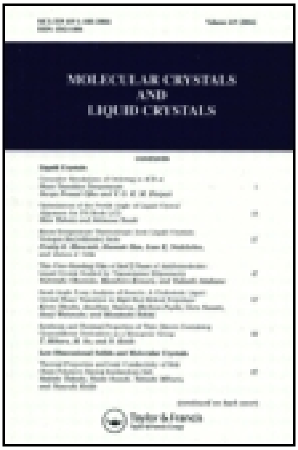

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Nanostructures Fabrication on Ta Thin Film Using Atomic Force Microscope Lithography

Sunwoo Lee [a], Haiwon Lee [a], Do Haing Lee [b], Byung-Jae Park [b] & Geun Young Yeom [b]

[a] Department of Chemistry, Hanyang University and The National Program for Tera-Level Nanodevices, Seoul, Korea

[b] Department of Material Science and Engineering, Sungkunkwan University, Suwon, Korea

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Sunwoo Lee
Haiwon Lee
Department of Chemistry, Hanyang University and The National Program for Tera-Level Nanodevices, Seoul, Korea

Do Haing Lee
Byung-Jae Park
Geun Young Yeom
Department of Material Science and Engineering, Sungkunkwan University, Suwon, Korea

Atomic force microscope (AFM) lithography based on localized current injection was carried out for fabricating nanostructures of metal oxide on tantalum (Ta). Fabricated nanopatterns of tantalum oxide (Ta_2O_5) were selectively etched by magnetically enhanced inductively coupled plasma (MEICP) etching system. Nanopatterns of Ta with feature size in the range of a few tens-hundreds nm were successfully fabricated.

Keywords: atomic force microscope (AFM) lithography; etching; nanopattern; Ta

INTRODUCTION

Local oxidation by atomic force microscope (AFM) lithography is considerable as a technique for the fabrication of nanometer scale structures with high resolution. The demand of next generation lithography such as AFM lithography, etc is increased in field of nano-device fabrication because of optical diffraction limit. Moreover, the applications such as MOSFET by Minne *et al*. [1], side-gated

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Address correspondence to Haiwon Lee, Department of Chemistry, Hanyang University, Seoul 133-791, Korea. E-mail: haiwon@hanyang.ac.kr

silicon FET by Campbell *et al*. [2], EUV mask by Sundermann *et al*. [3] have been accomplished until now.

Sugimura *et al*. reported the electrochemical reaction between an AFM tip and a substrate ($Si + 2OH^- - 4e^- \rightarrow SiO_2 + 2H^+$) [4]. Based on the electrochemical reaction of field enhanced oxidation in the presence of oxygens, metal oxide nanopatterns have been fabricated on metal thin film by AFM anodization lithography. As this lithographic technique is closely related to the magnitude of bias, the size of the protruded oxide pattern is strongly depended on the amount of electrons flown into the substrates. The fabrication of nanopatterns is also known to be affected by applied voltage, lithographic speed, humidity and substrate property [5].

In this study, we have investigated the fabrication of the anodic oxidations of Ta depending on applied bias voltage and the nanopatterning of Ta using AFM lithography.

EXPERIMENTAL

For fabricating of nanostructures on metal thin film, Ta was deposited on n-type Si (100) wafer ($\rho \sim 14$–$23\,\Omega\,cm$, LG Siltron, Korea) at the condition of DC 100 W bias power, 5 m torr working pressure by magnetron sputtering system (CSS12, Chungsong, Korea) after rinsing with acetone. Thickness of Ta thin film is ~10 nm. The lithographic process using Autoprobe CP (Park Scientific Instruments, USA) and imaging process using Autoprobe CP and XE-100 (advanced scanning microscope, Korea) were accomplished with platinum coated tip (CSC12/Pt, μ mash, USA) under the contact mode. The relative humidity and ambient temperature during the AFM lithography were maintained at the condition of 35% and 30.8°C, respectively. The dry etching of fabricated Ta_2O_5 was carried out by C_4F_8 gas using MEICP etching system. It was controlled at the condition of gas flows of 11 sccm, working pressure of 10 m torr, rf power of 600 W, bias power of −120 V and the etching time of 20 sec.

