MEMS - Semiconductor Process Integration Monolithic Manufacturing Technology

(The Search for a New MEMS Sensing Principle)

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Forming components comprising semiconductor ICs and sensors, actuators, or other MEMS devices in an integrated manner will make it possible to create more compact, more highly functional and more reliable devices. The need for improvement is particularly keen in areas such as automobile components and medical sensors, in which advancement is a must.

In the case of MEMS semiconductor integration, the technical complexity increases along with the level of integration, due to the complexity of conducting the design using different processes, the duplication of manufacturing equipment and so on. Moreover, whereas the size of the transistors making up the IC is in the sub-μm domain, the size of the elements making up the sensor are in the μm domain. As a result, a size of several mm is needed to accommodate the entire sensor, and this increases the size of the chip with which the IC is integrated. In this way, the complexity of the technologies used in the manufacturing process and the resulting lowered yield and increased chip size reduce the yield constant, making it impossible to maintain profitability in cost terms.

The purpose of this development project was to resolve this problem by developing a manufacturing technology for creating MEMS and semiconductors in an integrated manner, thereby providing higher added value and more advanced functions. The ultimate goal was to increase the international competitiveness of Japan's unique leading-edge technologies.

In particular, we aimed to create the advantages that would be obtained from higher added value and more advanced functions. We focused on the piezoelectric element that is one of the basic sensor elements, working to determine its properties at the sub-μm level and to find a sensing principle that would lead to higher sensitivity.

Achieving a nanomechanical structure and determining nanoelastic properties

It is not yet clear whether the same mechanical properties are maintained or different mechanical properties are exhibited when a mechanical sensor mechanism is reduced to the sub-μm scale or smaller. The purpose of this study was to measure this experimentally in the hope that the results would serve as useful data for the design of highly integrated MEMS. **Fig. 1** shows an autonomous silicon nanomechanical structure manufactured by means of Scanning Probe Nano Lithography (SPNL). **Fig. 2** shows the structure of a nanoelectromechanical system (NEMS) resonant device. From these resonance properties, the mechanical properties were measured and their application in sensors was studied. The planned width of the nanowire and the gap between electrodes is less than 100 nm.

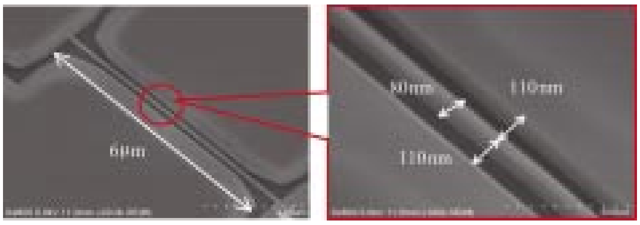

Fig. 1 Stand-alone Si nanowire manufactured using Scanning Probe Nano Lithography (SPNL)

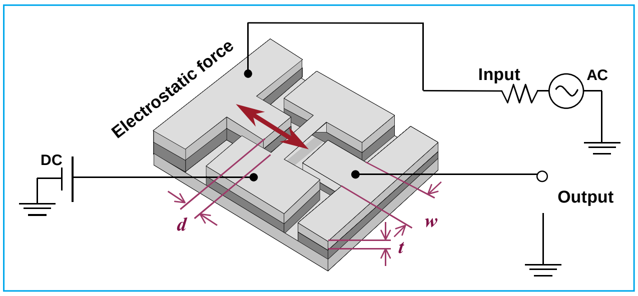

Fig. 2 Structure of Nanoelectromechanical system (NEMS) resonant device

Determining the piezoresistance effect of nanoscale silicon

The piezoresistant elements used as sensing elements in mechanical sensors are simple in terms of structure and detection path. For this reason, they have been widely used in pressure sensors and acceleration sensors and so on. As shown in **Fig. 3**, when the width of the silicon piezoresistant element is reduced to the sub-μm level or below, the coefficient of piezoresistance, which affects sensor sensitivity, increases greatly. We focused on this phenomenon in our efforts to increase sensor sensitivity. First, we reduced the width of the silicon piezoresistant element to 100 nm or below and conducted a theoretical analysis of piezoresistance based on the low-dimensional band structure. Based on these analytical predictions, we plan to manufacture a silicon piezoresistant element and determine the actual coefficient of piezoresistance. It is thought that, if the prediction is correct, sensor sensitivity will be increased anywhere from several times to nearly an order of magnitude greater.

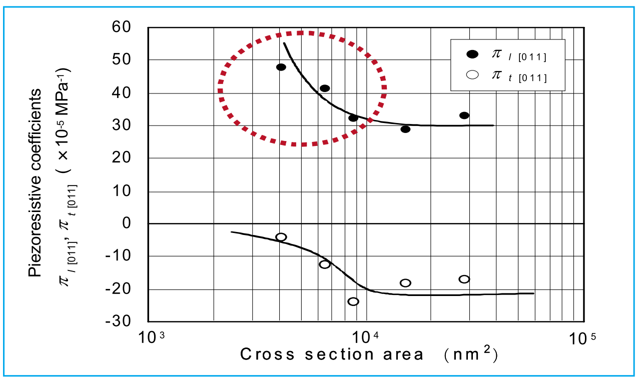

Fig. 3 Relationship between Si piezoresistance effect and section area