.

Thin film interference occurs when light waves reflected by the film on the upper and lower boundaries interfere with each other, producing constructive or destructive interference and a varied wavelength of light that reflects back to the viewer. Light incident to the film experiences a phase shift when it passes through the first layer of film, and then again when it reflects off the bottom layer of the film. When this reflected light passes back through the first layer, it interferes with light that reflected off of the first layer originally. This interference is the cause of the spectrum of light seen in the image. For soap bubbles, the governing equation for the wavelength is shown below (for destructive interference in this case).

$$2n_{\text{film}} d \cos(\theta_2) = m\lambda$$

Where n is the refractive index of the film, theta is the angle of incidence of the light on the bottom boundary, and d is the thickness of the film. Based on common colors at various thicknesses, it is estimated that the thickness of the film in this instance is between 200 and 500 nm.

The second effect of interest is the foaming behavior by the bubbles, dictated by Plateau's laws. In the mid-19th century Joseph Plateau put forth a series of governing laws for foams created that describe how the foam is structured. These laws illustrate many natural structures, and are evident in this image. Plateau asserts that soap films always meet in threes along an edge at a specific angle, and that those edges (called Plateau borders) meet in fours at the tetrahedral angle to form a vertex. He also asserts that the average curvature of each bubble in a foam is constant at any point on the same film. (Almgren and Taylor 1976)

The constant curvature effect is easily seen in the image, as each bubble obviously has constant curvature, giving it a uniform appearance. It can also be seen that everywhere a bubble meets another bubble, a third bubble is present, confirming this observation. Because of the vastly varying size on the bubbles, the last observation involving the borders meeting at a vertex is obscured. The final piece of Plateau's laws states that any section of foam not conforming to these laws will quickly rearrange itself to meet these laws. (Almgren and Taylor 1976) Therefore, it can be said that any bubble in this image in violation of Plateau's laws was about to change position, shape, or location at the time the image was captured.

PHOTOGRAPHIC TECHNIQUE

This image was captured using entirely artificial light. No coloring was used in the soap or the background, or the lighting. The only color evident in the image is solely a result of the thin film interference. Light was provided by three 100W CFL light bulbs in a desk lamp positioned above and behind the soap bubbles approximately 1.5 meters away. The black background was an iPhone 6S plus screen that the soap was sprayed onto. The camera was handheld, requiring a high shutter speed.

The image was captured using a DSLR camera at 5184 x 3456 pixels. The photo was then cropped to 4904 x 2756 pixels for publishing. The camera used was a Canon EOS Rebel SL1 from 2016, shot at 18 megapixels in JPEG format. The SL1 uses a hybrid CMOS crop sensor.

The image is an example of macro photography, as the field of view is less than 4 centimeters wide. This was done to reveal interesting effects in a soap foam often invisible to the naked eye. The colorful soap splotch was about 2 cm from the lens, and the front out of focus bubbles are less than 1 cm from the lens. The lens used for this image is an 18-55mm zoom lens, zoomed to 55 mm with a 36 mm macro extension tube installed, giving an effective focal length of 91 mm. This macro tube was necessary to get as close as possible to the subject. The camera was set at ISO 6400, as this was shot in fairly low light. The F stop was f4, which gives an extremely shallow depth of field when combined with the macro extension tube. The range of focus in this image is less than 1 cm. This extremely narrow focal range gives the image a sense of drama and lends an artistic effect to the image, although it does obscure some foam detail. The shutter speed was 1/250s, which was fairly fast for the application only because the camera was handheld. Had a tripod been used, a slower shutter speed could have been used. One major stumbling block when taking this photo was focusing the image. Because the macro tube used has no electronic connections, autofocus could not be used. Furthermore, the focusing ring on the lens is not a true manual focus. The focusing ring on the lens is merely an encoder that tells the autofocus what to do. Therefore, focusing involved removing the macro tube, adjusting the focus using the ring, reinstalling the tube, checking the focus, and repeating until the desired result was achieved. The photo was processed in the free editing software GIMP. The only changes made were to contrast and white balance. Contrast was increased to help 'purify' the whites and blacks in the image, and the white balance was adjusted to ensure that the white reflections on the bubble surfaces appear as white as possible.

CONCLUSION

This image reveals bubbles interacting in a foam, as well as thin film interference, two often forgotten about phenomenon. The aim of this image when it was taken was only to test the capabilities of a macro extension tube. I discovered that very fine and interesting detail can be captured using a macro tube, and even reveal effects invisible to the naked eye, like the scale of the bubbles shown. I am very glad I captured the thin film interference that provides color to the image, and I am very pleased with the level of detail show in the bubble foam. I also like the shallow depth of field, but it is a bit too shallow. I would prefer the depth of field to have more of the image in focus, while still blurring the far and near edges of the photo. If I used a tripod, I could increase the F stop while decreasing the shutter speed, which could help achieve this effect.

While writing this report and researching this image, I came across many striking images of soap bubbles displaying thin film interference. With a different soap material, and larger bubbles, and by using different light, I would like to capture some more dramatic examples of thin film interference. I would like to capture a full range of colors in one image on one soap bubble.

REFERENCE

Almgren, Frederick J., Jr., and Jean Taylor E. "The Geometry of Soap Films and Soap Bubbles." *Scientific American* (1976): 82-93. *Nature.com*. Web. <http://www.nature.com/scientificamerican/journal/v235/n1/pdf/scientificamerican0776-82.pdf>.