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# Development of a two dimensional scanning Seebeck coefficient measurement system by a micro-probe method

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ABSTRACT

A Seebeck micro-probe measurement system with high spatial resolution has been developed to examine two-dimensional spatial distribution of Seebeck coefficient for thermoelectric materials at room temperature. A contact area of 10 μm$\phi$ is realized by using a Copper probe tip fabricated by a mechanical machining process. The two-dimensional spatial distribution of the Seebeck coefficient for the Bismuth–Telluride and Zinc–Antimonide systems has been measured. The sign inversion of the Seebeck coefficient from p- to n-type is clearly detected along the crystal growth direction in the Bismuth–Telluride system. On the other hand, the anisotropic Seebeck coefficient reflecting grain distribution is conspicuously observed in the Zinc–Antimonide system.



## 1. Introduction

A micro-probe method has been developed to examine local physical properties and/or distribution of physical quantities originating from inhomogeneity of chemical composition and crystal structure of materials [1–4]. Furthermore, the micro-probe method has been applied to use a high-speed combinatorial examination of thermoelectric properties for various thermoelectric materials [5–7]. Recently, the development of new measurement methods for physical properties at a micro- or nano-scopic area becomes so important and is highly desirable associated with the recent development of functionally graded materials and nano-structured materials. The purpose of this study is to develop a two dimensional scanning Seebeck coefficient measurement system by a micro-probe method with high spatial resolution and to examine the two-dimensional distribution of the Seebeck coefficient for the Bismuth–Telluride and Zinc–Antimonide thermoelectric systems.

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## 2. Seebeck micro-probe measurement system (SMP-MS)

### 2.1. Fabrication of Seebeck micro-probe tips

Fig. 1 shows photographs of two different types of Seebeck micro-probe tips fabricated in this study. Copper was selected as a probe-tip material because of the high-thermal and electrical conductivities and low Seebeck coefficient as well as an easy machining process. A contact area of 10 μm$\phi$ was obtained by a mechanical machining process using a microscope (Fig. 1 (a)). The dimension of the probe tip is 4 mm in diameter and 4 mm in length with flat surfaces on both sides by spark-erosion cutting to attach heaters on the flat surfaces as explained later. An angle of relief of 120° for the probe tip is adapted to secure mechanical strength of the probe tip and to lower thermal resistance between the tip and a sensor position in the probe. A Teflon coated Alumel–Chromel thermocouple of 0.076 mm$\phi$ was selected as a sensor and attached to a drilled hole with a diameter of 0.2 mm$\phi$ located 0.5 mm above from the probe tip by a silver paste as shown in Fig. 1 (b). Two strain gauges (Kyowa KFL-1-120-C1-16) connected in a serial way with a total electrical resistance of 240 Ω were used as a heater to generate temperature difference between top and bottom surfaces of a sample. These heaters are attached on both side walls of the probe tip by a wanish.

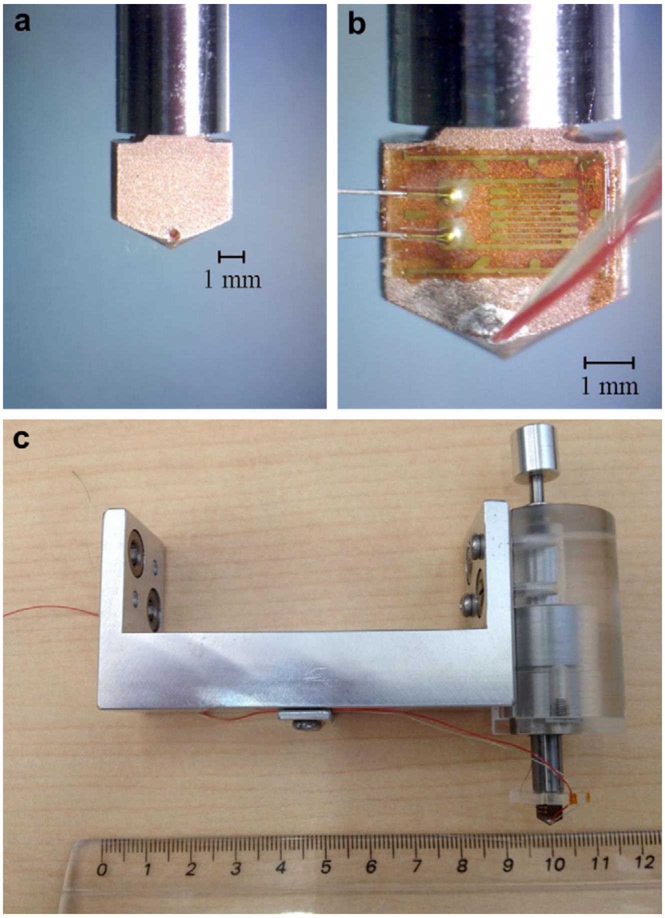


**Fig. 1.** Two different types of the Seebeck-micro probe tips fabricated by a mechanical machining process (a) and (b), and the whole figure of the Seebeck micro probe with the mechanical machined tip (c).

