NEWS RELEASE

NTT

NIPPON TELEGRAPH AND TELEPHONE CORPORATION

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Three-Dimensional Nanofabrication Using Electron Beam Lithography

- The world's smallest globe
with a resolution 100 times higher than previously possible -

Nippon Telegraph and Telephone Corporation (NTT; Head Office: Chiyoda-ku, Tokyo; President: Norio Wada) has created an electron beam (EB) lithography (*1) system that enables the fabrication of extremely small three-dimensional (3D) structures with sizes measured in nanometers (A nanometer is a billionth of a meter). NTT demonstrated the 3D nanopatterning and nanofabrication by exposing a small sphere to the EB to form the world's smallest globe.
This highly advanced technique promises to become the technological foundation of nanotechnology (*2), which is expected to give rise to many new industries and new markets.

Key Features

- 3D nanofabrication and nanopatterning down to the 10-nanometer level.
- A drive that rotates a sample around two axes with a high precision.
- A height sensor that enables the EB to be focused on a 3D sample. The focus error is less than 1-2 micronmeters.
- A new beam-positioning system, which detects the outline of a sample using a transmitted-electron signal for accurate placement of patterns.

Background

EB lithography is of creating two-dimensional (2D) patterns for semiconductor integrated circuits. The resolution at present is on the order of tens of nanometers (billionths of a meter). On the other hand, 3D fabrication methods should have a much wider range of application. However, current 3D methods have found only limited applications because of some disadvantages. For example, deposition using a charged-particle beam is time-consuming, which makes it very difficult to build complicated structures. Many methods of 3D fabrication have been developed for microelectromechanical systems (MEMS, *3). However, since those methods use an optical or X-ray beam, the minimum size is limited by the wavelength or lithographic resolution, which is on the order of one micron.
The new technique developed by NTT uses a special drive to rotate a sample and EB nanolithography, which has a resolution 100 times that of methods using an optical or X-ray beam. This enables reasonably fast 3D fabrication and patterning. As demonstrations of the technique, NTT used it to fabricate the world's smallest globe and a 3D nano-filter.

Overview of Techniques

One key technique is the ability to rotate a 3D sample in such a way that any of its faces can be exposed to the EB. To accomplish this, NTT developed a two-axis-of-rotation drive system that can be loaded into the EB lithography apparatus (See Fig. 1) and rotate a sample around the R-axis by 360 degrees and the T-axis by 45 degrees. It has an accuracy of better than 0.1 degree. Since the shape of the drive is similar to that of a semiconductor wafer holder, the drive loads easily into the apparatus.
Another key technique is EB focusing on a 3D sample. This requires an ability to determine the height (Z coordinate) and horizontal position (X and Y coordinates) of any point on a sample.
To measure the height, NTT developed a new height measurement system (See Fig. 2) that uses a confocal laser microscope (*4). The system makes a height map of a sample, thus enabling the height of any point on the sample to be determined, even if the sample is rotated. In addition, an outline of the shadow of a sample is mapped with a transmission electron detector, and patterns are written at the designed position relative to the outline (See Fig. 3).
The world's smallest globe, shown in Fig. 4, was made by writing a map of the world on a micro-sphere made of resin. This nano-globe has a diameter of about 60 micrometers, which is finer than a human hair. The smallest pattern is about 10 nanometers in size, which corresponds to 2 kilometers on the actual earth.
Repeated EB patterning and development produced the nano-filter, which is shown in Fig. 5. The first exposure and development formed the framework of the filter, and the second formed an array of small holes on the sidewalls of the framework. The smallest holes have a diameter of about 30 nanometers.

Future prospects
Plans call for the development of methods of applying this technique to nanofabrication on various materials, such as semiconductors. In addition, investigations will be carried out to determine how this technique can be used to make new types of highly functional nanoelectronic devices.

Explanation of terms
*1 Electron beam lithography
This is a technique for making very fine patterns for the fabrication of semiconductor integrated circuits. An electron beam can be focused down to a diameter as small as a few nanometers (billionths of a meter), which can then be used to form fine patterns less than 10 nanometers in size.

*2 Nanotechnology
This refers to a variety of technologies related to structures from 1 to about 100 nanometers in size. Researchers in many fields are now focusing on techniques for the fabrication and evaluation of very tiny structures and ways of using them in practical applications. The main technologies in this field concern fabrication.

*3 Microelectromechanical systems (MEMS)
These include micro-machined parts, electrically controlled microdevices, and microsystems, but not microelectronic circuits. Some have very complicated three-dimensional structures.

*4 Confocal laser microscope
This microscope can measure the three-dimensional surface morphology of a sample by using a small aperture in the image plane. It provides a height resolution of better than 10 nanometers, and uses light from a high-intensity laser.

- Attachment : Figure 1-Figure 5

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