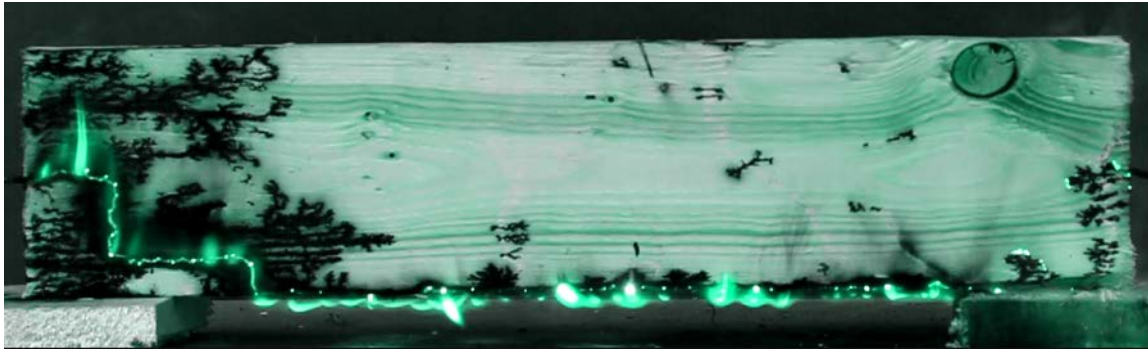
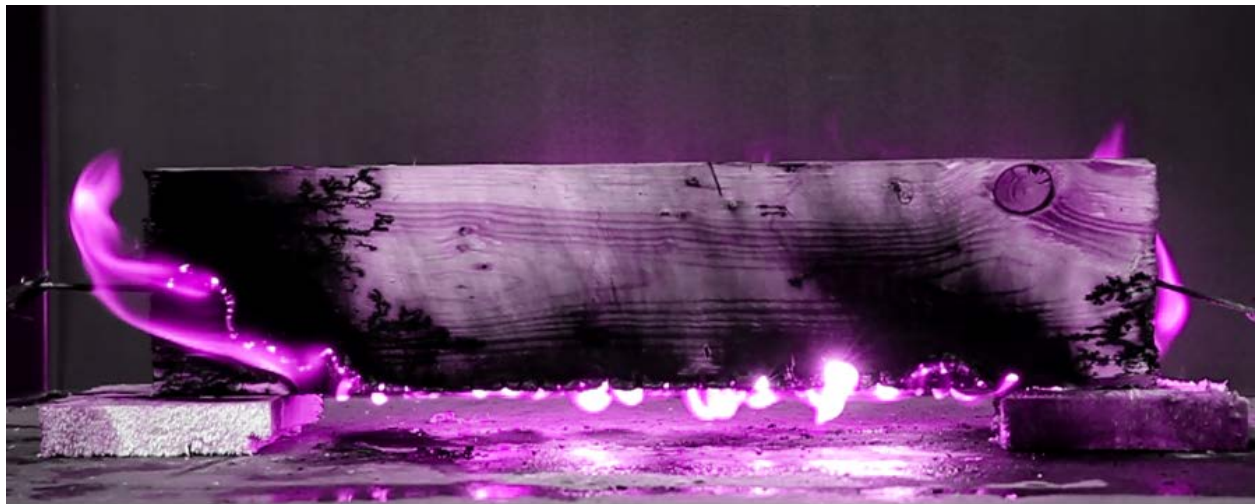


Visualizing the Interactions Between a High-Voltage Transformer and an Electrically Conductive Surface



<https://vimeo.com/144305447>



Rachel C. Grosskrueger
Professor Jean Hertzberg
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1. Introduction

