Large-Area Permanent-Magnet ECR Plasma Source

This device is a good source of ions for plasma processing applications.

John H. Glenn Research Center, Cleveland, Ohio

A 40-cm-diameter plasma device has been developed as a source of ions for material-processing and ion-thruster applications. Like the device described in the immediately preceding article, this device utilizes electron cyclotron resonance (ECR) excited by microwave power in a magnetic field to generate a plasma in an electrodeless (noncontact) manner and without need for an electrically insulating, microwave-transmissive window at the source. Hence, this device offers the same advantages of electrodeless, windowless design — low contamination and long operational life.

The device generates a uniform, high-density plasma capable of sustaining uniform ion-current densities at its exit plane while operating at low pressure [$<10^{-4}$ torr (less than about 1.3×10^{-2} Pa)] and input power <200 W at a frequency of 2.45 GHz. Though the prototype model operates at 2.45 GHz, operation at higher frequencies can be achieved by straightforward modification to the input microwave waveguide. Higher frequency operation may be desirable in those applications that require even higher background plasma densities. In the design of this ECR plasma source, there are no cumbersome, power-hungry electromagnets. The magnetic field in this device is generated by a permanent-magnet circuit that is optimized to generate resonance surfaces. The microwave power is injected on the centerline of the device. The resulting discharge plasma jumps into a "high mode" when the input power rises above 150 W. This mode is associated with elevated plasma density and high uniformity.

The large area and uniformity of the plasma and the low operating pressure are well suited for such material-processing applications as etching and deposition on large silicon wafers. The high exit-plane ion-current density makes it possible to attain a high rate of etching or deposition.

The plasma potential is <3 V — low enough that there is little likelihood of sputtering, which, in plasma processing, is undesired because it is associated with erosion and contamination. The electron temperature is low and does not vary appreciably with power.

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

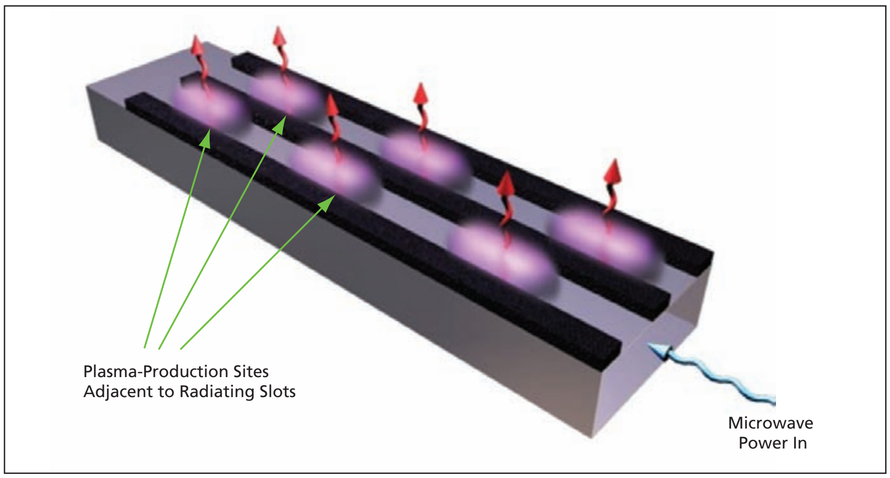
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17561-1

Slot-Antenna/Permanent-Magnet Device for Generating Plasma

Characteristics include uniformity of plasma, scalability, versatility, and long life.

John H. Glenn Research Center, Cleveland, Ohio

A device that includes a rectangular-waveguide/slot-antenna structure and permanent magnets has been devised as a means of generating a substantially uniform plasma over a relatively large area, using relatively low input power and a low gas flow rate. The device utilizes electron cyclotron resonance (ECR) excited by microwave power to efficiently generate plasma in a manner that is completely electrodeless in the sense that, in principle, there is no electrical contact between the plasma and the antenna. Plasmas generated by devices like this one are suitable for use as sources of ions and/or electrons for diverse material-processing applications (e.g., etching or deposition) and for ion thrusters.



Plasma Is Produced at sites adjacent to matched radiating slots in a rectangular-waveguide/slot-antenna structure.

The absence of plasma/electrode contact essentially prevents plasma-induced erosion of the antenna, thereby also helping to minimize contamination of the plasma and of objects exposed to the plasma. Consequently, the operational lifetime of the rectangular-waveguide/slot-antenna structure is long and the lifetime of the plasma source is limited by the lifetime of the associated charged-particle-extraction grid (if used) or the lifetime of the microwave power source.

