Physical Sciences

Ferroelectric Devices Emit Charged Particles and Radiation

Compact, lightweight, low-power sources could be useful in numerous applications.

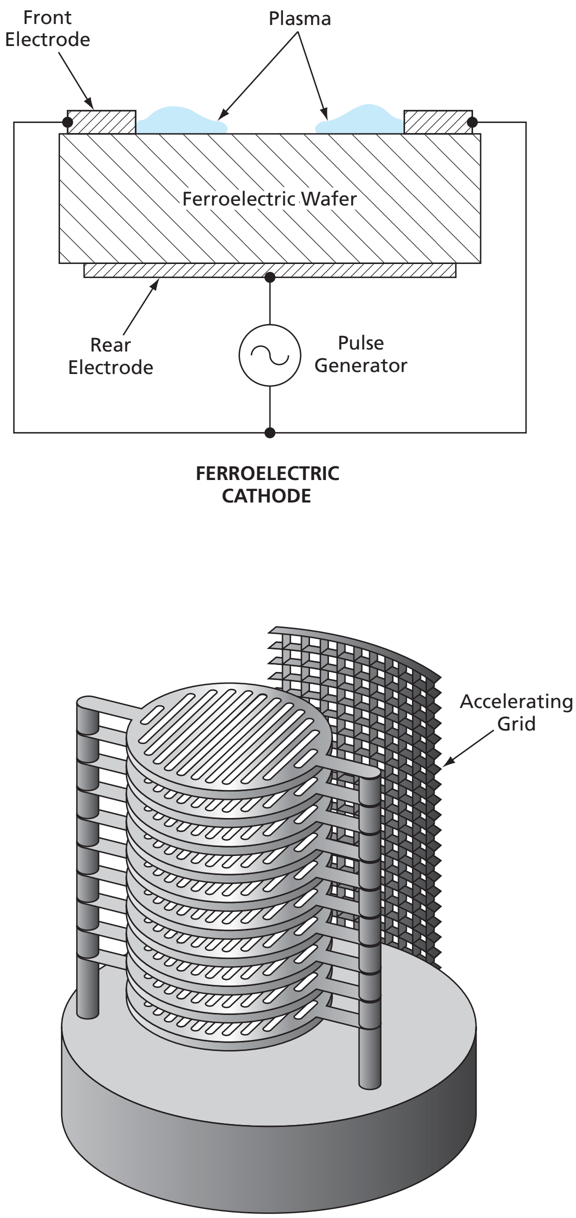
NASA's Jet Propulsion Laboratory, Pasadena, California

Devices called "solid-state ferroelectric-based sources" (SSFBSs) are under development as sources of electrons, ions, ultraviolet light, and x-rays for diverse applications in characterization and processing of materials. Whereas heretofore it has been necessary to use a different device to generate each of the aforementioned species of charged particles or radiation, a single SSFBS can be configured and operated to selectively generate any of the species as needed using a single source. Relative to comparable prior sources based, variously, on field emission, thermionic emission, and gaseous discharge plasmas, SSFBSs demand less power, and are compact and lightweight.

An SSFBS exploits the unique physical characteristics of a ferroelectric material in the presence of a high-frequency pulsed electric field. The basic building block of an SSFBS is a ferroelectric cathode — a ferroelectric wafer with a solid electrode covering its rear face and a grid electrode on its front face (see figure). The application of a voltage pulse — typically having amplitude of several kilovolts and duration of several nanoseconds — causes dense surface plasma to form near the grid wires on the front surface.

The shape of the applied voltage waveform determines the characteristics of the emitted charged particles and radiation and can be tailored to maximize the yield of electrons or ions. For example, one could utilize bipolar pulsing and/or a succession of pulses with different time intervals between them. Although the parameters of the surface plasma do not depend strongly on the polarity of the voltage, it is preferable to apply negative pulses to the rear (solid) electrode while keeping the front (grid) electrode at ground potential.

The plasma generates intense visible and ultraviolet light. If a grid is placed at a suitable short distance near the front face and a synchronized positive voltage pulse is applied to this grid, then electrons are extracted from the plasma and accelerated toward and through the



A **Ferroelectric Cathode** is the basic building block of an SSFBS. To enhance performance, one could construct an SSFBS containing an array of multiple ferroelectric cathodes electrically connected in parallel, possibly in combination with one or more accelerating grid(s). The array and/or the grid(s) could have any of a large variety of shapes.

grid. The resulting electron beam can be aimed at a target. The impingement of the energetic electrons on a suitable target can be utilized to generate x-rays. Another option is to pulse an accelerating grid negative with respect to the front face so as to extract and accelerate positive ions.

Typical parameters of an optimized design for a basic SSFBS include a ferroelectric-plasma area of 10 cm^2, operating pressure of about 10^{-2} torr (about 1.3 Pa), pulse-repetition frequency of 20 Hz, electron or ion current up to 10 A under an accelerating pulse of 30-kV amplitude and 50-ns duration.

