
Sensor for Monitoring Nanodevice-Fabrication Plasmas

Temperature and trace amounts of chemical species could be measured *in situ*.

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The term “plasma process diagnostics” (PPD) refers to a spectroscopic technique and sensing hardware that have been proposed for monitoring plasma processes used to fabricate electronic devices that feature sizes as small as several nanometers. Nanometer dimensions are characteristic of the quantum level of miniaturization, where single impurity atoms or molecules can drastically change the local properties of the nanostructures. Such changes may be purposely used in nanoscale design but may also be extremely damaging or cause improper operation of the fabricated devices. Determination of temperature and densities of reactants near the developing features is important, since the structural synthesis is affected by characteristics of the local microenvironment. Consequently, sensors capable of nonintrusive monitoring with high sensitivity and high resolution are essential for real-time atomistic control of reaction kinetics and minimizing trace contamination in plasma processes used to fabricate electronic nanodevices. Such process-monitoring sensors are required to be compact, multiparametric, and immune to the harsh environments of processing plasmas. PPD is intended to satisfy these requirements.

The specific technique used to implement plasma diagnostics with a PPD sensor would be an advanced version of

continuous-wave cavity-ringdown spectroscopy (CW-CRDS) capable of profiling spectral line broadenings in order to derive both Doppler and Stark components. CRDS is based on measurements of the rate of absorption of laser light in an optical resonator. The ultimate sensitivity results from a very long absorption path length within the cavity and immunity to variations in incident laser intensity. The proposed version of this technique would involve the use of multiplexing tunable laser diodes and an actively modulated high-reflectivity optical resonator, thus offering a synergistic combination of simplicity, compactness, high sensitivity, and high resolution.

The multiplexing capabilities of diode lasers could be utilized to make the PPD sensor a single, simple, compact, and inexpensive tool for the acquisition of multiparametric data. A PPD sensor would be capable of continuous measurement of such physical parameters as gas temperature, gas velocity, electron number density, and absolute densities of reacting chemical species. A laser beam can be easily adjusted to analyze the immediate vicinity of the growing nanostructures (or features etched down) in real time. The absorption enhancement in an optical cavity would afford the sensitivity needed for measurement of the temperature and densities of species at concentrations significantly

lower than measurable by other nonintrusive techniques.

It is anticipated that fully developed PPD sensors would enable simultaneous measurement of local temperature and determination of plasma species responsible for the synthesis and functionalization of nanodevices. These sensors would also enable tracking the pathways and origins of damaging contaminants, thereby providing feedback for adjustment of processes to optimize them and reduce contamination. The PPD sensors should also be useful for optimization of conventional microelectronics manufacturing plasma processes.

Going beyond plasma processes for fabrication of electronic devices, PPD sensors could be used for monitoring of atoms, molecules, ions, radicals, clusters, and particles in a variety of other settings, including outer space. Because of their high sensitivity, such sensors could also prove useful for detecting traces of illegal drugs and explosives.

This work was done by Alexander Bol'shakov while he held a National Research Council associateship award at Ames Research Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-15084-1.

Backed Bending Actuator

Such an actuator could exert a large force at small displacement.

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Bending actuators of a proposed type would partly resemble ordinary bending actuators, but would include simple additional components that would render them capable of exerting large forces at small displacements. Like an ordinary bending actuator, an actuator according to the proposal would include a thin rectangular strip that would comprise two bonded layers (possibly made of electroactive polymers with surface electrodes) and would be clamped at one end in the manner of a cantilever beam. Unlike an ordinary bending actuator,

the proposed device would include a rigid flat backplate that would support part of the bending strip against backward displacement; because of this feature, the proposed device is called a backed bending actuator.

When an ordinary bending actuator is inactive, the strip typically lies flat, the tip displacement is zero, and the force exerted by the tip is zero. During activation, the tip exerts a transverse force and undergoes a bending displacement that results from the expansion or contraction of one or more of the bonded lay-

ers. The tip force of an ordinary bending actuator is inversely proportional to its length; hence, a long actuator tends to be weak.

The figure depicts an ordinary bending actuator and the corresponding backed bending actuator. The bending, the tip displacement (d), and the tip force (F) exerted by the ordinary bending actuator are well approximated by the conventional equations for the loading and deflection of a cantilever beam subject to a bending moment which, in this case, is applied by the differential