What are Lichtenberg Figures and how are they created?

Lichtenberg Figures are branching, tree-like patterns that are sometimes formed on the surface or within the interior of insulating materials by high voltage electrical discharges. The first Lichtenberg Figures were two-dimensional patterns formed in dust on charged insulating plates by the German physicist who discovered them, Georg Christoph Lichtenberg (1742-1799). The principles involved in the formation of these early figures are also fundamental to the operation of modern copy machines and laser printers. Using modern materials and powerful particle accelerators, beautiful 3-D Lichtenberg Figures can now be created inside clear acrylic, creating lightning sculptures.

We use acrylic (Polymethyl Methacrylate or PMMA) to make our Lichtenberg Figures, since it has an ideal combination of optical, electrical, and mechanical properties. We also use a linear accelerator (LINAC) to create a beam of high-speed electrons. Electrons in the beam are accelerated to as much as 99.5% of the speed of light. These “relativistic” electrons have a very large amount of kinetic energy, measured in millions of electron Volts (MeV). Polished acrylic specimens are placed in the path of the beam. As speeding electrons hit the acrylic surface, they don’t stop immediately. Instead, they collide with acrylic molecules, rapidly slowing down, and eventually coming to rest deep within the acrylic.

As we continue to irradiate the specimens, huge numbers of electrons accumulate inside, forming an invisible cloud-like layer of excess negative charge. Since acrylic is an excellent electrical insulator, the excess electrons are trapped within the charge layer. The growing charge creates very strong electrical stresses inside the plastic, similar to the way that regions of excess charge grow within clouds in a thunderstorm. If the electrical stress becomes too large, it overcomes the insulating strength of the plastic, and branching ionized (electrically conductive) pathways rapidly form within the acrylic in an irreversible process called electrical breakdown. The excess charge violently escapes, creating a brilliant blue-white flash of miniature lightning and a loud bang. The high current main discharge may last for less than 100 billionths of a second, but secondary discharges may randomly occur for 30 seconds or more afterwards.

Electrical breakdown occurs on a much grander scale during a lightning flash as a powerful electrical discharge drains highly charged regions within storm clouds. However, unlike sparks in air, the discharge paths within acrylic leave a permanent record of their passage as they melt and fracture the polymer along the way. It is no accident that the branching discharge paths in the acrylic look similar to a miniature lightning bolt — the breakdown processes are similar. The exit point of the discharge appears as a small hole at the surface of the acrylic. The hot discharges sometimes cause heavier fracturing and slight charring near the exit point. We try to charge the blocks so that they are just below the point where they’ll self-discharge. We then manually trigger the discharge where we want by poking the surface of the acrylic with a sharp tool. This must be done very carefully, since the stored charge in the acrylic can deliver a very powerful electrical shock. Poking the acrylic concentrates the electrical stress at the tip of the tool, triggering the discharge process at that point. The rounded, crystalline flakes appearing within the figure are actually small conchoidal fractures that are created by the hot electrical discharge as they force their way through the acrylic. These fractures are characteristic of the way that amorphous (non-crystalline) materials fracture when mechanically overstressed.

Every Lichtenberg Figure is unique. Most Lichtenberg Figures exhibit tree-like or fern-like structures that possess a high degree of self-similarity at various scales of magnification. The figure’s self-similar structure can be modeled by a branch of mathematics called Fractal Geometry. The outer surfaces of the acrylic specimen and the surrounding air form an interface where some of the excess charge can leak away. The region of reduced charge causes the blank region seen along the perimeter of most Lichtenberg Figures. Your Lichtenberg Figure was created by an electron beam with an energy of 3 to 5 million electron volts. Beam current, acceleration voltage (energy), and dosage are all carefully adjusted to produce centered, well-developed figures. Illuminating your figure with a commercial LED light base will cause the figure within to glow brightly with the colors of the LED’s. This will significantly enhance its appearance and highlight even the finest paths.

New Lichtenberg Figures usually have an amber tint, called solarization. Solarization appears on the side of the block that was directly hit by the electron beam. It is thought to be caused by the formation of defects, called color centers, within the acrylic structure as the molecules absorb ionizing radiation or are modified by electron collisions. The ionizing radiation is not from the electron beam, but is actually caused by powerful X-rays that are generated as the electrons are rapidly slowed down by the acrylic. Electrons within the beam are initially traveling at almost the speed of light when they hit the surface of the acrylic. As they collide with the acrylic molecules, they rapidly slow down, releasing their kinetic energy in the form of high energy X-rays which are absorbed by the acrylic. This secondary X-radiation (called Bremsstrahlung or “braking” radiation) is responsible for causing most of the solarization. Solarization usually fades with time, and applying gentle heat accelerates the fading process. Many specimens also show slight changes in the refractive index due to residual stresses near the discharge fractures. For more information, search for “Lichtenberg Figures” on Google or on Wikipedia.

http://en.wikipedia.org

Caring for your Lichtenberg Figure

Acrylic is soft and easily scratched. With care, your lightning sculpture will remain beautiful for many years. Dust carefully using a dampened flannel cloth. Remove fingerprints using mild detergent and water, then rinse well and blot dry using a damp flannel cloth. Never wipe your sculpture with dry paper towels or Kleenex tissues, since these will scratch the surface. Never apply window cleaners containing ammonia, solvents, or scouring compounds, since these can permanently damage your sculpture. To restore your sculpture’s original luster, use a soft cloth and a polish specifically made for acrylic, such as Novus #2 from Novus Plastic Polish, Ltd. If your specimen should develop heavier scratches, use Novus #3 Heavy Scratch Remover first, then polish to a high luster using Novus #2.

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