Enhanced Thermopower in PbSe Polymer Nanocomposites

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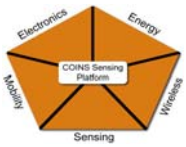
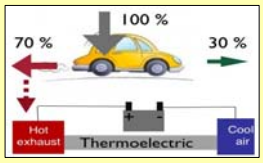


Abstract

Thermoelectric devices, which directly convert waste heat to electricity, are an attractive technology for alternative, clean energy production. However, they are currently too inefficient for large scale applications. To improve the efficiency, thermoelectric materials with high thermopower and electrical conductivity, but low thermal conductivity are required. The thermoelectric performance of polymer nanocomposite films composed of lead selenide (PbSe) nanoparticles and a conductive polymer poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) was measured. The effects of varying nanoparticle loading on thermoelectric properties were investigated. It was found that incorporating PbSe nanoparticles enhances the thermopower, but decreases the electrical conductivity whereas doping the polymer nanocomposite with dimethyl sulfoxide increases the conductvity without decreasing the thermopower.

Background

- Thermoelectric devices directly convert waste heat into electricity
- Advantages:
  - Abundant fuel source
  - No moving parts
  - No CO_2 emissions
  - Reliable



Linke , 2009: http://www.nano.lth.se/research/meso-scopics/project-3-1

- Efficiency depends on Figure of Merit:

$$ZT = \frac{S^2\sigma}{k}T$$

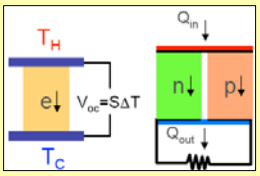
S = Seebeck coefficient (Thermopower)

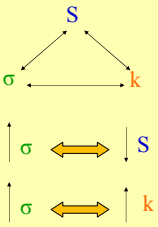
σ = electrical conductivity

k = thermal conductivity

T = absolute temperature

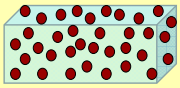
- Current materials ZT ~ 1
- To compete, need materials ZT > 3
- ZT difficult to maximize because S, σ, and k interdependent





Goals

- **Develop polymer nanocomposite with improved ZT by increasing $S^2\sigma$**
- **Determine effects of nanoparticle loading on thermoelectric properties (S and σ)**

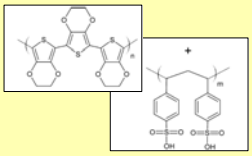


Nanoparticles in polymer matrix

Materials

Conductive Polymer:

PEDOT:PSS



- High σ
- Low k
- Aqueous solution

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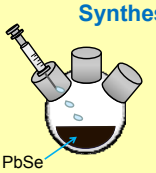
Nanoparticles:

Lead Selenide (PbSe)

- Semiconductor
- High S
- Easy to synthesize

Synthesis of Water Soluble PbSe

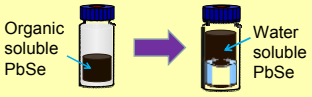
Synthesis of PbSe nanoparticles



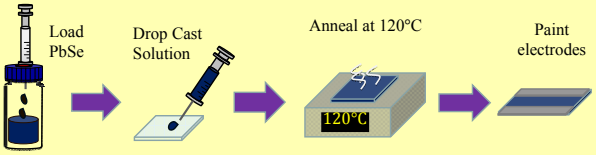
- React lead oleate with trioctylphosphine selenide
- Form PbSe nanoparticles 8-10 nm diameter

Ligand Exchange

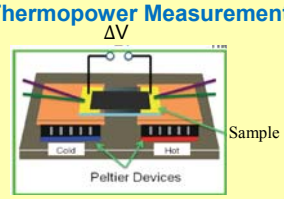
1. Add MUA (ligand) in $CHCl_3$
2. Add TMAH (base) in H_2O

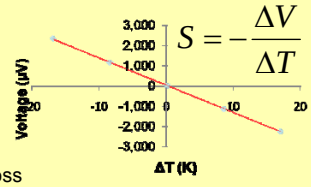


Sample Prep and Measurement



Thermopower Measurement

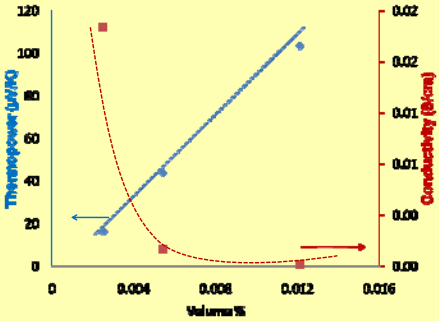




- Apply temperature difference across sample and measure voltage produced

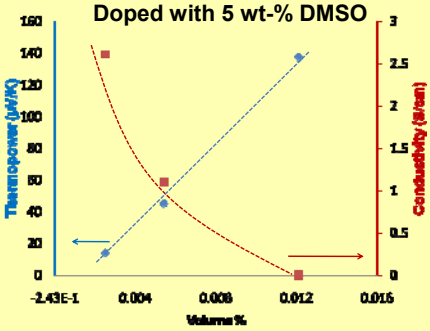
Effects of PbSe Nanoparticles

Polymer Nanocomposite Loaded with PbSe



S increases and σ decreases with PbSe loading

Polymer Nanocomposite Loaded with PbSe Doped with 5 wt-% DMSO



Doping increases σ without affecting S

PbSe Volume %	ZT (undoped)	ZT (doped)
0	1.06E-06	7.12E-03
0.0025	7.75E-07	7.99E-05
0.0054	3.34E-07	3.21E-04
0.0121	2.57E-07	2.572E-07

Doping improves ZT values

Trend shows promise for polymer nanocomposite as thermoelectric material

Summary and Conclusions

- Water soluble PbSe nanoparticles were synthesized
- Polymer nanocomposites with various PbSe loadings were prepared
- Thermopowers of films were measured
- **Incorporating PbSe nanoparticles enhances thermopower (S), but decreases electrical conductivity (σ)**
- **Doping polymer increases σ without decreasing S**
- Polymer nanocomposites are promising material for thermoelectric devices

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References

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