Zack Cymanski
Flow Visualization
Get Wet
Sept. 28 2016

Get Wet Report: Sublimation of Dry Ice in Blue-Dyed Milk

My main focus was to implement and capture dry ice in some type of visual. My initial thought for dry ice was to use dye and water, and capture the dry ice gas in the color of the dye I used. I quickly discovered that the dye was much denser than the gas particles of dry ice and the sublimation taking place only produced white gas. I wanted something cooler and much more visually appealing. I then decided to use milk, and what I found was extraordinary. The milk actually captured the gas into small bubbles, as if it were boiling, and was very visually appealing. This was what I wanted my project to be, so I started capturing images throughout the chemical reaction.

The chemical reaction with dry ice in milk produces a fascinating result, and the shown below is a visual on what exactly is happening.

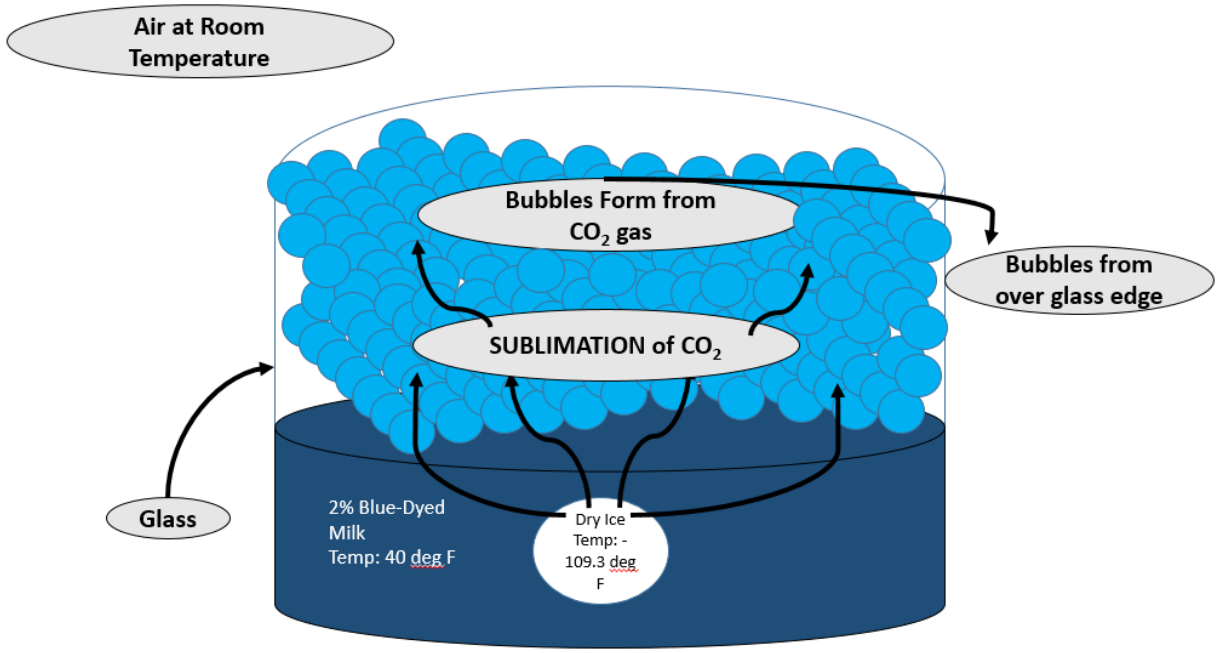

Image 1: Diagram of CO_2 sublimation in milk

The basic concept of this experiment/chemical reaction is the frozen carbon dioxide (Dry Ice) sublimates (solid to gas state directly) and the gas is then "captured" by the milks surface tension to produce bubbles of CO_2 gas. The bubbles are not possible in water because the surface tension of the milk is much lower than milk, mainly because of the proteins in milk (Nicholas Academy, 2000), and water cannot keep the bubbles intact for a long period of time. The milk film still had the blue-dye in it making the bubbles appear a lighter shade of blue. The

scale of this experiment is what it seems like, I had a glass (roughly 10 inches tall), and filled it three-quarters with milk, poured about 10 droplets of blue dye and mixed until the dye was uniform. After the milk was ready, I set up my camera about one foot away, with one light source above and behind me. The small piece of dry ice was carefully dropped into milk and the reaction was immediate. The bubbles were forming and after the container couldn't hold the bubbles, the bubbles overflowed to the side while still staying intact to the large mass of bubbles. I took many pictures at different points of the reaction (different amounts of bubbles) and even recorded a video to help visualize the process in real time.

