Extended Abstracts of the 1991 International Conference on Solid State Devices and Materials, Yokohama, 1991, pp. 678-679

Nanometer-Scale Process Technology on Graphite Surfaces by Scanning Tunneling Microscope

K. Uesugi, T. Kurosu*, M. Iida*, and T. Yao

Department of Electrical Engineering, Hiroshima University,
1-4-1 Kagamiyama, Higashi-Hiroshima 724, Japan
*Faculty of Engineering, Tokai University, 1117 Kitakaname,
Hiratsuka, Kanagawa 259-12, Japan

Holes and carbon dots on a nanometer scale are formed on highly-oriented pyrolytic graphite (HOPG) surfaces by scanning tunneling microscope (STM). A hole of 25Å in diameter and 7Å in depth are made by applying a voltage pulse on the graphite surface in air. The pulse height is -10V with pulse width of 0.1ms. On the other hand, the deposition of carbon is achieved by applying voltage pulses across the tunneling gap in a mixed gas of acetone and hydrogen gas at 20Torr. A carbon dot of 8Å in diameter and 7Å in height is deposited by applying a short voltage pulse (-4V, 50μs). The results indicate possibility of nanostructure fabrication by Angstrom-size electron beam emitted from a STM tip through reactions with ambient gas molecules.

Introduction

Recently, scanning tunneling microscope (STM) has been utilized not only to observe surface topography, but also to modify surfaces on a nanometer scale.[1,2) This paper describes the formation of holes and the deposition of carbon dots on graphite surfaces through reactions of electron beam emitted from an STM tip with ambient gas molecules. Since the size of electron beam emitted from an STM tip is ~4Å,[3) the fabrication of nanometer-scale structures can be achieved.

Experiment

The instruments used in the these experiments is a two-chamber STM system operated in ultrahigh vacuum. The tips are platinum wire or platinum iridium (80:20) wire. Samples of highly-oriented pyrolytic graphite (HOPG) are cleaved with an adhesive tape in air before being loaded into an STM. All STM images are obtained in a variable-current mode. The tip voltage is -0.3V and the average tunneling current is 0.9nA. We have investigated the effects of controlled ambient gases to modify the graphite surface by applying voltage pulses across the tunneling gap at selected points.

Results and discussion

Figure 1 shows a hole made by applying a voltage pulse on the graphite surface in air. The size of the image is 61x61Å^2. The pulse height is -10V (tip is negatively biased) with pulse width of 0.1ms. The hole is 25Å in diameter and 7Å in depth at the center. The graphite lattice is clearly visible around the hole. The holes are created by applying a voltage pulse in the range from -5 to -10V in air. However, the deposition of contamination is observed around the hole on the graphite surface. The hole is considered to be formed by selective oxidation of graphite surface induced by the electron beam.

The deposition of carbon has been achieved by applying voltage pulses across the tunneling gap in a mixed gas of acetone and hydrogen gas at 20Torr. A carbon dot of 8Å in diameter and 7Å in height is deposited by applying a short voltage pulse (FIg.2). The pulse height is -4V with pulse width of 50μs. Similarly, the deposition of contamination carbon dots has been performed in hydrogen gas of 1atm by applying a short voltage pulse. Figure 3 shows a carbon dot deposited by applying a voltage pulse (-3V, 50μs). The dot is 25Å in diameter and 20Å in height. A minimum feature size of 10Å in diameter is created by applying a voltage pulse in hydrogen gas. The electron beam from the tip decomposes the acetone molecules to deposit carbon on the graphite surface in the former case and possibly induces such reaction as

$$C_nH_m \rightarrow n\,C + \frac{m}{2}H_2$$

in the latter case on the graphite surface. We note that neither the formation of hole nor the deposition of contamination dot is observed by applying the voltage pulse in vacuum.

Conclusions

In conclusion, holes and carbon dots with nanometer-scale structures are formed on graphite surfaces by applying a voltage pulse across the tunneling gap of STM with the tip bias being negative in different ambient gases. The results indicate possibility of nanostructure fabrication by STM.