Fig. 1 (c) shows a photograph of a whole figure of the Seebeck micro probe. The Copper probe tip is attached to a metal shaft made by stainless steel mediated by an insulating acryl spacer to suppress heat leaking from the Copper tip to an upper part of the probe. A coil spring with a spring constant of 10 gf/mm is equipped in an upper acryl cylinder to make good thermal and electrical contacts between the probe and sample. A typical contact pressure is estimated to be of the order of 100 kgf/mm$^2$ when a contact area of 10 $\mu m\phi$ and a spring stroke of 1 mm are assumed. Any remarkable effect of the contact pressure on Seebeck coefficient is not observed. Seebeck coefficient does not depend on the contact pressure when the pressure is changed by five times by increasing the spring stroke from 1 to 5 mm. As shown later, the measured values of the Seebeck coefficient for the Bismuth–Telluride and Zinc–Antimonide systems are in good agreement with those measured by other commercially available apparatus. The Alumel–Chromel thermocouple and lead wires of the heater are fixed on a probe arm made by Aluminum through an acryl wire-guide plate and connected with twisted Copper wires at a thermal anchor located on a thermal bath made by Copper.

### *2.2. Constitution of the SMP-MS and a measurement procedure*

Fig. 2 shows a schematic drawing of the Seebeck micro-probe measurement system (SMP-MS) developed in this study. The system consists of two digital nano-voltmeters (Agilent 34420A), a dc current source (Agilent E3647A), a function generator (nf DF1906), *XY* and *Z* stages (SURUGA SEIKI KS202-70 and PZG413-L05AG), a stepping motor controller for the stages (SURUGA SEIKI D223) and a personal computer. All the instruments are controlled by the PC via GPIB-USB interface (Agilent 82357B) with a full-automatic measurement program composed by LabView. Data analysis software is also developed in this study. The measurement condition such as shape and size of a measurement area, a magnitude of heater current, trigger frequency and points for data acquisition, a probe stroke and temperature equilibrium condition are input as initial parameters of the measurement.

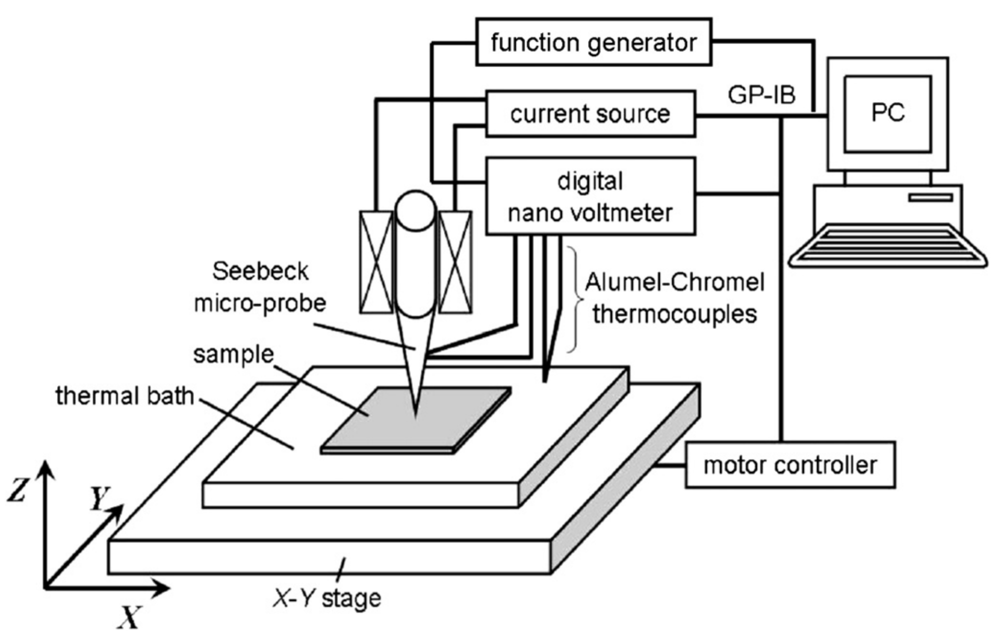


**Fig. 2.** Schematic drawing of the Seebeck micro-probe measurement system.