FORTY YEARS OF DEEP DIELECTRIC CHARGING
A Random Walk Through the Physics of Space Charge

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This work is archived as a full paper in A. R. Frederickson, "Progress in High-Energy Electron and X-Irradiation of Insulating Dielectrics," Brazil Journal of Physics 29, 241-53, June, 1999. Please refer to it for a more complete description of the last forty years of deep dielectric charging. Along with selections from that paper, the following briefing charts were presented at the 1998 Spacecraft Charging Conference, Hanscom Air Force Base, MA, USA.

HIGH VOLTAGE INSULATORS

Breakdown Strength

1. Not a property of the material but a property of interfaces and flaws.
2. Breakdown Occurs at 500 V/mil or 20 kV/mm in most thick insulators only after years of service.
3. One can achieve breakdown strength of 5 kV/mil (or 200 kV/mm) for years by using thin “flawless” insulators.
4. Breakdown occurs when plasma streamer forms, typically at local field concentration > 200 kV/mm.
5. Streamer formation is a mystery, like atmospheric lightning. Streamer formation is most rapid at the tip of a conductive needle.

Breakdown Concepts

1. True material breakdown occurs when the electric field strips outer valence electrons from each atom faster than the valence bonds can reform (roughly 1-V/atom).
2. Practical breakdown occurs when a streamer forms and propagates across the insulator (typically 0.1 V/atom average field).

RADIATION TRANSPORT IN MATERIAL

Several fields of study encompass the question "Where does the radiation go/stop?"

Dosimetry and Patient Treatment for Medicine
Material and Biology Processing by Irradiation
Radiography
Electron Microscopes, SEM, Electron Microprobes
Nuclear Reactors and Weapons
High Energy Physics, Astrophysics

EXPERIMENTAL MEASUREMENT OF THE CONCENTRATION OF TRAPPED CHARGE

Laser-induced Pressure Pulse
Mechanical/Acoustic Shock Wave
Thermal Step Wave
Other Names Encompassing the Same Concepts
Most of these reports are in the recent 20 years IEEE Transactions Electrical Insulation

DEVICE APPLICATIONS of Deep Dielectric Charging

Electret Microphones
Compton Diode Intense Radiation Detector
Thermally Stimulated Current Dosimeters
Frozen Lightening Decorative Art
Electrostatic Flue Gas Precipitators
Spark Ignitors (polarization)

WHAT IS LIGHTNING? (10^4 to 10^6 Amperes)

AT THE MUSEUM OF SCIENCE:

A Streamer in air between metallic electrodes. Conduction in the electrodes delivers large quantities of charge that flow easily in the streamer.

IN THE ATMOSPHERIC STORMS:

A cooperative phenomena amongst an initial streamer and many small streamers or glow discharges which spread out to gather charge from a large region of the atmosphere. The charges gathered by the many small streamers, and by the glow, deliver current to form the main streamer.

With deep dielectric charging we have diffuse charge throughout solid insulators. The streamers that do form gather only a small fraction of that charge. But the streamers provide a source of highly-mobile gas molecules, ions and free electrons, all of which can respond to electric fields and generate large currents.

IMPORTANT REMAINING PROBLEMS

Secondary Electron Emission From Insulators
Dark Conductivity of Insulators-in-Vacuum
Conduction Properties of Plasma Gas Burst
Spatial Evolution of Gas Burst
Mechanisms Other Than Streamer Gas Burst
Modeling of Discharge Coupling to Circuits
Determination of Voltage at Insulated Internal Surfaces
How to Prevent Burst into Vacuum
What pulses are generated by the internal streamer alone?
Guidelines for Safe Systems if an Event Occurs