Electrochemically Grown Individually Addressable Nanowires for Sensor Arrays

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One-dimensional structured materials, such as nanowires and nanotubes (NTs), the primarily building materials for nano-sensors because they can function both as sensor elements and as the electrical contacts that access them. Cui *et al.* demonstrated that silicon nanowire-based sensors are capable of highly sensitive and selective real time detection of biomolecules [1]. Star *et al.* demonstrated the carbon nanotube based FET devices [2]. The other methods currently being used in the fabrication of nanowires include template synthesis [3], electrochemical step edge decoration [4], carbon nanotube encapsulation [5], and use of nanogap [6]. While these methods offer good flexibility of the processes, they have intrinsic drawbacks of controllability and low throughput. In this work, we report an approach to grow individually addressable nanowires for sensor array application using e-beam lithography and room temperature SiO deposition.

Electrodeposition is an alternative method to fabricate nanowire sensor array with wide ranges of sensing materials available including metals, alloys, metal oxides, semiconductors, and conducting polymers. The electrodeposition allows a high degree of specificity in location and chemical identity of a deposit, as well as a high degree of control over thickness [7]. In addition, electrodeposition allows to directly fabricate nanowires between contact electrodes, eliminating expensive and tedious post assembly.

The growth of nanowire sensors with controlled dimensions is very important in sensor detection limits and response time. We report a fabrication technique, which has potential to produce nanowire sensors with controlled dimensions. This technique has the potential of allows producing individually addressable nanowire sensor arrays with multi-chemical sensing capabilities.

Figure 1 shows the schematic procedure of fabricating an electrodeposited nanowire sensor with controlled dimensions. The processes used in this work including cleaning, dry etching, low-pressure chemical vapor deposition (LPCVD), lithography, dielectric deposition, e-beam lithography, metallization and electrochemical deposition are standard semiconductor fabrication techniques. When an electrical potential is applied between the electrodes, the nanowire grows from the cathode to the anode through the nanochannel because of the locally high electric field. The dimensions of the nanowire are predetermined by the width of the nanochannel and the distance between electrodes.

To demonstrate the technique, palladium wires with 1 micron diameter and 3 to 7 micron lengths were electrodeposited. The lengths of the wires can be either much shorter or longer. Two different electrodeposition solutions (i.e. palladium chloride acid bath and palladium p-salt alkaline bath) were initially considered. However, the preliminary experimental results indicated that palladium p-salt (diaminodinitrite) solution produces a smoother deposition with minimum dendrite formation at higher cathodic potentials. Figure 2 shows Digital images of electrodeposited palladium wire grown between electrodes.

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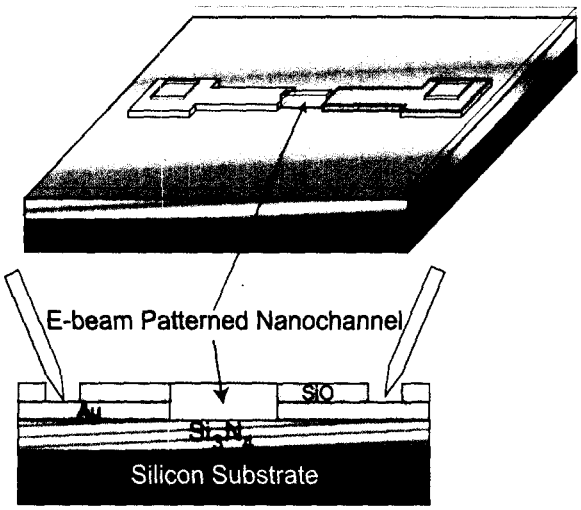

Figure 1. Schematic of nanowire sensor. (a) Top view represents double wires connected between electrodes. (b) Cross-sectional view shows Si substrate, Silicon nitride (1 μm), Au as a contact metal up to 3000 Å, and thermally evaporated SiO. Nanochannels are formed between electrodes using SiO for electrolyte solution channels.

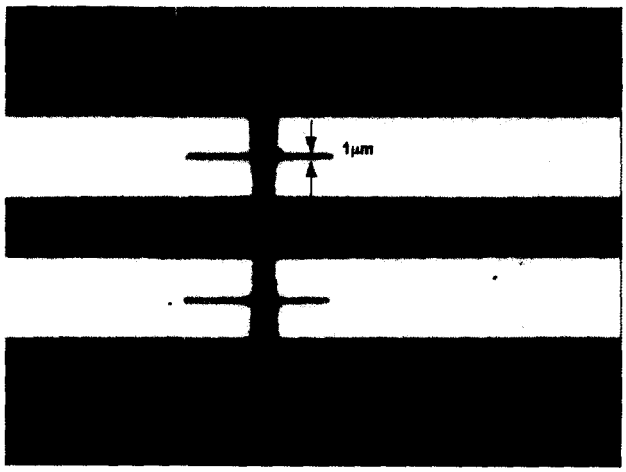

Figure 2. Digital images of electrodeposited palladium wire grown between electrodes: double wires on same electrode with 3 to 5 micron spacing.