The intent of this video was to show the interactions between a high-voltage transformer and an electrically conductive surface, specifically to show the phenomena of the Lichtenberg fractals. The discovery of this phenomena dates back to the late 1700s by the German physicist Georg Lichtenberg, but with two-dimensional dust figures. These figures would form when dust in the air settled on the surface of electrically-charged plates creating the tree-like branching figures shown in the video. Lichtenberg further developed his experiments to demonstrate the effects of positively charged particles and negatively charged particles depositing on the electrically charged surfaces. The positively charged high-voltage figures resembled that of the ones seen in the video. To replicate this phenomena, a high voltage transformer is needed along with a wood beam covered in an electrically conductive solution. Wood by itself is not electrically conductive and therefore would not produce the effect when connected to the transformer. Thus, the need for an ionically bonded solution is necessary to allow the current to flow across the surface of the wood beam. The necessity for an ionically bonded solution is that it increases the conductivity of the solution due to ionization, which is ideal for this setup over a covalently bonded solution which does not increase the conductivity. Examples of the desired solutions would be a mixture of water and any of the following: table salt, Epsom salt, and baking soda which was used in the video. The high voltage transformer can be plugged directly into a standard house outlet and wired to the saturated wood beam. Once power is allowed to pass through the transformer, the Lichtenberg figures can be observed “crawling” across the surface of the wood and smoldering as the wood is charred. An interesting effect associated with this phenomena is that once the figures stemming from the anode and cathode connect, the result is a flame that burns through the main veins in the figures as seen in the video. The wood is not burning, but rather the charge is connected resulting in combustion. This is demonstrated in the end of the video when the power is turned off and the flame instantly dies rather than allowing the wood to keep burning. With the help of Vincent Staverosky, the video was able to capture the stages of the Lichtenberg fractals and the interactions between the high-voltage transformer and the electrically conductive surface.

2. Methods and Discussion

To achieve the phenomena captured in the video, the high-voltage transformer used was a 2,000 volt transformer obtained from a microwave oven provided by Vincent. The transformer was plugged into a power strip with a built in circuit breaker which was plugged into a regular 120 volt house outlet. The transformer was then wired to the wood plank using insulated banana cables with alligator clips at the ends, provided by Rachel Grosskrueger. The alligator clips were clamped around two nails at each end of the wood plank. These nails were on the side of the plank, not on the face as shown in the second cover image representing the video. The nails were centered and half an inch into the side of the wood. The wood originated from a salvaged wood pallet from a dump site and pulled apart using the blocks as lifts in the video and one of the horizontal planks for the surface. The nails used also originated from the wood pallet. The ionic mixture was a supersaturated mixture of baking soda, purchased from Safeway, and water. The ratio was approximately one to one for the mixture. The solution was applied using a sponge to “paint” the top surface and sides of the beam with a thick even layer and allowed to soak in and dry ten minutes prior to the activation of the transformer. The shell of the microwave oven was used as the backdrop for safety purposes and aesthetics. The video was shot on the concrete floor in Rachel’s

garage just at the opening of the garage. Figures one and two shown below, offer a visual representation of this setup.

