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Fabrication and Characterization of DNATemplated Gold Nanowires for the Application to Nanodevices

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Abstract. We investigated an efficient method for large-scale alignment of DNA molecules and thus DNA templated gold nanowires (AuNWs) on 3aminopropyltriethoxysilane (APS) coated Si wafer. It was confirmed that virtually all the DNA molecules were aligned in long-range order (from 16 to 20 μm) over large areas (from 30 to 40 μm) along one direction, which was the same as the flow direction created by tilting. Surface tension and flow rate (tilt angle), and DNA concentration were used to control the density and height of DNA aligned on the surface. In addition, DNA-templated AuNWs with a complete contact between particles were obtained when the treatment time and the DNA concentration were optimized. For electrical conductivity measurement, an isolated AuNP chain was fixed between two gold electrodes. And, the AuNP chain based on DNA showed an ohmic behavior at room temperature with the conductivity of two orders of magnitude lower than the bulk value.

Keywords; DNA; AuNPs, AuNWs; Nanodevice

1. Introduction

DNA molecules are essential building blocks in nanotechnology. They are being extensively investigated for application to nano-scale electronic devices, such as fieldeffect transistors (FETs) [1,2], chemical and biological sensors [3,4], and

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nanodiodes [5]. DNA itself is a nanowire with a diameter of about 2 nm and has a very long well defined polymeric sequence with functional groups [6,7]. However, it is difficult to apply it to nanodevices as conducting wire due to its high resistance and the high contact resistance with metal electrodes. This lowers its potential applications.

In this work, we present a fabrication of conductive nanowires made of gold nanoparticle (AuNP) chains based on DNA molecules immobilized on a surface of 3-aminopropyltriethoxysilane (APS)-coated Si wafer as the template. A tilting technique was used to align and stretch the DNAs on the surface. Aniline-capped AuNPs ANAuNPs) were electrostatically assembled along the immobilized DNAs by careful control of the AN-AuNPs treatment time and the DNA concentration. AuNPs are attached on DNA with a reduction in Au surface potential as the treatment time increases. Also, the interparticle spacing is dependent on the treatment time and the DNA concentration. AuNP chains with a complete contact between particles were obtained when the treatment time and the DNA concentration were optimized. For electrical conductivity measurements, an isolated AuNP chain was fixed between two gold electrodes. The AuNP chain based on DNA showed an Ohmic behavior at room temperature with the conductivity of two orders of magnitude lower than the bulk value.

2. Methods

Silicon (Si) substrates was functionalized to align DNA molucules using two methods: the first is to coat APS on Si substrate and the second is to functionalize organic polymer films. Firstly, a Si substrate was cleaned in a piranha (H2SO4:H2O2 v/v = 2:1, Sigma) solution to form OH on its surface, and then rinsed with doubly distilled water and dried out with N2 flow [7]. Next, it was immersed in a 0.1 mM APS (Sigma) solution of anhydrous toluene (Sigma) and maintained for 30 minutes to obtain surface functionalized with an NH2-terminated self-assembled monolayer (SAM). The APS coating was to enhance the attachment of DNAs by electrostatic interaction between the -NH3+ moiety and the negative DNA backbone [7]. Finally, The organic polymer film with 200 nm average thickness was deposited on Si substrate at RF power of 20 - 50 W by the PECVD method using cyclohexane, and these organic films were then treated by the dielectric barrier discharges (DBD) method in a nitrogen (N2) environment under atmospheric pressure at RF power 150 W for 60 seconds to form the amine groups on the polymer film surface. The NH2-functionalized surface plays an important role in attaching the DNA onto substrate through a strong electrostatic interaction between the amine groups of the sample surface and the negatively charged phosphate backbone of the DNA [7].

3. Results

Fig. 1 shows the AuNPs assembled along the aligned DNA chains after the treatment with AN-AuNPs solution. The average height of DNA nanowire assembled with AuNPs was 15.3 ± 2.3 nm. Several parameters were varied while others were fixed to understand the controlling factors for the formation of AuNP chain. One important control factor is considered to be the time to treat DNA with AN-AuNP solution. During the treatment, the solvent was evaporated and the ionic strength in the solution increased. Under ambient condition, the evaporation typically shrinks the droplet with the centre thickness of 10 mm and the height and contact angle was changed by evaporation with the time. However, the radius of the droplet was not shrinked because its contact line was pinned by surface tension.

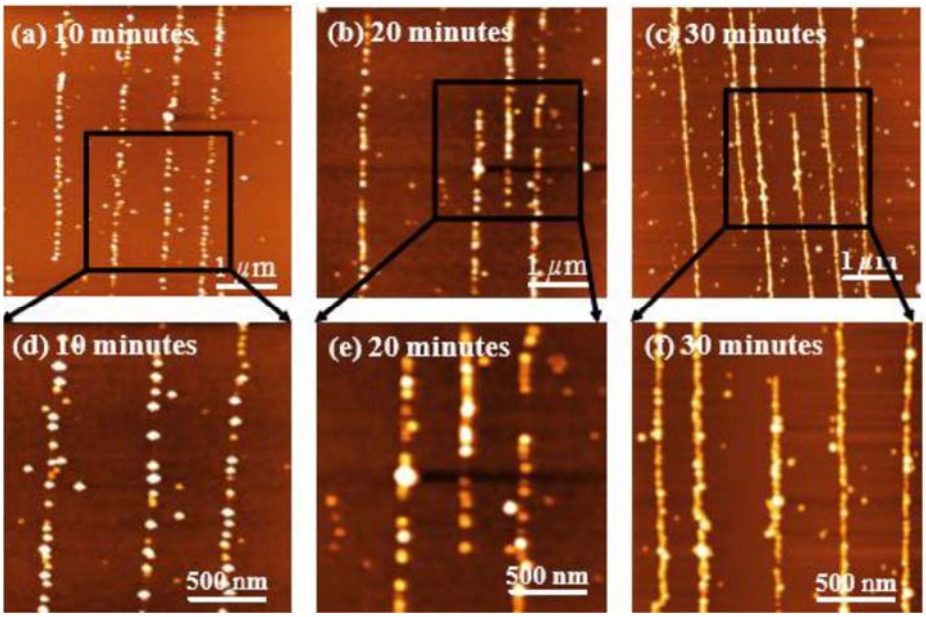

Fig 1. AFM images of the larger scale area with better resolution.

4. Conclusion

a simple and efficient method was demonstrated for large-scale alignment for DNA molecules and thus DNA templated gold nanowires (AuNWs) on a surface of 3-aminopropyltriethoxysilane (APS)-coated Si wafer. The main parameters controlling the alignment of DNA on an APS-coated surface were the surface tension (APS concentration), tilt angle (meniscus speed) and DNA concentration. The observation

DNA demonstrated that the average count and height of the aligned DNA depended on the parameters used in the alignment process.

Secondly, the highly conductive gold nanoparticle chains were formed using DNA templates. The estimated conductivity of the wire was only two orders of magnitude less than that of bulk gold, giving clear evidence of the metallic character of the wire. We found that the important parameters in the fabrication of the conductive AuNP chains were the DNA density on the APS-coated Si surface and the treatment time of the positively charged AuNPs reacting with DNA. The average interparticle spacing between AuNPs decreased when the treatment time increased and the DNA density decreased.

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