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(News release)

Nippon Telegraph and Telephone Corporation

Fabrication of Superior-Quality "Diamond"
-- Breakthrough towards High-Power High-Efficient Devices for Communication Satellites --

Nippon Telegraph and Telephone Corporation (NTT) has developed a technique for fabricating superior-quality "diamond". This is the first step toward the development of the next generation devices.
NTT Basic Research Laboratory (BRL) has succeeded in observing the intrinsic properties of diamond. The fabrication technique is a microwave plasma chemical vapor deposition (CVD) method in which the temperature is controlled very accurately and the source gases are purified (Fig. 1). The temperature control and pure source gases decrease the densities of residual impurities and crystalline defects by more than two orders. As a result, we have obtained superior-quality diamond whose carrier velocity is 20 times higher than that of conventional diamond. This is the first time that a diamond film has shown the intrinsic electrical properties theoretically predicted for pure diamond.
Diamond promises to be the ultimate high-power semiconductor material, providing devices that can operate at five times the temperature and 30 times the voltage of common silicon devices (Fig. 2). Possible applications of this superior-quality diamond thin crystal include efficient high-power transmission devices that can operate in the hazardous environment of space, i.e., with limited power at high temperatures and in intense solar radiation. This would greatly improve the efficiency and reliability of satellite communication.

<Feature>
Electron-microscopy observation revealed that the crystalline defect density in NTT's diamond thin crystal is more than two orders lower than that in conventional diamond crystal (Fig. 3).
Because NTT's diamond thin film includes neither the non-diamond component nor residual impurities, it has a mirror surface and is transparent (Fig. 4).
Because NTT's diamond crystal contains no residual impurities, it has an extremely high carrier velocity of 1300 cm^2/Vs, which is about 20 times higher than that of conventional diamond films (Fig. 5).

<Technology>
Researchers in NTT BRL first learned to control the fabrication conditions very accurately on the basis of knowledge obtained in their wide-gap semiconductor research, and clarified that the carrier velocity is governed by residual impurities, the non-diamond component (graphite), and crystalline defects.
Then they isolated residual impurities that affect mainly the carrier velocity and purified the source gases.
Next they ascertained the temperature ranges in which non-diamond components and

crystalline defects are generated, and succeeded in depositing superior-quality diamond outside these temperature ranges. (Fig. 3) The optimized temperature, from 650 to 750 ^{o}C, is lower than the lowest temperature used previously, about 800 ^{o}C. As a result, they have obtained superior-quality diamond.

<Future>

NTT BRL is now working to further improve the carrier velocity and develop devices with high carrier velocity. Also underway is work aimed at elucidating the solid-state physics of diamond semiconductor.

<Definitions of Terms>

1) Microwave plasma CVD

Chemical vapor deposition is abbreviated CVD. In microwave plasma CVD (Fig. 1), typical source gases are methane and hydrogen. Microwave power generates plasma in the gases. Inside the plasma, hydrocarbon gases are decomposed and carbon radicals generated. When carbon radicals with four chemical bonds deposit on the substrate, diamond thin crystal forms. However, in this CVD, the diamond thin crystal is heated by both the substrate heater and the plasma, which makes controlling the temperature very difficult. NTT success in improving the temperature controllability enabled the deposition of the superior-quality diamond.

2) Carrier velocity

Carriers are electrons or positive holes, and their velocity governs how a device performs. Generally, a crystal with higher crystalline quality has a higher carrier velocity, and this results in higher switching speed in a device.

3) Residual impurities, non-diamond component (graphite), crystalline defects

Any atoms in a diamond crystal other than carbon atoms are residual impurities. Ideal diamond consists of carbon atoms with four chemical bonds. Graphite is a carbon atom with three bonds and is referred to as a non-diamond component. When a carbon atom forms in a crystal structure different from that of the ideal diamond structure, it becomes a crystalline defect. Residual impurities, a non-diamond component (graphite), and crystalline defects decrease carrier velocity drastically.

- Fig. 1 Diamond fabrication technique
- Fig. 2 Background
- Fig. 3 Temperature optimization
- Fig. 4 Superior-quality diamond
- Fig. 5 Characteristics

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