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Improvement of Thermoelectric Properties of PEDOT/PSS Films by Addition of Gold Nanoparticles: Enhancement of Seebeck Coefficient

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Thermoelectric properties of hybrid films composed of poly(3,4-ethylenedioxythiophene)/poly(styrenesulfonate) (PEDOT/PSS) and gold nanoparticles (AuNPs) stabilized with 3-mercaptopropinoic acid (Au-MPA NPs) and 6-mercaptohexanoic acid (Au-MHA NPs) were investigated. Several factors such as the size and content of the AuNPs, and the chain length of the NP stabilizer were found to influence the thermoelectric properties of the hybrid film. The Seebeck coefficient can be raised by varying the size of the Au-MPA NPs or the content of Au-MHA NPs. The enhancement in the Seebeck coefficient is suggested to be a result of reduced carrier concentration due to the increased number of AuNPs. This could be the first report on the fact that AuNPs enhance the Seebeck coefficient in PEDOT/PSS hybrid films.

Key words: Organic thermoelectric materials, PEDOT/PSS, Au nanoparticles, hybrid film, Seebeck coefficient

INTRODUCTION

Global demand for renewable and green energy resources leads to important issues because of concerns relating to the shortage of carbon-based fossil fuels in the future. One way to sustain electricity generation is by utilizing waste heat through thermoelectric converters. Thermoelectric energy conversion has been a major focus of research. A simple figure of merit to determine the performance of thermoelectric materials is defined by

$$ZT = S^2\sigma T/\kappa, \quad (1)$$

where S is the Seebeck coefficient, σ is the electrical conductivity, T is temperature, and κ is the thermal conductivity.

Inorganic thermoelectric materials such as Bi_2Te_3, MgSi, etc. have been the focus of research,[1–3] while research related to organic thermoelectric materials has received less attention, mainly because of their low figures of merit.[4,5] However, inorganic materials have several disadvantages such as difficulty in processing, high cost in production, and environmental problems due to their toxicity. Organic thermoelectric materials, particularly conducting polymers, have various advantages over inorganic materials. The solubility of conducting polymers allows not only blending or compositing with other organic/inorganic materials but also easy processing. Their flexibility results in soft and bendable materials, which can be applied to any surface or unusual topology. Additionally, their low thermal conductivity is crucial to achieve good thermoelectric properties. Due to such intrinsic advantages of conducting polymers, improvement of their thermoelectric efficiency has become increasingly attractive to researchers.

Our group previously investigated the thermoelectric properties of conducting polymers, for example, a series of films of polyaniline (PANI) and polyphenlyenevinylene derivatives.[5] Some specific acid-doped PANIs were demonstrated to have low thermal conductivity and high electrical conductivity.[6–8] Derivatives of polyphenlyenevinylene subjected to stretching treatment showed good performance with high Seebeck coefficient and increased electrical conductivity.[9,10] Hybrid materials formed from PANI

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