Electrical, Thermal, and Mechanical Properties of Nano Mechanical Structures

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1. Introduction

To achieve practical nanotechnology, which has garnered much attention in recent years, it is essential to establish a method of evaluating small matter on the nano order. In this study, we investigated methods for measuring electrical, thermal, and mechanical properties of nano-size matter using micromachine technology. There are two conceivable methods for measuring the properties of nanostructures. One method integrally forms a nanostructure with an approachable electrode structure. The other method uses multiple nanoprobes to probe nanostructures. The following is a report of these two methods as studied in our research.

2. Four-Terminal Freestanding Silicon Nanostructure

We produced a four-terminal nanostructure for measuring the thermal response of silicon nanostructures. Fig. 1 shows an SEM photograph of this element. The cross-section of the wire is shaped as an isosceles triangle with a width of about 0.5 μm and a length of 4 μm. Fig. 2 shows the inverse relationship between input power and the resistance variations of the element. We can see there is a sharp peak in the resistance at a particular input power. Fig. 3 shows the properties of this element as a flow sensor and its frequency characteristics, illustrating that an air flow can be measured even by such a nano scale element.

3. Silicon Nanostructure Testing Device Using an Integrated Microactuator Element

We developed a process for integrally forming a silicon wire structure with an electrostatic actuator in order to study the mechanical properties of nanostructures. Fig. 4 shows an SEM photo of this device. This device is manufactured with a three-layer SOI wafer, wherein the electrostatic actuator is formed by the middle SOI layer and a nanostructure having an electrode terminal is formed by the top SOI layer. A special technique is implemented in this process to produce the nanostructure in freestanding form.

4. Conclusion

This was a report on nano-scale measurements using micromachining technology. The present study was limited to devices for measuring silicon nanostructures. However, there has recently been increasing interest in bio-nano objects, such as DNA, thereby necessitating a system capable of routinely measuring such objects. To aid in these measurements, we are developing integrated microactuator devices called nano-grippers and nano-testers. Please take a look at these devices, as well.

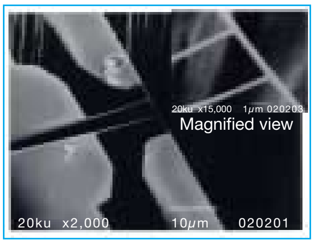

Fig. 1 SEM photo of a four-terminal free-standing silicon element

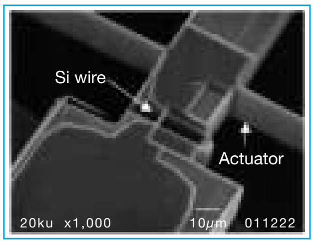

Fig. 4 An integrated electrostatic actuator type mechanical nanostructure testing device

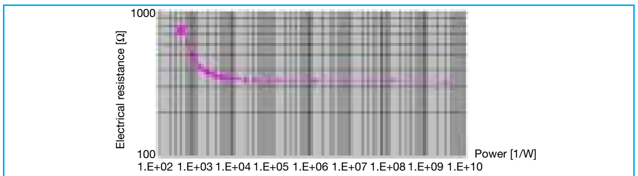

Fig. 2 Resistance variations in the free-standing nano wire

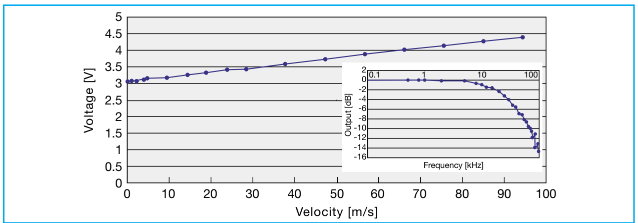

Fig. 3 Characteristics of a flow sensor employing a free-standing silicon nano wire

Integration of Chemical Systems toward Artificial Organs

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1. Introduction

It is believed that chemical conversion processes performed by organs, including metabolism, detoxification, and bio-synthesis, consist of cell response, enzymatic reactions, synthesis, and the like that progress very efficiently as a series of reactions within micro spaces, such as capillaries and cell surfaces.

We concluded that we could use microchannels, having a width of several tens to several hundreds of microns and manufactured on a microchip, in place of capillaries and accumulate elementary processes of organs, such as cell response, enzymatic reactions, and synthesis to achieve an efficient model of an artificial organ on a microchip, which would transcend a simple combination of macroscale reaction processes. The objective of this study was to detect multiple stage chemical conversion processes of sugar by integrating cell response, enzymatic reactions, and synthesis.

2. Integrating Modeled Chemical Reactions of an Organ on a Microchip

Fig. 1 shows our designed microchip, which comprises a cell culture bath, enzymatic reaction section, synthesis section, and sensing section. When lipopolysaccharide is introduced from an external source as a sugar and reacted with microphage, nitric oxide (NO) is produced. The generated NO is immediately converted into NO_2 and NO_3 by a reaction with water. Of these, NO_3 is converted into NO_2 by an enzyme introduced through a separate channel and subsequently generates a colored chemical species through a reaction with a mixing reagent introduced through the next channel. Hence, it is possible to confirm a series of chemical conversion processes by detecting this colored chemical species through a thermal lens microscope.

While it required half a day to detect the above series of reactions using a simple combination of macroscale reaction processes, the same series on a microchip only took 30 minutes. This indicates that by introducing a sugar into an artificial organ, such as a microchip, a colored chemical species is efficiently produced through various chemical processes.

3. Conclusion

The integration of elementary processes in a micro space, as described above, is extremely important to the realization of organ functions and other advanced biological functions on an artificial device. In the future we hope to be able to construct even more complex biological function mimicking devices by integrating many technologies, such as molecular fixation and a technique for fabricating functional separation membranes on a single chip. We also hope to apply this new knowledge to reproduction engineering and artificial organ development.

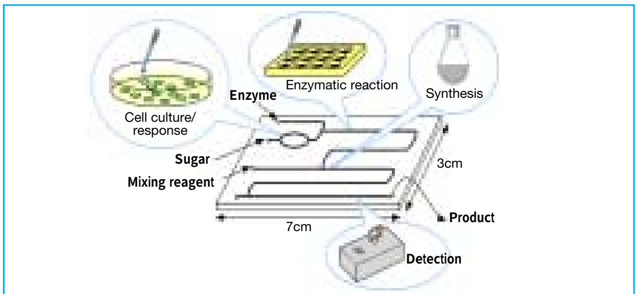

Fig. 1 Integrating Organ Chemical Reactions on a Microchip