Fire and Lightning: Lichtenberg Figures in Wood

Figure 1: Final, edited image

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Introduction

This image was produced for the Team Second assignment for the Fall 2015 Flow Visualization course offered in the University of Colorado School of Engineering. The objective of the assignment was to produce an aesthetically appealing image that captures a unique physical phenomenon that can later be analyzed. The intent of the experiment behind this image was to examine the dynamics of electrical current as it flows through a dielectric material. In other words, what happens when wood is soaked with water and baking soda and has 2000V of electricity run through it?

The image shown on the cover page in Figure 1 is a composition of two separate photographs. They were taken during the afternoon of October 29th in cooperation with Rachel Grosskrueger.

Experimental Methodology and Observations

The setup for this experiment was relatively straightforward. A saturated solution of water and baking soda was applied to a small board of pine wood with a sponge. Two nails were inserted at opposite ends of the board, as shown in Figure 2, and were then connected to the output leads from a high voltage microwave transformer. The transformer steps the standard 120V AC from the wall outlet to approximately 2000V AC output. This high voltage makes it easier for the electricity to travel across any given path, so meticulous safety precautions were taken to avoid contact with that path, as a shock can be lethal. The setup was only adjusted when the power was completely off. Power was only turned back on when both experimenters were completely clear of the setup. Goggles and gloves were also worn to help prevent any accidents.

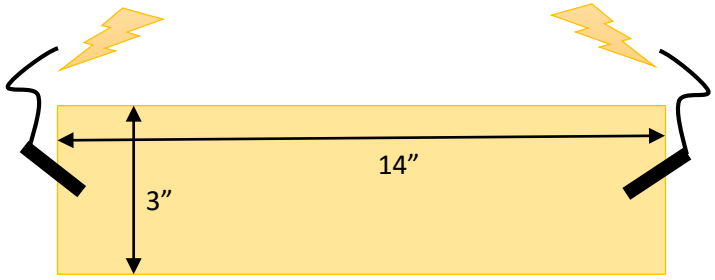

Figure 2: Schematic of experimental setup

After a few trial runs, some issues with the setup were ironed out. One of the main problems was that the board was originally laid horizontally on the concrete garage floor and, incidentally, the high voltage transformer was also sitting on the concrete which served to ground both objects and interrupt the desired circuit. It worked better to set the board vertically on a pair of wood blocks to insulate it from the floor. Occasionally the board needed to be re-wet with the sponge, but this was simply a matter of turning off the power and reapplying the solution.

The primary phenomena being observed are Lichtenburg figures. Named after German physicist Georg Lichtenberg, the figures are the result of branching electric discharges that appear on the surface or interior of insulating materials. They are now known to occur on solids during electrical breakdown.[1] A paper from the *Journal of Electrical Systems* identifies the breakdown voltage of plywood to be 3580V.[2] Using this experimentally obtained value as a rough analogue to the wood used to make these Lichtenberg figures, it is not difficult to see how soaking the wood with an electrolytic solution would reduce its breakdown voltage to under 2000V.

The phenomenon of the electrical “fingers” branching across the wood resembles that of a lightning strike occurring in slow motion. While this comparison is not entirely accurate, since lightning is a direct

current and the figures in this experiment were produced with alternating current, many general principles remain the same. As was shown during the experiment, streamers of electric charge emanated from both contact points within the wood. They grew steadily toward each other, branching out in various directions in accordance with subtle, seemingly random changes in resistance. In general, the fingers appear to follow paths along the grain of the wood as shown in Figure 3 below. This phenomena could be explained by the vascular structure of the wood. That is to say the grain of the wood is a result of the tree's xylem, which is used to transport water via capillary action.[4] These channels probably help to wick the electrolyte solution through the wood, making those paths more conductive to the electricity.

Figure 3: Close up time lapse of Lichtenberg figure growth

An interesting phenomenon that was observed during the process is that once the two trees of electricity met in the middle, the current continued to flow even though the wood had completely dried out and caught fire. If the electricity was cut off, the flames would stop. They would reignite if the electricity was then turned on again shortly after. This flow of electrons, despite the electrolyte being dried out, may be due to the conductive nature of the charred carbon. This charred material (soot) may also be responsible for the arc of fire that was captured in the final image, allowing the electrical current to briefly follow a path of least resistance through the air.

Visualization Technique

The board used in this experiment was taken from a wood pallet. It is a softwood, probably pine. The electrolyte solution was made of tap water that had been saturated with sodium bicarbonate (baking soda) which was transferred to the wood by using a kitchen sponge. The transformer was pulled from a 1200W microwave oven and is estimated to produce an output of 2000V. Banana cables, alligator clips, and nails were used to transmit the output voltage through the board.

Photographic Technique

The field of view was intended to capture the majority of the board, with emphasis on the fingering of the Lichtenberg figures as well as the rising flames. The photo was captured using a 55mm diameter lens with a focal length of 45mm, doubled to 90mm with an adapter, and has an image size of 4592 x 3056 pixels. At a distance of approximately two feet from the setup in order to achieve the appropriate field of view, the field of view is roughly 12" wide by 8" high. It was captured using a Sony DSLR-A290 which was adjusted to the following settings: aperture = f/20, exposure time = 1/80 sec, ISO speed = ISO-400. Natural, indirect daylight was used to illuminate the image. These settings were chosen, respectively, to increase the field of focus as much as possible to account for the angle of the camera, to freeze the

motion of the flames, and to increase the exposure since the previous two settings significantly dropped the light level. One of two raw images used to make the final composite is shown below in Figure 4 (left). The two original images are almost identical, excepting a slight difference in time and focus, which made their composition fairly simple, even with only a little Photoshop experience.

Figure 4: Comparison of before editing (left) and after (right)

Figure 4 also shows the corresponding final image (right), after processing. A series of edits were made to improve the aesthetics of the image and the ability to visualize the flow. Mid-tone contrast was increased to improve the clarity of the wood and considerable care was taken to create a deep black background while also maintaining the natural look of the flames.

Critique

Ultimately, this piece effectively captures a number of interesting flow characteristics and provides a pleasing aesthetic experience. Not only is the electrical flow captured indirectly via the burning of the wood grain, and directly where it is actively sparking, but the flow of the flames adds another dimension to the whole experiment. The composition of the two images was not flawless, as Figure 4 shows a loss of the lighting that the flames provide. And while the soft focus of the leftmost flames was unavoidable in this case, the editing of the background really helps to bring an artistic emphasis to the subject of the wood and flames.

Unfortunately, since the images were taken based upon a more aesthetic impression, they are lacking in data resolution which is necessary for more precise analysis. In order to further investigate these phenomena, the experiment could be repeated with a variety of standardized camera angles, along with more controls to electrolyte concentration, voltage/current readings, and wood type might all help to enhance the amount of information that can be obtained.

Bibliography

[1] https://en.wikipedia.org/wiki/Lichtenberg_figure

[2] http://journal.esrgroups.org/jes/papers/8_2_8.pdf

[3] http://regentsprep.org/regents/physics/phys03/alightnin/

[4] https://faculty.unlv.edu/landau/wood.htm