A study on flexible thermoelectric materials with nanostructured oxide semiconductors for wearable power generator

（課程博士・様式７）(Doctoral qualification by coursework,Form 7)

学 位 論 文 要 旨

Abstract of Doctoral Thesis

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論文題目：

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論文要旨：

Abstract : In the case of long-term monitoring for patients with chronic diseases, hospitalized patients or the elderly, their activity is restricted due to the wiring of the medical devices. To free patients from these restrictions, low-cost and personalized wireless physiological diagnostic tools are desired. However, for measuring the physiological electric signal such as electroencephalography (EEG), electrocardiography (ECG) and electromyography (EMG), the wireless sensor attached to the body requires a battery for amplifier and transmitter included in the sensor. This leads to a limitation in the device miniaturization and to the frequent exchange of the battery. Therefore, we propose a novel wireless sensor with self-power generation by using wearable thermoelectric devices not only as a power generator from body heat but also as an amplifier of electric signals. For this device, flexible thermoelectric materials with appropriate thermoelectric properties are required to enhance the heat-electricity conversion efficiency. To achieve high power-generation efficiency using thermoelectric technology, it is necessary to increase the thermoelectric figure-of-merit Z, denoted as, $Z = (S^2\sigma)/\kappa$, where S is the Seebeck coefficient, σ is the electrical conductivity and κ is the thermal conductivity of the thermoelectric material. Therefore, it is necessary to achieve an increase in S and a decrease in κ simultaneously. One method of overcoming this issue is the introduction of nanostructured semiconductors due to the confinement effect of carriers and phonons. We have focused our attention on nanostructured ZnO and rGO as a thermoelectric material since ZnO and rGO are easily obtainable materials, they are inexpensive, and moreover, they are non-toxic for human skin. Hence, ZnO and rGO related flexible materials are available for clothing. For a thermoelectric device, however, the characteristics of these materials are not sufficient near room temperature.

In our previous papers, although we have measured the Seebeck coefficient of ZnO/cotton-fabric materials, it was obtained by applying the temperature gradient along the layer plane (in the horizontal direction). However, the temperature gradient must lie along the thickness direction of the layer (in the vertical direction) for practical use of wearable devices. There are some reports related to the evaluation of the Seebeck coefficient in the vertical direction of the sample. However, these Seebeck coefficient measurements were applied not to the flexible layer materials but bulk or rigid materials. Also, since the cotton fabric is an insulator, less power in the vertical direction may be obtained due to its small electric current. Therefore, we have focused on conductive carbon fabric (CAF), nickel-copper fabric (NCF) and silver fabric (50% Ag), as a flexible substrate. Many researchers worked on the Seebeck coefficient and electrical conductivity of flexible materials such as carbon fiber, nickel foam. However, none reported the thermoelectric properties of these fabrics, especially in the vertical direction. In this study, we have fabricated nanostructured ZnO and rGO materials over three conductive fabrics using a two-step hydrothermal method. Different morphologies were prepared by altering the reactant's concentration ratio, growth time, annealing temperature and analyzed by x-ray diffractometer (XRD), scanning electron microscopy (SEM) and energy dispersive x-ray (EDX) analysis. Furthermore, we constructed systems for the measurement of Seebeck coefficient and electrical conductivity of flexible layer material in the vertical direction. It will be demonstrated that the Seebeck coefficient of these fabrics in the vertical direction is close to that evaluated in the horizontal direction. Moreover, the influence of air on the Seebeck coefficient in the stacked fabric layers will be presented.