GET WET – DROPPING CHEMILUMINESCENT FLUIDS INTO WATER

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ABSTRACT

In this paper we shall look at how the use of a chemiluminescent material obtained from glow sticks were used in conjunction with a jar of water to produce the accompanying picture. The overall desired result was to successfully capture a number of chemiluminescent droplets falling in the water. There were several conditions that improved the overall quality of the picture including the similarity of temperatures of the water and the glow stick fluids as well as the use of multiple colors and proper manual settings on the camera that was used.

Flow Visualization

The use of dynamic motion in photographs has always been interesting to people. This could possibly be due to the fact that the inherent qualities of a still image of a flowing process lends to the imagination of the viewer in such a manner as to make him or her feel like the picture is moving. Flow visualization is the process of making the physics of fluid flows (gases, liquids) visible [1]. In this paper we will explore how the use of a chemiluminescent fluids from glow sticks were used in the picture to capture the dynamic motion of the glowing fluids into the water.

Chemiluminescence

Chemiluminescence is the generation of light that results from a chemical reaction. There are three main types of chemiluminescence which are the following: chemiluminescent reactions, electrochemiluminescent reactions, and bioluminescent reactions. Bioluminescent reactions are reactions that produce light and they come from living organisms such as a jellyfish or a firefly [3]. Electrochemiluminescent reactions are light emitting reactions that take place while an electrical current is applied [3]. While chemiluminescent reactions are reactions that use synthetic compounds and typically involve a highly oxidized species like a peroxide [3]. In a chemiluminescent reaction as the reactants go through the reaction and products are formed the products are in an excited state, and as they go from an excited state to a ground state they release protons. This can clearly be seen in Figure 1

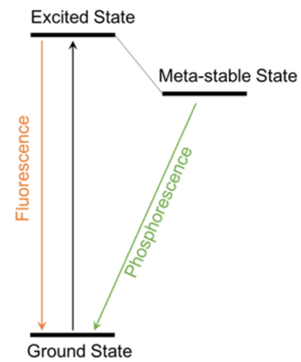

Figure 1: Light Emission from Excited State

For a glow stick like the one that was used in this piece the glow stick contains a diphenyl oxalate and a dye solution and a glass tube that contains a hydrogen peroxide solution [4]. When the glass tube is broken the chemical reaction occurs which creates light, and the dye that is in the diphenyl oxalate solution is what gives the glow stick its' color.

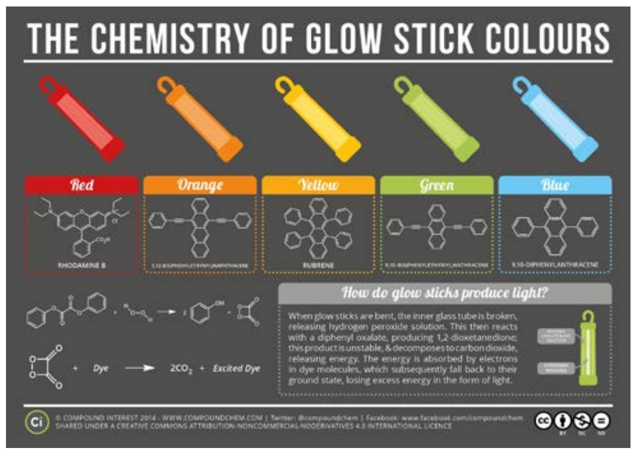

Figure 2: Chemistry of glow sticks

As you can see in Figure 2 each glow stick color has a unique chemical composition that results from the unique diphenyl oxalate and dye solution.

Set Up

To capture the picture a system was set up to establish a flow state that could easily be changed the following set up was utilized.

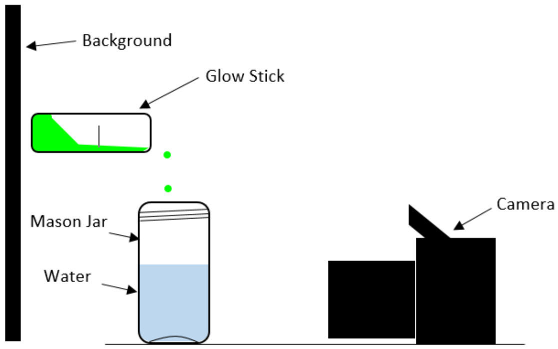

Figure 3: Picture Set Up

First the glow sticks are bent in such a manner that the internal cylinder that is holding the reactant fluids is broken. After this happens the reactants react and produce light. The Mason jar shown in Figure 3 is placed on top of a table that is in a dark room with minimal light being allowed in. The room that was used for this particular picture was ITLL 1B50. In addition to the low light room being used a background that consisted of a black poster board was used to eliminate any possibility of a distracting element from the background. The contents of 4 different colored glow sticks were poured individually into the Mason jar at varying pouring speeds. The pouring of each of the glow sticks were done by my peer Kate Gresh. Contained in the mason jar was approximately 16 oz of luke warm water.

