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Booming Low-temperature Plasma Sciences for a Creation of New Value

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Low-temperature plasma science is positioned as an important science and technology that fundamentally supports the creation of cutting-edge devices and systems, the establishment of innovative environmental improvement technologies, the challenge of the global food crisis, and next-generation medical technologies.
It is a strategic science and technology that can make a significant contribution to the SDGs. In other words, low-temperature plasma science is a driving force for creating new value by opening up the future of diverse fields, sparking disruptive innovation, and creating social innovation that interweaves diverse fields.

For example, logic devices for advanced large-scale integrated circuits are being developed toward ultra-fine processing with 1 nm dimensions. In this process, it is necessary to precisely control the kind and density of radicals in the plasma and to maintain a constant substrate temperature during the process. In the nano-patterning of organic thin films, a one-degree change in substrate temperature causes a change in dimension of 1 nm. As an approach to this problem, nano-pattern etching of organic thin films was performed in a dual-frequency capacitively coupled plasma etching system using a mixture of hydrogen and nitrogen gases. The absolute density of hydrogen and nitrogen radicals was measured by vacuum ultraviolet absorption spectroscopy, and the ratio of hydrogen to nitrogen radicals was kept constant. Substrate temperature was measured in real time using an optical interferometer, and the temperature was kept constant during the process by modulating the plasma on and off.

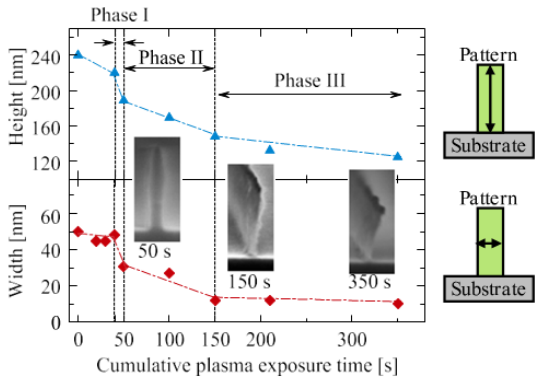

Figure 1 The evolution of organic film etching profile.[1]

As a result, nanometer-sized patterns were successfully formed as shown in Fig.1. [1] The significance of this research is that the etching characteristics of organic materials are not described by the parameters of the equipment (power, pressure, gas flow rate, etc.), but by internal parameters (radical density caused by particles, substrate temperature), it is significant that process characteristics (etching speed and shape) can be controlled by controlling these internal parameters with high precision. In order to further advance next-generation semiconductor plasma processes, it is necessary to accumulate a database expressed in terms of internal parameters.

Meanwhile, the development of atmospheric pressure and low-temperature plasma has begun to build science for new applications and mechanisms in the environmental and biotechnology fields. In addition to plasma chemistry, molecular biological elucidation of plasma and biological reactions is necessary to realize the development of selective killing of cancer and regenerative medicine, physiology of growth promotion through interaction between plasma and plants, and the science of efficient production of methanol by converting CO_2 to other substances.

For this purpose, it is necessary to accumulate these various sciences in a reliable scientific database and systematize them with AI. In particular, the behavior of radicals is unknown in low-temperature plasma science, and it is important to measure radicals and systematize and control their behavior.[2] Low-temperature plasma science is extremely attractive for the creation of a future society and can contribute significantly to the SDGs.

In this talk, the current status and future prospects of low-temperature plasma science will be outlined.
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References
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