References

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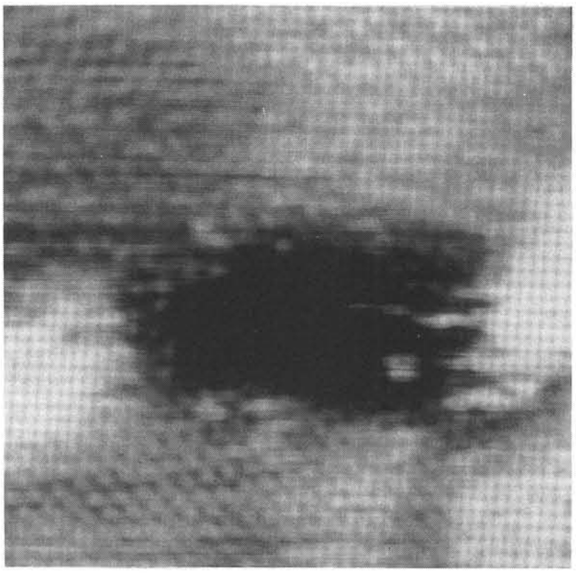

Fig.1. STM image of a fabricated hole on a 61x61Å^2 surface area. The hole is 25Å in diameter and 7Å in depth. Pulse height is -10V and pulse width is 0.1ms.

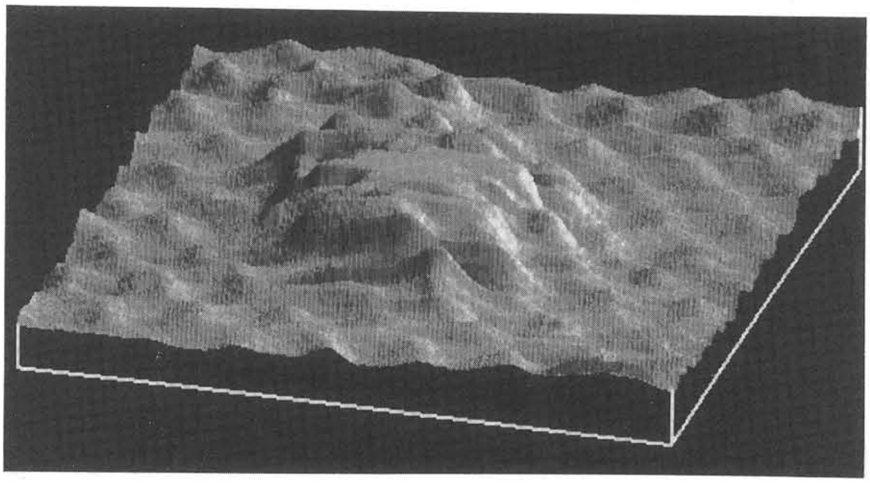

Fig.2. STM image of a carbon dot on a 18x18Å^2 surface area. The dot is 8Å in diameter and 7Å in height. Pulse height is -4V and pulse width is 50μs.

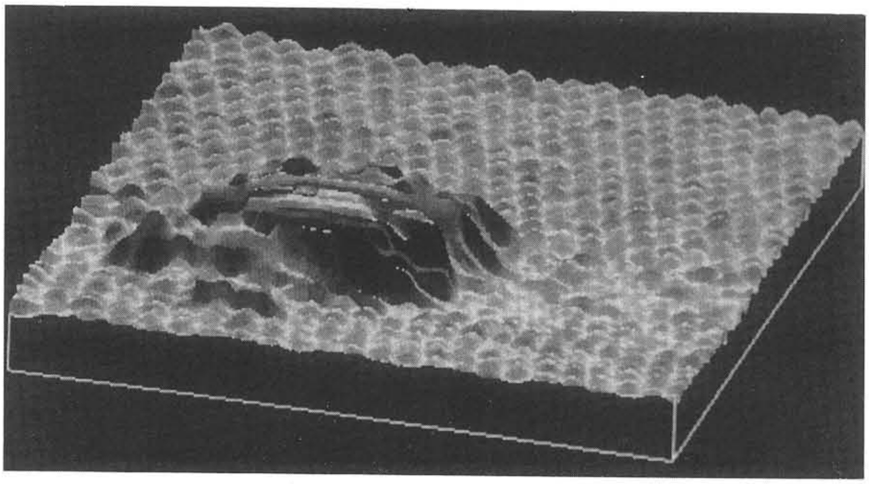

Fig.3. STM image of a carbon dot on a 53x53Å^2 surface area. The dot is 25Å in diameter and 20Å in height. Pulse height is -3V and pulse width is 50μs.