What are Lichtenberg Figures and how are they produced?

Lichtenberg Figures are patterns that are formed on the surface or inside insulating materials by high voltage electrical discharges. The first Lichtenberg Figures were actually two-dimensional patterns formed in dust on a charged plate in the laboratory of their discoverer, Georg Christoph Lichtenberg (1742-1799), a German physicist. The basic 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, 3-D Lichtenberg Figures can now be created inside clear plastic blocks, permanently forming beautiful "Captured Lightning ™".

Acrylic plastic (Polymethylmethacrylate - PMMA) is used as the medium for our Lichtenberg Figures because it has an excellent combination of optical, dielectric, and mechanical properties. A linear accelerator (LINAC) is used to produce large numbers of high-speed electrons - a high-energy electron beam (e-beam). Electrons in the beam are accelerated to up to 99.5% of the speed of light. These "relativistic" electrons have acquired a very large amount of kinetic energy (measured in Millions of Electron Volts or MeV). Specially selected and prepared pieces of acrylic are placed in the path of this electron beam. As the energetic electrons in the beam hit the surface of the acrylic, they don't immediately stop. Instead, they collide with the molecules of acrylic, slowing down and coming to rest deep inside the block.

Under continued irradiation, electrons rapidly accumulate inside the acrylic, forming a layer of excess negative charge called a space charge. Since acrylic is an excellent electrical insulator, the electrons are trapped, unable to escape. A huge electric field of up to 2 million volts/cm is developed inside the plastic, similar to the way that regions of excess charge are developed within clouds in a thunderstorm. The tremendous electrical stress finally overcomes the insulating strength of the plastic, forcing molecular bonds to break, forming ionized (electrically conductive) paths within the acrylic. The excess charge violently surges out of the acrylic, accompanied by a brilliant blue-white flash and a loud bang. The branching conductive discharge paths look like a miniature lightning bolt. The high current discharge may last for only 20 – 50 billionths of a second, and smaller secondary discharges may occur for up to 30 seconds after the main discharge.

Electrical breakdown occurs on a much larger scale during a lightning flash as the powerful discharge drains highly charged regions within storm clouds. However, unlike discharge in air, the discharge paths taken within the acrylic leave permanent records of their passage as they melt and fracture the plastic along the way. The exit point appears as a small hole at the surface of the acrylic. If the block doesn't self-discharge, a discharge may be triggered by poking the surface of the plastic with a sharp conductive object. This concentrates the electric field, creating a weakened area which starts the discharge process. The rounded, crystalline flakes appearing within the figure are actually small concoidal fractures that are created by the electrical discharge as it passes through the plastic. These fractures are characteristic of the way that amorphous (non-crystalline) materials break when mechanically overstressed. Like snowflakes, every Lichtenberg Figure is unique.

Lichtenberg Figures usually exhibit tree or fern-like structures that possess a high degree of self-similarity at various scales of magnification. As with many other phenomena in nature, this self-similar property can be modeled by a branch of mathematics called Fractal Geometry. The outer surface or edge of the acrylic sample and the surrounding air form a dissimilar dielectric interface where some of the excess space charge can leak away. This region of reduced charge causes the blank region seen along the perimeter of the block. Our Lichtenberg Figures were created with electron beams having energies of 3 - 5 MeV. Beam parameters are adjusted to produce well-developed figures in each block.

New Lichtenberg Figures have an amber or greenish tint, called solarization. Solarization appears on the side of the block that was bombarded by the electron beam. It's caused by the formation of defects, called color centers, within the structure of the acrylic as the polymer molecules absorb ionizing radiation. The ionizing radiation is not from the electron beam, but is actually from the electromagnetic (X-ray) radiation that comes from electrons as they are rapidly slowed down by the acrylic. The electrons within the beam are initially traveling close to the speed of light as they first hit the surface of the acrylic. As they collide with the molecules of the plastic, they rapidly slow down to zero velocity within a fraction of an inch. As they slow down, the electrons release their kinetic energy in the form of X-rays, which is absorbed by the acrylic. It's this secondary X-radiation, called Bremstrahlung or "braking" radiation, which actually solarizes the acrylic. Solarization usually fades with time. Applying gentle heat or sunlight will accelerate the fading process. "Fogging" may sometimes occur with older plastic formulations, forming a diffuse milky layer within the plastic.

Stoneridge Engineering is proud to offer the very best Lichtenberg Figures in the world!

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