Characteristics of carbon nano-dots fabricated by the Thermo-electrical Pulse Induced Evaporation

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The carbon quantum dot, one of Carbon based materials, has attracted tremendous attention from engineers and scientist. Carbon nano-dots have been fabricated by various methods, but they cannot adjust and control the size of dots. We have developed a novel method, i.e., Thermo-electrical Pulse Induced Evaporation (TPIE) of synthesizing a various kind of nanostructures. The thermal energy and electrical pulse are simultaneously introduced into a source material at a high vacuum condition and then source materials are evaporated. We will report the structural characteristics of carbon nano-dots fabricated by TPIE method. Carbon nano-dots were directly fabricated on the doped Si (111) crystal surface for measuring electrical properties of the dots. The formation of the dots was confirmed using atomic force microscope (AFM), scanning electron microscope (SEM) and high resolution transmission electron microscope (HRTEM).

Keywords : Carbon nano-dots or Quantum dots; Thermo-electrical Pulse Induced Evaporation(TPIE); Fabricating method

1. Introduction

A quantum dot (QD) is one of the semiconductors whose excitons are confined in all three spatial dimensions. Exceptional luminescent properties of QD such as the narrow emission spectra tunable throughout the entire visible spectrum suggest the use of various fields. The size of QD, about 3~12nm, is suitable to luminesce. The QDs have been fabricated by a laser ablation, chemical vapor deposition, arc-discharge and sol-gel method. However, it is difficult to control the size of them regularly.

At first, Field evaporation was discovered by Müller[1] in 1941. The process of Field evaporation is the process atoms are ionized and ejected from the surface due to an applied high electric field.[1,2] Even though field evaporation is fast and appears to offer better control of the direction and rate of atom transfer, it is not applied in the fabrication of nanostructures. Our method, Thermo-electrical Pulse Induced Evaporation (TPIE) is by using a combination of electrostatic and chemical forces. TPIE method is useful to fabricate nanostructures, nano-dots, nanotubes and graphenes.

We introduce the novel method, TPIE, and research the structural characteristics of carbon nano-dots fabricated by TPIE.

2. Experimental Method

2.1 Thermo-electrical Pulse Induced Evaporation (TPIE)

Thermo-electrical Pulse Induced Evaporation(TPIE) method is one of fabricating methods, electronic pulse and thermal energy are simultaneously introduced into a precursor at vacuum condition and then precursors are evaporated; escaping atoms from pre-cursor transfer to a substrate and grow into a variety of nanostructures. Varying temperature and strength of pulse induces various structures.

Thermal and field evaporations are the mechanism of TPIE. Thermal evaporation, a basic concept of physical vapor deposition, is the extrication of atoms from solid surface at high temperature near melting point of material in vacuum condition about 10-6 Torr. Field evaporation is also escaping phenomenon of atoms; external electrostatic field bring in extrication of ion from surface. Most important thing is that the energy at very low temperature below meting point and feeble pulse(～V) is extricable atoms from surface in TPIE. That is, interaction between two principles plays in an essentially key role of evaporation in TPIE method.