The device includes a series of matched radiating slot pairs that are distributed along the length of a plasma-source discharge chamber (see figure). This arrangement enables the production of plasma in a distributed fashion, thereby giving rise to a uniform plasma profile. A uniform plasma profile is necessary for uniformity in any electron- or ion-extraction electrostatic optics. The slotted configuration of the waveguide/antenna structure makes the device scalable to larger areas and higher powers. All that is needed for scaling up is the attachment of additional matched radiating slots along the length of the discharge chamber. If it is desired to make the power per slot remain constant in scaling up, then the input microwave power must be increased accordingly.

Unlike in prior ECR microwave plasma-generating devices, there is no need for an insulating window on the antenna. Such windows are sources of contamination and gradually become ineffective as they become coated with erosion products over time. These characteristics relegate prior ECR microwave plasma-generating devices to non-ion beam, non-deposition plasma applications. In contrast, the lack of need for an insulating window in the present device makes it possible to use the device in both ion-beam (including deposition) and electron-beam applications. The device is designed so that ECR takes place above each slot and the gradient of the magnetic field at each slot is enough to prevent backflow of plasma.

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, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17589-1.

Fiber-Optic Strain Gauge With High Resolution And Update Rate

Changes in strain are correlated with changes in speckle patterns.

Stennis Space Center, Mississippi

An improved fiber-optic strain gauge is capable of measuring strains in the approximate range of 0 to 50 microstrains with a resolution of 0.1 microstrain. (To some extent, the resolution of the strain gauge can be tailored and may be extensible to 0.01 microstrain.) The total cost of the hardware components of this strain gauge is less than $100 at 2006 prices. In comparison with prior strain gauges capable of measurement of such low strains, this strain gauge is more accurate, more economical, and more robust, and it operates at a higher update rate. Strain gauges like this one are useful mainly for measuring small strains (including those associated with vibrations) in such structures as rocket test stands, buildings, oilrigs, bridges, and dams. The technology was inspired by the need to measure very small strains on structures supporting liquid oxygen tanks, as a way to measure accurately mass of liquid oxygen during rocket engine testing.

This improved fiber-optic strain gauge was developed to overcome some of the deficiencies of both traditional foil strain gauges and prior fiber-optic strain gauges. Traditional foil strain gages do not have adequate signal-to-noise ratios at such small strains. Fiber-optic strain gauges have been shown to be potentially useful for measuring such small strains, but heretofore, the use of fiber-optic strain gauges has been inhibited, variously, by complexity, cost, or low update rate.

The improved fiber-optic strain gauge is partially composed of a multimode fiber optic which is wound in an elliptical pattern and bonded to the structure of interest. A laser is fixed within an adjustable cylindrical steel enclosure and aimed at one end of the optical fiber. The laser light emerging from the other end of the fiber forms a speckle pattern that changes as strain is applied to the structure. The speckle pattern is intercepted by an array of photocells, so that any change in the speckle pattern manifests itself in changes in the intensities of light measured by the individual photocells. The outputs of the photocells are collected by a customized data-acquisition system that includes a signal-conditioning subsystem. The photocell outputs are then fed to a neural network that recognizes the correlation between changes in the outputs and changes in strain.

Inasmuch as the changes in the intensities of light incident on the photocells are repeatable for a given amount of change in strain, the neural network can be quickly trained by use of speckle patterns associated with known levels of strain. For measurement of temporally varying strain (for example, when vibrations are present), the update rate and, hence, the dynamic analysis rate depends on the data-acquisition rate.

This work was done by Fernando Figueroa of Stennis Space Center and Ajay Mahajan, Mohammad Sayeh, and Bradley Regez of Southern Illinois University, Carbondale.

Inquiries concerning rights for the commercial use of this invention should be addressed to Intellectual Property Manager, NASA Stennis Space Center; (228) 688-1929. Refer to SSC-00243.

Broadband Achromatic Telecentric Lens

Lens works with a matched spectrometer for applications covering the entire solar-reflected spectrum.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new type of lens design features broadband achromatic performance as well as telecentricity, using a minimum number of spherical elements. With appropriate modifications, the lens design form can be tailored to cover the range of response of the focal-plane array, from Si (400–1,000 nm) to InGaAs (400–1,700 or 2,100 nm) or InSb/HgCdTe reaching to 2,500 nm. For reference, lenses typically are achromatized over the visible wavelength range of 480–650 nm.

In remote sensing applications, there is a need for broadband achromatic telescopes, normally satisfied with mirror-