This work was done by Yoseph Bar-Cohen, Stewart Sherrit, Xiaoqi Bao, Joshua Felsteiner, and Yakov Karsik of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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Dusty-Plasma Particle Accelerator

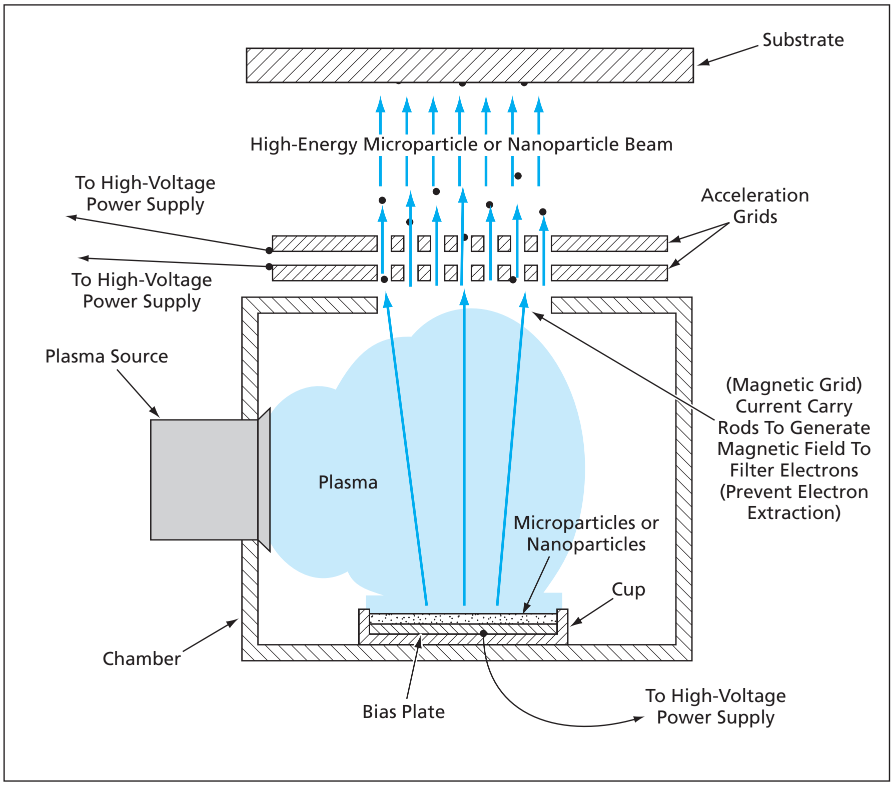
Microparticles and nanoparticles can be accelerated to controllable kinetic energies.

John H. Glenn Research Center, Cleveland, Ohio

A dusty-plasma apparatus is being investigated as means of accelerating nanometer- and micrometer-sized particles. Applications for the dusty-plasma particle accelerators fall into two classes:

- Simulation of a variety of rapidly moving dust particles and micrometeoroids in outer-space environments that include micrometeoroid streams, comet tails, planetary rings, and nebulae and
- Deposition or implantation of nanoparticles on substrates for diverse industrial purposes that could include hardening, increasing thermal insulation, altering optical properties, and/or increasing permittivities of substrate materials.

Relative to prior apparatuses used for similar applications, dusty-plasma particle accelerators offer such potential advantages as smaller size, lower cost, less complexity, and increased particle flux densities.



In a **Dusty-Plasma Particle Accelerator**, microparticles or nanoparticles in a cup exposed to a plasma become electrically charged and are then accelerated by applying a pulsed electric field.

A dusty-plasma particle accelerator exploits the fact that an isolated particle immersed in plasma acquires a net electric charge that depends on the relative mobilities of electrons and ions. Typically, a particle that is immersed in a low-temperature, partially ionized gas, wherein the average kinetic energy of electrons exceeds that of ions, causes the particle to become negatively charged. The particle can then be accelerated by applying an appropriate electric field. A dusty-plasma particle accelerator (see figure) includes a plasma source such as a radio-frequency induction discharge apparatus containing (1) a shallow cup with a biasable electrode to hold the particles to be accelerated and (2) a holder for the substrate on which the particles are to impinge. Depending on the specific design, a pair of electrostatic-acceleration grids between the substrate and discharge plasma can be used to both collimate and further accelerate particles exiting the particle holder. Once exposed to the discharge plasma, the particles in the cup quickly acquire a negative charge. Application of a negative voltage pulse to the biasable electrode results in the initiation of a low-current, high-voltage cathode spot. Plasma pressure associated with the cathode spot as well as the large voltage drop at the cathode spot accelerates the charged particles toward the substrate. The ultimate kinetic energy attained by particles exiting the particle holder depends in part on the magnitude of the cathode spot sheath potential difference, which is proportional to the magnitude of the voltage pulse, and the on the electric charge on the dust. The magnitude of the voltage pulse can be controlled directly, whereas the particle's electric charge can be controlled indirectly by controlling the operating parameters of the plasma apparatus.

This work was done by John E. Foster of **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17438.