RESULTS AND DISCUSSION

The AFM image of protruded Ta_2O_5 nanostructures and the variation of height and width of nanostructures on Ta, which is depended on applied bias voltage at the constant condition of lithographic speed and humidity, are shown in Figure 1. Nanostructures on Ta have the width in the range of about 100 nm at condition of bias voltage of 18 V. The height of nanostructures is increased linearly. Whereas, the width of nanostructures is dramatically increased as bias voltage

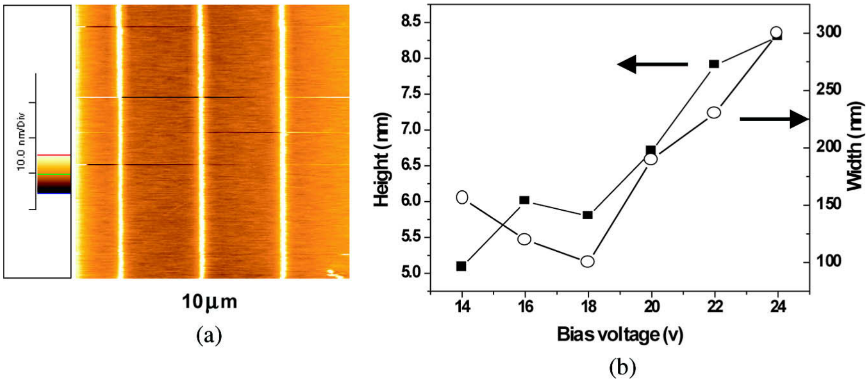

FIGURE 1 (a) AFM image of the fabricated nanostructures and (b) variation of height and width depending on applied bias voltage.

is increased in 18 V and above. Generally, the electrical field is enhanced depending on the increasing of bias voltage. OH^- ions, which play a role in fabricating of oxide, are dissociated from water bridge because of electrical field and also enhanced. Below 18 V bias voltage, Ta_2O_5 is grown in local area depending on the diffusion of a few OH^- ions, the width of nanostructures is decreased; whereas, above 18 V bias voltage, the fabrication of Ta_2O_5 is rely on the surface reaction between OH^- ions and surface because of much OH^- ions, the width of oxidized nanostructures is increased. Thus, it is suggested that the optimized lithographic voltage for fabricating of Ta_2O_5

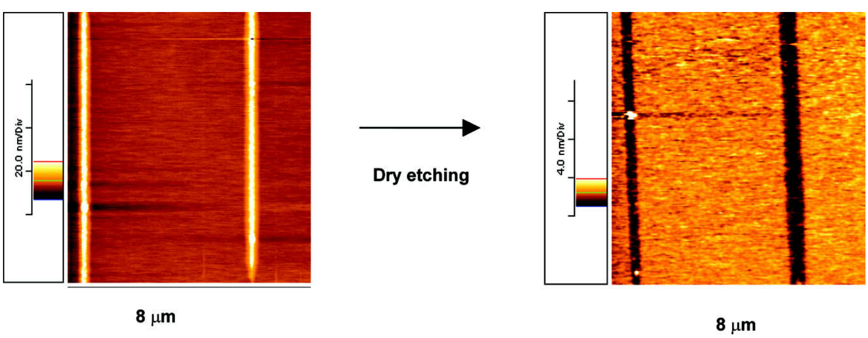

FIGURE 2 AFM images of nanopatterns etched by dry etching.

nanosructures with fine pattern at the constant condition of humidity and lithographic speed is 18 V between a tip and a substrate.

For fabricating nanopatterns of Ta, pure C_4F_8 gas as an etching gas was used. The etching of oxidized Ta_2O_5 was carried out without shadow mask because of high selectivity between Ta and Ta_2O_5. Nanopatterns of Ta is shown in Figure 2. The etching of Ta_2O_5 was accomplished by volatile by product (TaF_5), which formed by chemical reaction between C_4F_8 and Ta_2O_5. Nanostructures have etching depth in the range of about 1–2 nm and the width in the range of about 200 nm.

CONCLUSION

It is shown that protruded nanostructures of metal oxide by AFM lithography and nanopatterns of metal thin film by dry etching is successfully fabricated. The fabrication of metal oxide nanosrtuctures is powerfully affected by applied bias voltage between a tip and a substrate. C_4F_8 gas, which is used for dry etching of metal oxide, had high selectivity between Ta and Ta_2O_5 and was suitable for etching with maskless between them. Nanopatterns with feature size in the range of 100–200 nm are fabricated by two methods. It is shown that nanopatterns of several metal thin films such as Ta is able to the application of device using AFM lithography.

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