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EXPLORING ELECTRICAL AND MAGNETIC RESONANCES

**BIN HU
UNIVERSITY OF TENNESSEE KNOXVILLE TN**

**04/29/2015
Final Report**

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14. ABSTRACT
The research efforts have made following major breakthroughs:

1. Developed new strategy to couple pi-d electrons for the development of molecular metamaterials [J. Am. Chem. Soc. 134, 3549, 2012]
2. Explored new mechanism to utilize intermolecular excited states for realizing electric-magnetic coupling towards developing molecular metamaterials [Adv. Mater. 23, 2216, 2011]
3. Developed new method to use radicals for electric-magnetic coupling towards radicals-based metamaterials [Adv. Mater 26, 3956, 2014]
4. Discovered a novel mechanism to generate magneto-optic properties by establishing spin-exchange interaction in electron-hole pairs in ferroelectrically semiconducting materials [Advanced Materials, DOI: 10.1002/adma.201405946, 2015]
5. Developing new strategy to separately control electrical and thermal conductivities by using interfacial polarization [Adv. Mater. 23, 4120, 2011]

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Final Report

July 01, 2011 – December 31, 2014

Project title:

Exploring Electric and Magnetic Resonances from Coherently Correlated Long-Lived Radical Pairs towards Development of Negative-Index Materials

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Agreement Number:

FA9550-11-1-0082

Objectives:

This project has two objectives: (i) exploring electric and magnetic responses from spin radical pairs to develop molecular metamaterials and (ii) investigating new mechanisms to control the co-operative relationships between key thermoelectric parameters for developing high thermoelectric effects based on hybrid metal/polymer/metal thin-film devices.

Status of Effort:

The research efforts have made following major breakthroughs on molecular metamaterials by using spin radicals and on thermoelectric effects by using polymer/metal interface-controllable thermal and electric conductions.

1. Developed new strategy to couple semiconducting π electrons and magnetic d electrons for the development of molecular metamaterials [*J. Am. Chem. Soc.* 134, 3549-3554, 2012]

The project has developed a new strategy for coupling semiconducting π electrons and magnetic d electrons by combining optically-generated intermolecular excited states with surface-modified magnetic nanoparticles. This new strategy can lead to optically-controllable composite metamaterials.

2. Explored new mechanism to utilize intermolecular excited states for realizing electric-magnetic coupling towards developing molecular metamaterials [*Adv. Mater.* **23**, 2216-2220, 2011]

The project has developed a new mechanism for realizing electric-magnetic coupling by using optically-generated intermolecular excited states in organic semiconducting materials. This new mechanism can generate optically-controllable molecular metamaterials.

3. Developed new method to use spin radicals for realizing electric-magnetic coupling towards radicals-based metamaterials [*Adv. Mater* **26**, 3956-3961, 2014]

The project has introduced spin radicals into organic semiconducting materials for the development of radicals-based metamaterials. This new method can develop spin-tunable electric-magnetic coupling for development of radicals-based metamaterials.

4. Discovered a novel mechanism to generate magneto-optic properties by establishing spin-exchange interaction in electron-hole pairs in ferroelectrically semiconducting materials [*Advanced Materials*, DOI: 10.1002/adma.201405946, 2015]

The project has discovered a novel mechanism to generate magneto-optic properties by establishing spin-exchange interaction in ferroelectrically semiconducting perovskites. This new mechanism leads to a breakthrough to create magneto-optic functions in all functional materials.

5. Developing new strategy to separately control electrical and thermal conductivities by using interfacial polarization [*Adv. Mater.* 23, 4120-4124, 2011]

The project explored a new strategy by using interfacial polarization to address the challenging issue: separate controlling on electric and thermal conduction. This new strategy can lead to a significant enhancement on Seebeck effect.