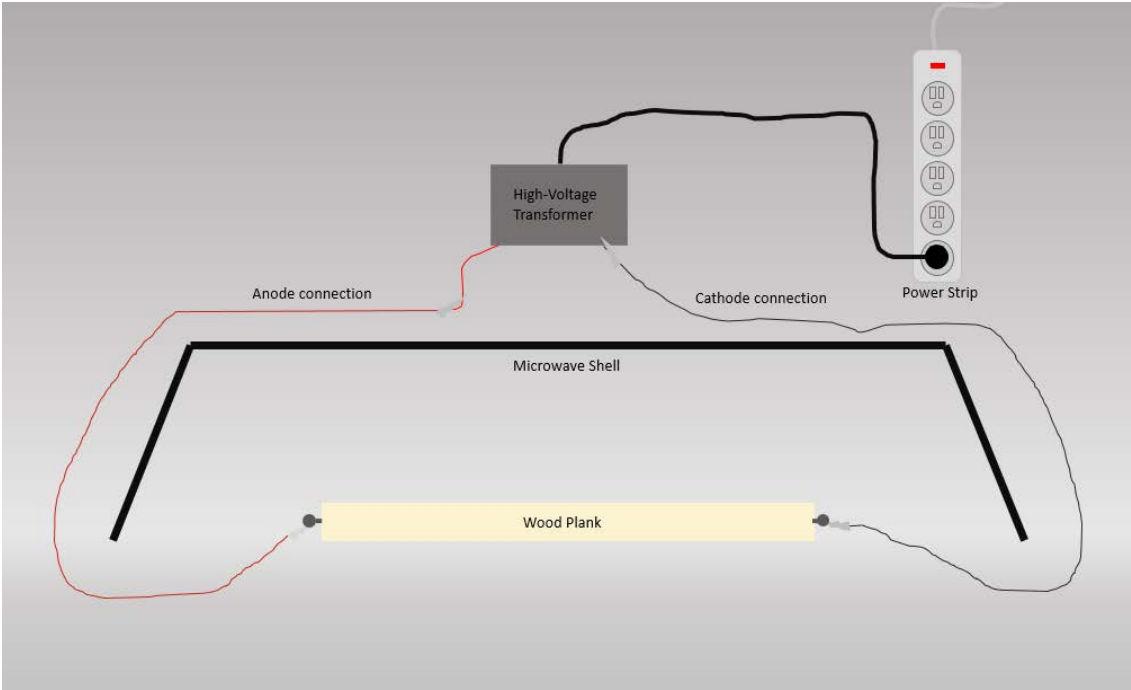


Figure 1: Schematic of setup

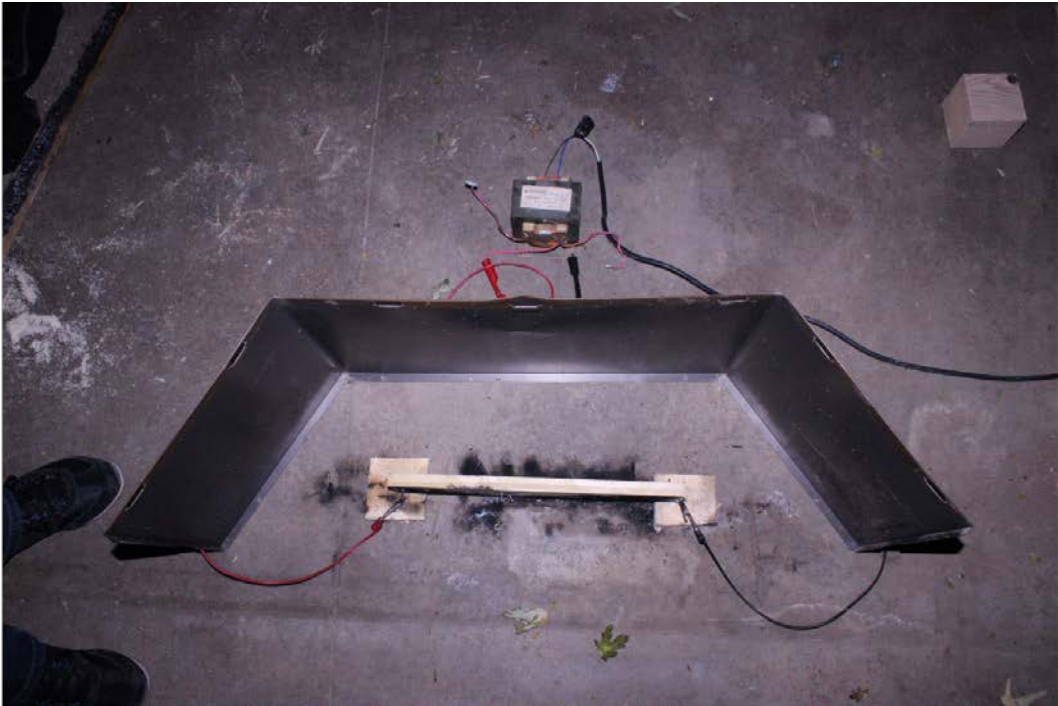


Figure 2: Image of actual setup

The camera was approximately two feet from the setup and placed on a two inch platform. The wood plank used was twenty two inches long, one inch wide, and four inches high. The platform blocks were one inch high, three inches wide, and three inches long. The figures themselves varied from quarter of an inch squared to roughly twenty two inches squared depending on the location on the beam. The flames also varied in this same manner and reached up to a foot in height (seen in the flames behind the plank).

The flow of the figures seemed to take a path with the least amount of resistance as seen when the figures on the left side went along with the grain. This was also demonstrated on the right side where the figures traveled across the bottom of the plank where the largest concentration of the ionized solution was, due to the effects of gravity. This is the reasoning behind the flames appearing to burn on the back of the plank. Instead the flames were splitting direction between the front and the back but were still formed at the main Lichtenberg vein along the bottom of the plank. The back of the plank was slightly charred from direct contact with the flames, but the wood on the back side was never on fire. To further prove this point, a four inch section was sawed off from the plank used in the video and shown in figure three below.