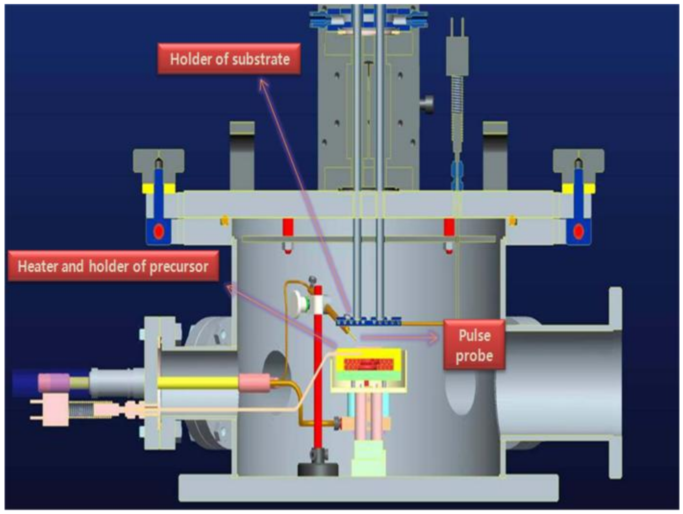

Fig.1 Outline of TPIE

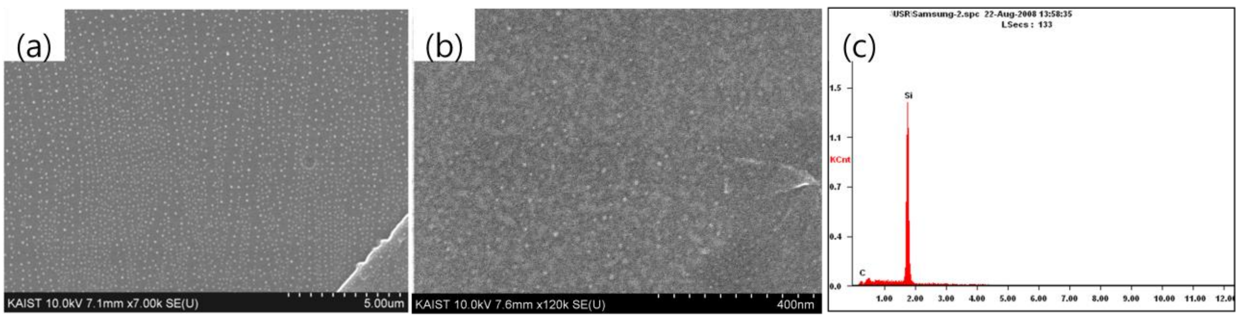

Fig.2 SEM images of Dots on (a) HOPG at 500℃ 5V, (b) Si(111) at 500℃ 5V,(c) EDS of (b)

2.2 Fabrication of Carbon nano-dots

The source material, Highly Oriented Pyrolytic Graphite is placed on the heating stage and the Cu grid, Si(111) and HOPG on the substrate holder. The heating stage was heated to 500°C and 550°C for carbon nano-dots in a vacuum of ~10^{-5} Torr. The distance between the substrate and the target was maintained to few µm with the z-motion controller. Then, an electrical pulse for the carbon nanostructure (5V and 7 V, 500 ns) was applied to the heated target to initiate the evaporation of an individual atom from the surface. The composition and crystal structure of the nanostructures grown on the substrates were directly identified using scanning and high-resolution transmission electron microscopy (SEM/HRTEM). An atomic force microscope (AFM) was definitely useful to investigate the nano-dots size. We also try to analyze them through Raman spectroscopy and observe the property of photoluminescence.

3. Result and Discussion

To set proper temperature and the strength of pulse could control the morphology of nanostructures, using the TPIE method. The method could minimize damages of substrate due to the condition of low temperature (below melting point) in inducing low voltage (~V).

Especially, TPIE method is independent of substrates and targets; any materials could be sources of various nanostructures. We were made on the experiment used different substrates, Si(111) and HOPG(Fig.1). To facilitate for investigating nano structures, copper coated with amorphous carbon grids used as substrates.

To fabricate carbon dots on different condition brought in different size of dots. The dots produced at 550℃ and 500℃ respectively but same field and observed by and high resolution transmission electron microscope (HRTEM) and atomic force microscope (AFM). The size distributions of nano-dots were different depending on temperatures. At more high temperature, were fabricated smaller nano-dots.

TEM images show the morphology trendy of carbon nano-dots. This method is based on field evaporation, so the carbon particle of +1 or +2 charge would be evaporated. The ionized particles made a nano-crystalline and then the aggregation of them formed carbon nano dots.

4. Conclusion

Field-induced evaporation in combination with thermal energy, a method produced by the TPIE apparatus and used to fabricate carbon nano dots was successfully applied to fabricate carbon nanostructures. Using this method, we expected to fabricate a crystal nanostructure for various materials, lower the processing temperature, and reduce the processing time. These features of the TPIE method are due to combining field evaporation with thermal energy.

REFERENCES

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