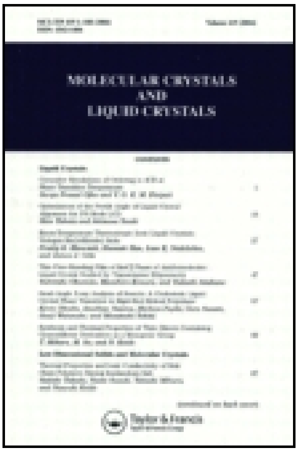

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A Scanning Tunneling Spectroscopy Study on TCNQ/n-Si and/p-Si

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A thin film (thickness: 1.5 nm) of tetracyanoquinodimethane (TCNQ), a well-known electron acceptor, was fabricated on p-Si and n-Si using a spin casting method. The junction properties of these systems were investigated using scanning tunneling spectroscopy (STS). I/V curves of the two systems showed rectifying properties with different polarity. It can provide a new technology to fabricate molecular-level rectifier if nanolithography is accomplished on these systems.

Keywords TCNQ; Spin-coated film; AFM lithography; rectifier.

INTRODUCTION

The ultimate goal of nanotechnology is to fabricate nano-sized devices using an individual molecule after Aviram and Ratner proposed a molecular rectifier.[1] Several fascinating methods have been developed to achieve this goal mainly using based on an asymmetric molecular junction between molecules and molecules.[2-4]

In this study a new method is designed to fabricate a molecular-level rectifier using the heterojunction between an organic molecule and inorganic Si. A traditional method to make a solid-state rectifier is to use a combination of p-doped Si and n-doped Si. If a p-type semiconductor is regarded as an electron acceptor, an organic electron acceptor may replace a p-type inorganic semiconductor. Tetracyanoquinodimethane (TCNQ, Figure 1) was selected as an electron acceptor. As TCNQ has 8 -electrons, each molecule tends to accept two

electrons from the environment so that the Hückel theorem can be satisfied. A spin casting method is used to fabricate a junction of TCNQ and p- type or n-type Si due to its simplicity and easiness.
The I/V property between TCNQ and p-doped or n-doped Si will be measured using scanning tunneling spectroscopy.

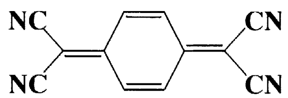

FIGURE 1. Structure of TCNQ

EXPERIMENTAL

For a practical application, the TCNQ film was fabricated by a spin casting method. 0.01 g of TCNQ (Aldrich, USA) solution in hexane was prepared and filtered through a 0.2 ſm membrane filter. The TCNQ film was fabricated on a Si wafer at the speed of 3000 rpm for 30 seconds and heated at 100 °C for 1 minute in order to vaporize residual solvent using a spin coater. An n-type (14~23 Ω cm) or a p-type (7~25 Ω cm) Si wafers (Siltron Inc., Korea) was chosen for investigation whether the junction properties of electron acceptor/n-Si or p-Si will affect the lithographic results. Before used as a substrate, 1 cm x 1 cm of Si wafer was cleaned in a 1:3 solution of 30% H_2O_2 and concentrated H_2SO_4 at room temperature for 30 minutes and rinsed with deionized water (Milli-Q reagent grade 18 MΩ cm, Millipore Co., USA) for 10 minutes.
The thickness and roughness of the spin-coated film were characterized using an AutoEl II null-type ellipsometer (Rudolph Technology Inc., USA) and an AFM (Digital Instruments Inc., USA), respectively.
All scanning tunneling spectroscopy (STS) experiments were performed under an air-operated STM system (DI, USA). An STM tip was prepared by a mechanically cutting Pt/Ir (80/20) wire without an etching process. During STS measurements, all feedback was opened with adjusting tip bias voltage and tunneling current to be 0.5 ~ 2.0 V, 1.5 nA for TCNQ /n-Si and -0.5 ~ -2.0 V, -1.5 nA for TCNQ/p-Si, respectively.

RESULTS AND DISCUSSION

1.5 ± 0.2 nm of TCNQ thin film was fabricated on p-doped or n-doped Si. The uniformity of the film was confirmed using AFM.
Figure 3 exhibits an I/V curve of doped Si only. Regardless of dopant

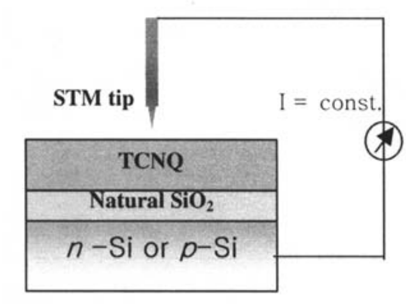

Figure 2. Scheme of STS

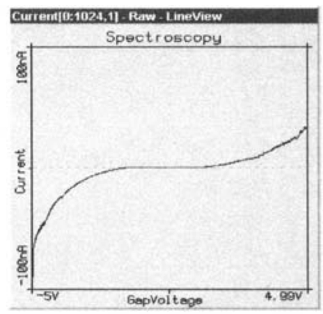

Figure 3. I/V of SiO_2/Si

type, this nonlinearity was commonly measured. No current was measured between –1 V and 1 V. Figures 4 and 5 present I/V curves of TCNQ/n-Si and TCNQ/p-Si, respectively. The I/V curves of the two systems were dramatically changed to reveal a rectifying property. The presence of only 1.5 nm TCNQ film altered I/V curves of the two systems dramatically. Even though there exists 1 nm thick natural SiO_2 layer, it can be regarded as a potential barrier which only limits current flowing through the system. The role of silicone oxide as a barrier is also found in other molecular-level device.[3]

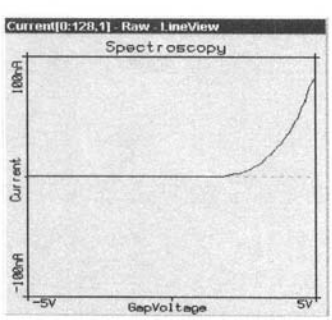

Figure 4. I/V of TCNQ/SiO_2/ n-Si

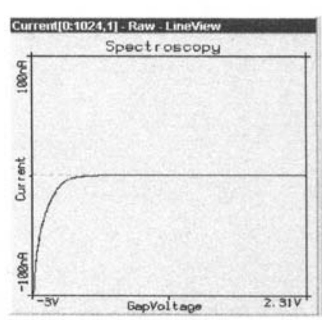

Figure 5. I/V of TCNQ/SiO_2/ p-Si

Further detail study has been carrying out for elucidation on mechanism of a rectifying property shown in the junction between an organic acceptor and n-/p-Si. The I/V data shown in Figures 3, 4, and 5 were confirmed by STS measurements at more than 10 different places with different tips.

For a fabrication process, AFM anodization lithography can be applied to this system.[6] It is expected that nano-sized patterning by the lithography enable us to make 50 nm x 50 nm rectifying units directly. Since TCNQ is a good electron acceptor, this active resist will reduce the starting voltage and widen the voltage range for the lithography.

CONCLUSIONS

We designed a methodology to build a nano-sized rectifier using a junction between organic molecules and a Si substrate. The rectifying property of the system was confirmed by STS. The application of AFM lithography to the system enables us to practically fabricate 50 nm x 50 nm rectifiers.

ACKNOWLEDGMENT

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