Figure 3: Piece sawed off from original plank used

The interior and back side of the wood never burned, only the areas where the fractals connected could ignite. This image also reveals that the fractals could only form on the surface of the wood since that was the only area that was conductive. As stated previously, the flames were caused from the contact between the Lichtenberg figures on the left and right side of the plank resulting in the flame demonstrated in the video at exactly 1.00 minute. The video also demonstrates the numerous arcs of flames jumping the gap between other smaller Lichtenberg figures forming on the surface of the plank, allowing them to connect in the same manner as first demonstrated. This can be observed near the nails in the plank at times 1.39.27 and again at 2.21.68. Additional arcs were formed to connect the front face of the plank to the sides of the plank that were also painted over with the ionized solution allowing more Lichtenberg figures to form outside the scope of the camera. Some of these figures also would connect to the main vein and displayed the same behavior. The flames at times would wrap around to the back side of the plank furthering the illusion that the plank was on fire. This would happen due to several factors: the breeze itself, the flow of air around the bends in the microwave shell, and from the figures still forming along the

width of the plank connecting to that main vein. The air flow behind the plank is what caused the flames on the left side to bend backward pulling them in with the pressure difference created. Many other flow features were demonstrated in the video such as through the smoke at the end of the video, but the main focus was on the interaction between the transformer and the surface itself with the resulting fractals and flames.

3. Visualization Technique

The visualization technique used was intended to bring out the detail in the fractals and the flames by using a dark background with a bright wood color. The lighting used was natural sunlight at 1215 on 29 October 2015. When the setup was illuminated by indoor lighting, the contrast in the figures was lost, thus sunlight was found to be the best source of lighting to fulfill the desired intent of the video. The Lichtenberg figures formed and burned at a bright enough level that they were not washed out by the sunlight.

4. Photographic Technique

The video recording technique was intended to decrease motion blur and focus on the detail of the figures and flames as well as accentuate the contrast of the figures, flames, wood, and background. Thus, to achieve this, the camera settings of the Canon EOS REBEL T3i were adjusted to be at 60 frames per second, auto exposure, movie recording size of 1280 x 720, auto lighting optimizer, focal length of 35mm and 39mm, and manual focus. This allowed the camera to continuously adjust to the irregular lighting created by the fractals and the flames as well as when the flames dispersed. The size of the field of view was twenty three inches wide by twelve inches high at the beginning of the video, and twenty seven inches wide by sixteen inches high at the end. The panned out look allows for further visual understanding of the setup including the nails and the alligator clips. The plank was approximately two feet from the lens of the camera.

The video editing was performed in Windows Movie Maker 6.0 with the intent to bring out as much detail and contrast as possible while creating a beautiful and interesting video for viewers. To accomplish this, the hue, cycles entire spectrum effect was added to allow potential for more detail to be exposed by the various colors. The movie was also slowed down to half speed to allow more time for the viewer to process the fractal flow and the phenomena occurring. The original score in the video was composed by Daniel Morrison, specifically for this video. The original video for obvious reasons, could not be included in this report but an image extracted from the original video can be seen below in figure four.



Figure 4: Still from original unedited video

A copy of Daniel's score can be found at <https://soundcloud.com/color-blind-pilots/lich-frac>.

Conclusion

This video does an amazing job of revealing the behavior of Lichtenberg fractals from start to finish. It demonstrates the flow of the fractals all the way through combustion and termination with many flow phenomena occurring. The coloring effect helps clearly reveal the grain patterns in the wood, the flames burning on the wood, the flames reflecting off the surface of the ground, and the smoke at the end which are all very vividly detailed with this effect. Slowing the video down to half speed allows for a greater understanding of the phenomena and for more details to be noticed. The only setback to the half speed effect, it the length of the video was doubled and is arguably unnecessarily long. Not all frames are needed to demonstrate the phenomena occurring but the extra frames do allow more colors to cycle through the video in turn allowing more potential detail to be exposed. A recommendation for further development of this phenomena would be to compare the fractal formations side by side with a plank of wood of differing composite or a different ionic solution applied to the surface such as salt water.

The link to the final video is: <https://vimeo.com/144305447>

5. References

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