Protein-Induced Electrical Variation on Gold-Silicide Embedded Nanowires

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Recently, there has been an increasing demand to find simple and rapid methods for the detection of specific protein, which can also be used easily in non-specialized laboratories. Semiconductor processing devices such as nanowires and nanogaps possess the advantages of low cost and high sensitivity. Since crystal silicon nanowire is a promising material for gas, pH, and biosensor, silicide nanowire can be expected to be used in sensing technique, too. In this study, we propose the streptavidin molecule that can alter conductance of a self-aligned one-dimensional gold-silicide embedded nanowire and behave like a protein sensor.

The fabrication process for the gold-silicide embedded nanowire is described below. Prior to deposit the poly-silicon film, the field oxide is thermally grown on the silicon wafer. Then, the negative electron beam resist is spin-coated for nanowire patterning. After a series of electron beam exposure, wet development, TCP 9400 poly-Si etching, and resist stripping, the wafer is thermally deposited 50nm gold thin film. Then furnace annealing at the temperature of interest, the device is then immersed in the aqua regia ($HCl:HNO_3$=3:1) solution to remove the un-reacted gold metal. The 80 nm gold-silicide nanowire is successfully achieved. The SEM morphology of the nanowire is illustrated in Fig. 1. We use the HP-4156 analyzer to characterize the electrical signal.

As to the protein immobilization, Fig. 2 illustrates the surface immobilization and sensing procedures. We wash the gold-silicide embedded nanowires with ddH_2O, ethanol, and acetone, respectively. Then, the nanowire is immersed in the 1,2-ethanedithiol solution for 30 minutes. After DMF washing, the sample is again immersed in the 0.1 % sulfoSMCC solution for one hour. In order to confirm the success of surface immobilization, we use the 10 mM rhodamine to covalently bond with the sulfoSMCC. The red fluorescence in Fig. 3a clearly convinces that the molecule has already assembled onto the surface. In similar, the biotin molecule is first assembled onto the sulfoSMCC for the protein analysis. Due to the extremely high affinity of biotin-streptavidin interaction, the pre-assembled biotin molecule can recognize the FITC-conjugated streptavidin molecule in the solution. The observation in Fig. 3b indicates the streptavidin molecule has assembled onto the nanowire.

Figure 4 shows the electrical conductance ratio of unbinding nanowires in each experiment sequence. It exhibits no conductance change for silicide embedded nanowires from the modification step of ethanedithiol and sulfoSMCC. However, upon applying the biotin to attach on, the conductance ratio decreases. Once the streptavidin is bonded with biotin, the conductivity of the nanowire is enhanced. Table 1 list more detailed conductance data for various sizes of nanowires. The decreasing trend of conductance after binding biotin is observed. Due to the size effect, 100nm nanowire has the largest decrease of conductance ratio. Interestingly, the steptavidin molecules affect the nanowire's conductance independently with size effect. The reason of conductance variation and sensing mechanism are under investigations. The experimental results such as annealing conditions, four probe sheet resistances, and more biomolecules sensing examples will be given in this conference.

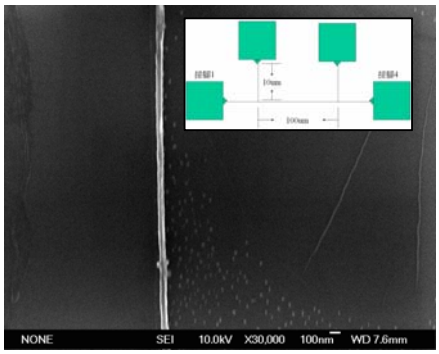

Figure 1. The SEM morphology of 80 nm gold silicide nanowire. Inset: the schematic diagram of Kelvin structure.

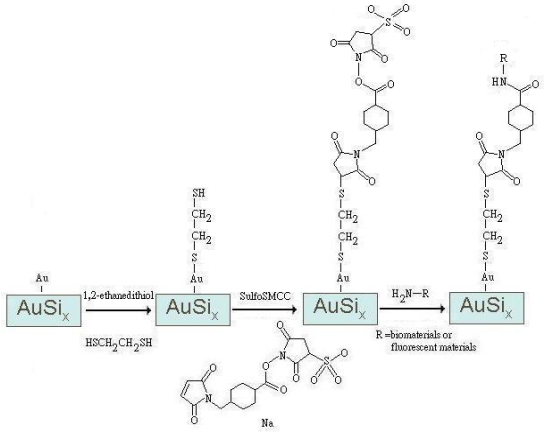

Figure 2. The process of immobilization of biomelecules to the gold silicide. R represents Rhodamine or biotin.

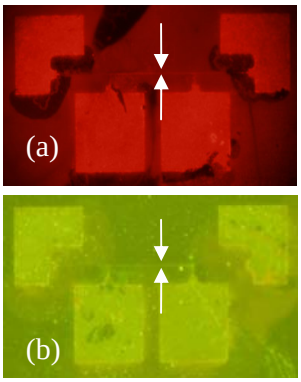

Figure 3. (a) The image of rhodamine fluorescent molecule on the gold silicide. The region with marked arrow is nanowire. (b) The immobilization of biotin and FITC-conjugated streptavidin on the gold silicide. The region with marked arrow is nanowire.

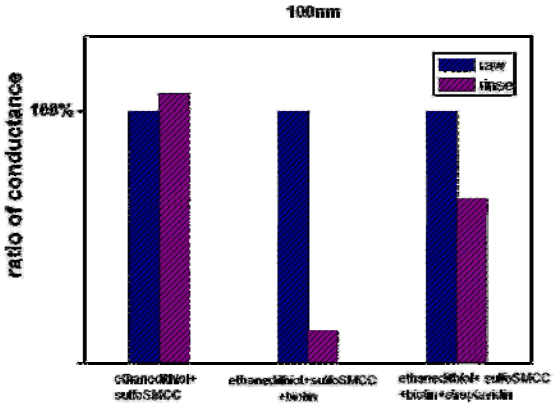

Figure 4. The conductance ratio of unbinding nanowire with steps of surface modification, biotin and streptavidin attachment.

Table I. The conductance ratio of nanowire of 80, 100, 120 and 200nm with steps of surface modification, biotin and streptavidin attachment.

Molecules Attachment	binding / raw (%)				
	80nm	100nm	120nm	200nm	average
ethanedithiol and sulfoSMCC	96.5%	107%	108%	91.6%	100.6%
ethanedithiol, sulfoSMCC and biotin	26.6%	12.9%	58.9%	36.7%	33.78%
ethanediditiol, sulfoSMCC, biotin and streptavidin	67%	65.5%	58.6%	68.9%	65%