The bubbles move upward out of the container because of the chemical reaction from the dry ice and milk. The gas released by the dry ice creates a gas (force) that rises because of different pressure gradients. This is a continuous reaction as long as there is still dry ice in the milk, and thus will keep pushing bubbles over the edge. The Reynolds number was estimated, with the velocity of the gas being hard to gather.

$$Re = \frac{UD}{v} = \frac{\left(\frac{0.01\text{m}}{\text{s}}\right)(0.0508\text{m})}{4.3e{-}06\ (\frac{m\text{^}2}{s})} = 118.4 \text{ (Engineering Toolbox)}$$

Equation 1: Reynolds Number, pipe

Using Reynolds number, this is acted as flow through a pipe and thus the flow is laminar because it is less than 2100. This is also verified by the uniform bubbles rising with really no sporadic movements.

As stated earlier in the report, this was done with 2% milk, blue-dye and dry ice. The chemical reaction between the milk and dry ice produces CO_2 gas that must exit the milk, in which the milks surface tension captures small pockets of gas producing bubbles. I just placed the glass on a counter in a room with one ceiling light illuminating the entire room. I also added a lamp behind and above the camera, which acted as the primary source because it was centralized towards the glass. The camera has no flash.

For my final image, I did not do a close up of just the bubbles but had the whole experiment in the frame. I chose this because I thought it would provide more information and would be easier to understand if you saw the entire contraption.

The distance from the object to lens was about 14 inches. I did not have any zoom on the image I submitted, and the zoom feature on my camera is 18-300 mm. Thus I used a 18mm focal length on a DSLR Panasonic GH4 camera. The sensor size is 4/3. This give the lens multiplication factor equal to 2.0 and the focal length equal to 36 mm (Lens Multiplication, n.d). I was just using the A-setting (aperture) setting on the camera so I have no idea what my shutter speed was, but I would guess pretty fast because there was a lot of light in the room.

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For post processing, I first cropped the image so there were no distracting pieces in the background especially just the excess empty space that is in the original. I changed the curves with the graph below:

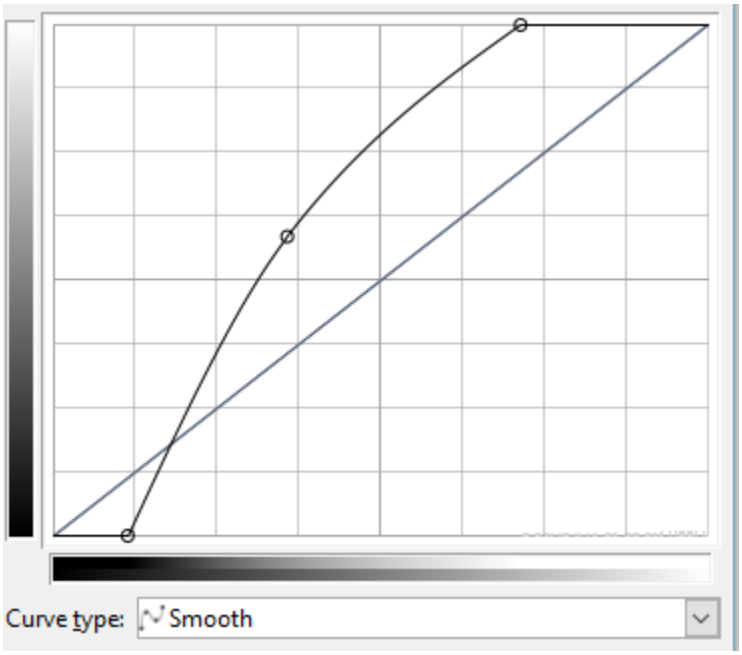

Image 2: Channel on Value, curve change for all RGB

This curve made the blue "pop" out even more to the viewer and also helped clean up the tan background wall that was behind the glass. This made the tan wall white, however the background wasn't completely white in some spots, so I had to go in and color in white over the small parts to produce a crisp background. Below is the before and after (post processing) images.

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Image 3: Original Photo

Image 4: Final Image

Taking the feedback on the website from my peers, I noticed a lot of people enjoyed the crisp background along with the blue “popping” out. Many people said it reminded them of “blue milk shakes.” Some of the complaints, that the focus is a little off, as it seems to focus on the bubbles behind the glass instead of the front bubbles falling out of the top. I agree with this and never really noticed it until I got to post processing. Another issue was the bottom bubbles seemed a little distracting, or “cut and pasted.” In my opinion it does look a little cut and pasted on the right side of the bottom bubbles and that is because I had to go in and paint white spots in that area. I should have been more careful or used another technique. The light on the bubbles are a little distracting to me, so maybe I could have experimented with different positioning of the light source trying to eliminate that effect. Overall I am very pleased with the feedback and the image itself. Maybe in the future you can use different dyes to try and create a very cool affect in the bubbles or focusing strictly on the bubble formation without the glass.

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