Temperature Importance

The temperature of the water was chosen to be room temperature because the contents of the glow stick were also at room temperature. So the thought at the time was that if we used water that was at the same temperature as the glow stick contents than the droplets that would fall into the water would be more round and this would also minimize the mixing of the glow stick products and the surrounding water that would directly result from heat transfer from the warmer liquid to the cooler one.

$$\dot{Q} = h * A * \Delta T \tag{1}$$

Where $\dot{Q}$ is the rate of heat transfer, h is the convective heat transfer coefficient, A is the surface area and ΔT is the temperature difference between the temperature of the surface of the droplet in water (T_s) and the bulk temperature of the water (T_b). From equation 1 we can clearly see that if ΔT is equal to 0 than there is no convective heat transfer either from the water to the droplet or from the droplet to the water.

$$k = Ae^{-\frac{E_A}{RT}} \tag{2}$$

This equation is called the Arrhenius equation where k is the rate constant, A is the pre-exponential factor, E_A is the activation energy, and R is the gas constant and T is the temperature usually given in kelvin [2]. From this equation we can easily see the direct correlation of temperature to the rate of the reaction. So as the temperature increases, the rate of reaction also increases. This means that for a substance like the chemiluminescence in the glow stick as the temperature of it increases so does the rate of reaction, which results in a decrease in time that the glowing lasts for.

From equation 1 and 2 we can see how important it is for the glow stick chemicals to be at a similar temperature as the water to maximize the reaction time of the chemiluminescence. This reaction time is very important when considering that for this piece is centered around the fact that you are trying to capture as many colors as possible.

Camera Set Up

The camera was also set up in a specific way to capture as many individual droplets falling through the water. The camera that was used in this piece was a Canon EOS Rebel T6 DSLR with an attached 18-55 mm lens, with the camera being place approximately 6 inches away from the mason jar on the table. There were 4 main manual features on the camera that were used to maximize the quality of this picture. These features were the aperture (f stop or f/number), exposure time or shutter speed, ISO, and the exposure bias.

The aperture on a camera refers to the size of the opening in the optics which light passes through to capture an image. The size of the aperture is one of the major factors that affects the depth of field for any given image. With a small f stop the subject stands out and the background is blurred. The aperture stop is typically referred to as the f stop, which is a ratio of the attached lens's focal length to the diameter of the aperture opening. The range of f stops for the camera used ranged from f/3.5 to f/36. For this picture an f/stop of f/5.6 was used which is not particularly small but did allow an adequate amount of light into the camera.

The shutter speed, also referred to as the exposure time, is the amount of time that the shutter is open when taking a given picture. This is important when considering whether the desired target is moving at a fast or slow pace. For fast moving objects like a falling droplet a relatively fast shutter speed is helpful. The range of shutter speeds on the camera used went from 1/4000 to 30 seconds. However, one drawback of utilizing a faster shutter speed is that it lets less amount of light into the camera. For this reason, a shutter speed of 1/50 of a second was used to balance the levels of light as well as the speed of the falling droplet.

The ISO sensitivity refers to how sensitive the camera film or in the case of a DSLR how sensitive the sensor is to the incoming light. ISO stands for International Standards Organization and this value just refers to how sensitive the sensor is to a given value of incoming light. For the camera that was used the range of the ISO sensitivity went from 100 to 6400. This value is extremely important when taking pictures at low level light conditions like the one in the case of this picture where the only light coming into the camera is coming from the chemiluminescent material. To maximize the amount of light that was coming in to the camera an ISO 6400 was used. One drawback of using such a high ISO is that it can sometimes give a grainy resolution, but for such a low level light condition the graininess wasn't a concern.

The final manual feature that was used was the exposure bias, which refers to the feature that allows the user to manually adjust the exposure that is measured by the camera's light meter. On the camera that was used to take the picture this ranged from -3 to 3, but an automatic setting was used. This is because on an artistic approach I as the artist didn't like what the over exposure and underexposure results were.

DISCUSSION & CONCLUSION

The desired result of capturing a number of chemiluminescent droplets falling in water was for the most part successful. While the sharpness of the droplets is what I as the artist would have desired, the use of multiple colors in conjunction with a dark background made for a drastic contrast between each of the colors and the background. In future iterations of this work one improvement that could be made is to use higher quality glassware over Mason jars because some of the blurriness in the image is due to the imperfections that are inherent in the Mason jar glass. Another possible improvement would be to explore in more depth with using a colder temperature glow stick and water. As mentioned earlier the temperature of the reaction plays a very important role in the rate and ultimately the reaction time that the glow sticks will glow.

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