High-voltage vacuum power switch for smart power grids: First successful power switch using diamond semiconductor

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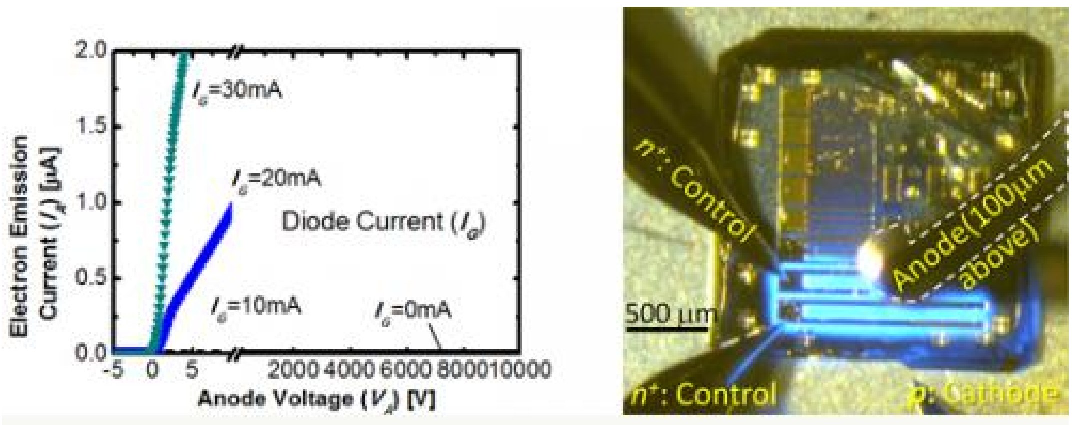

When the diode is “off” (IG = 0mA), no current passes through the vacuum. However, when a current is passed in the diode, the current passes through the vacuum. The current is started from a plate voltage of substantially zero. The right side of the figure shows the condition when the vacuum switch is “on” as seen from above. When the diode is “on,” visible light is emitted. Because light is emitted by the entire diode, it can be understood that a current is passing uniformly through the interior of the solid. It is also thought that electron emission is not concentrated, but occurs from the entire lighted diode.

As part of problem solving-oriented basic research sponsored by the Japan Science and Technology Agency (JST), a group consisting of researchers at the National Institute of Advanced Industrial Science and Technology (AIST) and the National Institute for Materials Science

(NIMS) succeeded in fabricating a vacuum-based high withstand-voltage power switch utilizing the features of a diamond semiconductor and demonstrating its operation.

As part of problem solving-oriented basic research, scientists have succeeded for the first time in the world in fabricating a vacuum-based high withstand-voltage power switch and demonstrating its operation. This result was achieved by utilizing the features of a diamond semiconductor.

In order to introduce renewable energy in power grids and realize the "smart grid" concept, compact power conversion devices (devices that combine multiple power switches) that make it possible to convert and control voltage, current, and frequency are necessary. However, for the power switches developed to date using silicon and similar materials, an extremely large-scale power conversion device had been necessary to withstand high voltages, and this had a been a problem for practical application. Because the withstand voltage (dielectric voltage) of a vacuum is superior to that of semiconductors, which are solids, the development of an innovative vacuum-based power switch that offers an ultra-high withstand voltage, high efficiency, and compact size has been expected.

In order to use a vacuum in a switch, an electron emission device that passes a current through a vacuum when the switch is "on" is necessary. This research group clarified the fact that electrons can be freely emissioned into vacuum when a diamond surface is covered with hydrogen atoms. Therefore, the group developed a vacuum power switch in which a diamond semiconductor is used as the electron emission source. In verification of switch operation, the group confirmed that the device functions as a power switch at a voltage of 10kV. Based on these experimental results, if a vacuum power switch that can withstand voltages as large as 100kV can be fabricated, high power conversion devices with a size 1/10 that of conventional devices are theoretically possible.

In the future, the use of this technology is expected to contribute to realizing a new energy strategy in Japan through introduction of offshore wind energy in the seas surrounding Japan, efficient power transmission across the Japanese archipelago, and similar efforts.

These research results were introduced online as one of the highlights of the 2012 International Electron Devices Meeting (IEDM 2012), and will also be announced at IEDM 2012 on December 10, 2012.

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