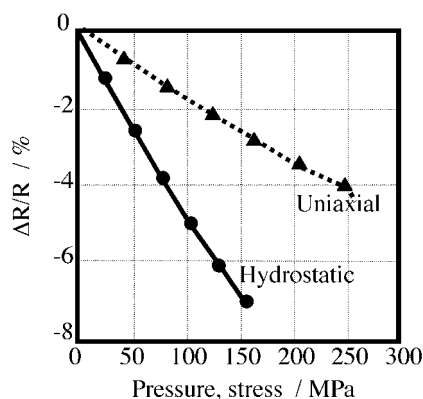


### 1. Introduction

A conventional force sensor consists of a beam or a diaphragm to which a thin-metal film strain gauge or a semiconductor strain gauge is glued. The force is detected by the resistivity change in the strain gauge in accordance with the applied force. The phenomenon that resistivity varies with the applied force is called piezoresistivity. The necessity of gluing the gauges to the beam or the diaphragm limits the downsizing and cost reduction of the conventional force sensor. If there were a material which had both the structural strength and the function to detect force such as piezoresistivity, the beam or the diaphragm would become unnecessary and the sensor could be miniaturized and the cost would be reduced. Therefore, the authors have developed a novel ceramic composite which has both the force detecting function and structural strength by distributing an oxide material having a piezoresistivity in a high strength ceramic.

### 2. Force sensor material and characteristics

For the matrix material, partially stabilized zirconia was selected from among ceramics for its high strength and toughness. For the distributing material, piezoresistive-effect  $\text{La}_{0.75}\text{Sr}_{0.25}\text{MnO}_3$ <sup>1,2)</sup> was selected for its chemical compatibility with zirconia and comparatively flat temperature characteristics near room temperature. The powders of both materials were wet-mixed, press-formed and sintered in an oxygen atmosphere to obtain a dense sintered body. An XRD analysis verified that a third phase is not generated and the EPMA analysis verified that diffusion at the interface is small. When the fraction of  $\text{La}_{0.75}\text{Sr}_{0.25}\text{MnO}_3$  is over 20 mass%, conductivity appeared to be due to percolation conduction. **Fig. 1** showed the relationship between the both uniaxial compression and hydrostatic pressure and variation in resistivity. The resistance varied almost linearly with either one of these stresses. Within the range of stress shown in the figure, the material showed a several percent variation in resistivity and it can be used for a sensor having a comparatively high rated force or load. What makes it different from the Si semiconductor



**Fig. 1** Relationship between stress and variation in resistivity.

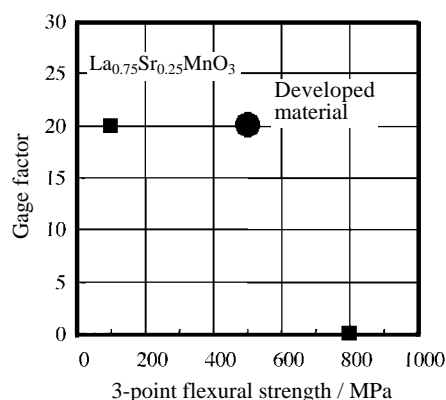
type sensor material is that it has a higher sensitivity to hydrostatic stress. This material can be used to design a simple pressure sensor device with a prospective application. **Fig. 2** showed the flexural strength of the developed material and the gauge factor for the uniaxial compression. The gauge factor was almost equivalent to the distributed  $\text{La}_{0.75}\text{Sr}_{0.25}\text{MnO}_3$  and the strength was about 500 MPa, which was enough for use as a structural member, although it was lower than the matrix. In other words, the developed material has been successfully provided with both a load detecting function and the strength required for a structural member. Using the developed material, we made a very small force sensor sample as shown in **Fig. 3**. Regarding the properties of the material, the resistivity variation drops when the temperature exceeds 50°C. To make this material more widely applicable, the temperature characteristics are being improved.

### 3. Conclusion

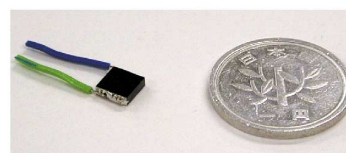
A force sensor material having both a sensor function and structural strength has been developed for the first time in the world. As it enables the structural member itself to become a sensor, the size of the sensor can be sharply reduced. The author expects that this sensor material will open up new potential applications for load detection.

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**Fig. 2** Relationship between 3-point flexural strength and gauge factor.



**Fig. 3** Force sensor sample for 500kgf.