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IN-SITU DIAGNOSTIC TECHNIQUE PROVIDES A CLOSER LOOK AT KEY SEMICONDUCTOR AND OPTICAL FIBER PROCESSES

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Researchers at the Georgia Institute of Technology have used a laser-induced fluorescence technique to detect and measure two gas phase silicon species which may be important in the fabrication of advanced semiconductor devices and optical fibers.

The ability to observe silicon atoms and silicon monoxide in the plasmas and flames used to manufacture semiconductors and optical fibers could lead to a better understanding of the complex chemical reactions involved -- and bring about improvements in the economically important processing techniques.

"Despite their enormous commercial importance, the mechanisms of silicon and silicon dioxide deposition in plasma-enhanced chemical vapor deposition are not understood in detail at the atomic and molecular scale," said Dr. Anthony Hynes, a research scientist in Georgia Tech's Electromagnetics Laboratory. "If you could determine the critical chemical reactions and model these processes, it might be possible to improve current manufacturing techniques, by -- for instance -- lowering processing temperatures."

Semiconductor researchers now rely on an empirical approach for studying plasma-enhanced chemical vapor deposition, a process commonly used for depositing films of silicon and silicon dioxide. The researchers change the flow rate of the chemicals used and alter the power levels of microwave fields, then attempt to relate those changes to the end result. The work must be done without a detailed understanding of the chemical reactions taking place.

Use of in-situ laser diagnostics would allow researchers to directly study the chemical reactions taking place in an operating production reactor. Researchers could tell which chemical species are involved, their concentrations, and where the reaction is physically taking place. This would clarify questions about the role silicon atoms and silicon monoxide play in the deposition process.

"There are a number of techniques for depositing layers of silicon dioxide on semiconductor chips," he said. "Typically, they will use mixtures of silane and oxygen. You end up with silicon dioxide, and it may be possible that silicon monoxide is an important intermediary in the process."

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The diagnostic technique could ultimately be the basis for a feedback system to automatically adjust process variables in commercial reactors to help gain the most favorable production rates and quality.

In addition to confirming the presence of the two chemical species, Hynes would like to measure their relative concentrations and determine whether the chemical reaction takes place in the gases swirling through the reaction vessel or on the surface of the chip or fiber optic material. The narrow focus of the laser would allow the researchers to pinpoint the locations where the reaction is taking place -- without upsetting the delicate chemical processes.

Existing methods for studying the reaction process involve sampling steps which can affect the on-going reaction, said Hynes. The laser technique, however, can produce accurate measurements in an operating reactor without disturbing the chemical reactions.

Laser-induced florescence (LIF) uses tunable lasers -- lasers whose wavelengths can be adjusted -- to direct light energy at gases whose chemical composition is unknown. At certain wavelengths, the individual components absorb the light energy and then radiate it back in a process known as fluorescence.

Because every material fluoresces at a specific wavelength, researchers can use the technique to clearly identify the constituents of the gas and measure the quantities present. Observation of the laser excitation spectrum also allows the flame temperature to be determined.

The sensitive LIF technique is widely used to identify trace elements and to study both atmospheric chemistry and combustion chemistry.

But researchers have been limited in the materials they could study because the laser technique could only be used with chemicals that absorb light at the wavelengths produced by their dye lasers. Scientists have expanded the operating range of the LIF process through a technique known as frequency doubling, in which the laser beams are passed through certain crystals which double their frequency -- and as a result, halve their wavelength.

Until recently, however, it was difficult to produce wavelengths shorter than 260 nanometers. But using a beta barium borate crystal available only from the People's Republic of China, scientists can now generate wavelengths as short as 205 nanometers, opening up a wider range of materials for study.

Because silicon atoms absorb light at 251 nanometers and silicon monoxide absorbs at about 230 nanometers, the LIF technique can now be used to observe the two species of silicon.

Results of the work were presented at a symposium on the characterization of plasma-enhanced chemical vapor deposition processes at the fall meeting of the Materials Research Society. They are scheduled for publication in the society's proceedings.

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