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Facile fabrication of Cu_2O thin film with high Seebeck coefficient

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Thermoelectric (TE) materials might offer potential solutions for power generation and cooling technologies due to their capability of direct and reversible conversion between heat and electricity [1]. Possessing unique features such as all solid-state assembly, no noise, and long lifespan, TE materials, nevertheless, suffer from low heat-to-electricity converting efficiency which limits applications in niche market [2]. Due to a variety of structural, electronic, and thermal properties, numerous works on copper-based thermoelectric were reported, such as $Cu_3Sb_{1-x}Sn_xS_4$ ($x = 0.05$) with maximum ZT value of 0.72 at 623 K [3], Cu_3SbS_4 showing a ZT of ~ 0.63 at 623 K [4]. Here we report thermoelectric properties of Cu_2O thin film with high Seebeck coefficient. The Cu_2O thin film was fabricated by oxidizing copper wire directly on stove at ambient environment. Figure 1 shows Cu_2O thin film Seebeck coefficient versus temperature. SC is on average about 2.5 mV/K, with a maximum ~ 4 mV/K, which is about four times of the currently reported 1 mV/K. The Seebeck coefficient is expected to change gradually with temperature without sharp peaks. The observed rapidly changed data points in Fig. 1 are possibly due to the measurement uncertainty. When the copper oxidation time is less than 3 min, it results in almost negligible SC. Therefore the data in Fig. 1 were obtained with samples oxidized for 4 min. Resistivity about $31\,\Omega\cdot$cm for our Cu_2O thin film was estimated from the IV curve; it is comparable to $11.6\,\Omega\cdot$cm reported in [5] for the Cu_2O thin film doped with F [5]. To avoid the parallel conductivity of copper in the bulk, we have repeated resistivity measurements with a thin copper wire (0.1 mm in diameter) oxidized thoroughly with prolonged heating in the stove. We measured the length dependence of resistance to get contact resistance and accurate resistivity of the Cu_2O wire. From the results shown in Fig. 1c, we estimate the contact resistance $\sim 80\,\mathrm{k}\Omega$, and resistivity $\sim 31\,\Omega\cdot$cm, which is similar to the previous results measured on partially oxidized thicker copper wires with substantial copper metal core. Using the estimated resistivity about $31\,\Omega\cdot$cm, power factor of the Cu_2O thin film reached $52\,\mu\mathrm{W/m\cdot K^2}$. We conjecture the relatively high Seebeck coefficient relates very likely to the band bending between Cu_2O–Cu, Cu_2O–SnO_2. High Seebeck coefficient and ensuing improved power factor could find applications in temperature/touch monitoring, transient thermoelectric cooling and space-constrained area.

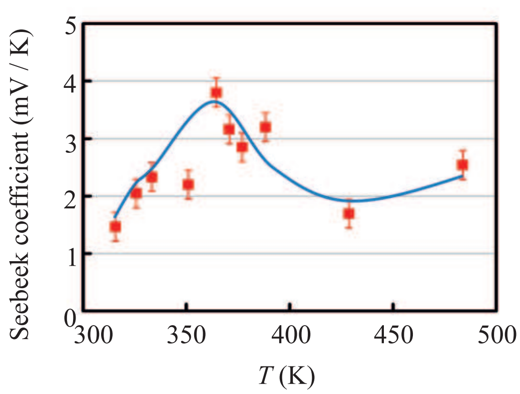

Fig. 1. (Color online) Cu_2O thin film Seebeck coefficient versus temperature (K)

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