Accomplishments/New Findings:

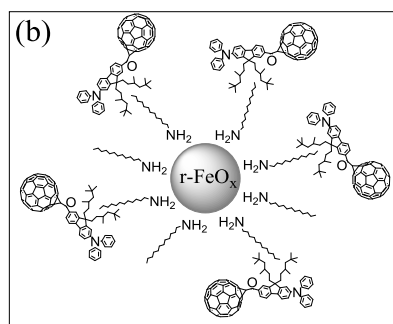
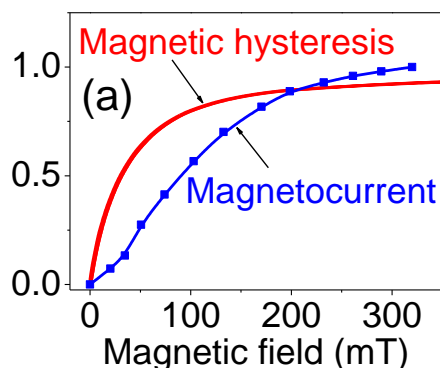
I. Radicals-based molecular metamaterials

This research task has made the following five accomplishments including:

1. Discovery: new mechanism to realize electric-magnetic coupling by using π -d electron coupling for the development of molecular metamaterials

◆ Electric-magnetic coupling from organic-magnetic nano-composite in ground state [*J. Am. Chem. Soc.* 134, 3549-3554, 2012]

We found that a significant electric-magnetic coupling between charge-transfer states, and spin dipoles in ground state can be realized when intermolecular charge-transfer complexes are combined with soluble surface-modified magnetic nanoparticles through nano-composite design. Fig. 1 shows a very interesting magnetocurrent phenomenon that consists three components related to organic semiconducting molecules, magnetic nanoparticles, and a coupling between semiconducting molecules and magnetic nanoparticles. Clearly, this interesting magnetocurrent phenomenon implies that combining intermolecular charge-transfer complexes with magnetic d electrons leads to a new strategy to generate an electric-magnetic coupling in ground state.



Semiconducting-magnetic nano-composite

Fig. 1 (a) Magnetocurrent to show semiconducting, magnetic, and semiconducting-magnetic components. (b) Chemical structure of semiconducting-magnetic nano-composite to show π -d electron coupling.

◆ Enhanced electric-magnetic coupling from organic-magnetic nano-composite in excited state metamaterials [Submitted to *Advanced Electronic Materials*].

We found that a stronger electric-magnetic coupling between charge-transfer states and spin dipoles in electric-magnetic nano-composite can be realized when exciting the nano-composite into excited state. Fig. 2 shows an obvious enhanced amplitude and a line-shape change of

magnetocapacitance in excited state from electric-magnetic nano-composite. Apparently, this striking magnetocapacitance change suggests that photoexcitation provide a new method to enlarge the electric-magnetic coupling between charge-transfer states and spin dipoles in the electric-magnetic nano-composite in excited state.

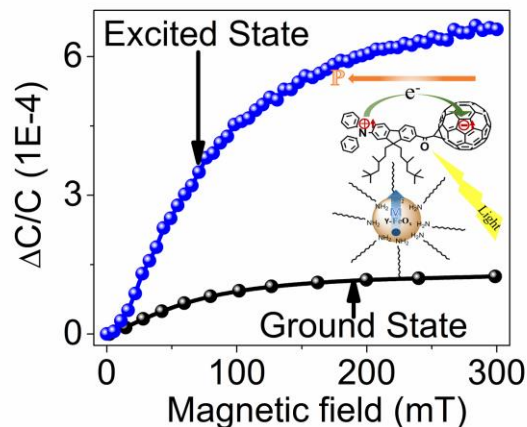


Fig. 2 Magnetocapacitance to show the larger electric-magnetic coupling in excited state.

◆ **Electric-magnetic coupling from radical pairs in organic molecules** [*Adv. Mater* **26**, 3956-3961, 2014].

We have discovered a new mechanism to generate electric-magnetic coupling by using radical pairs in organic semiconducting donor:acceptor systems. We can see in Fig. 3 that a pure semiconducting donor:acceptor (BBOT:TPD) demonstrates a significant magneto-dielectric function under photoexcitation: a magnetic field can change capacitance in organic semiconducting materials under photoexcitation. This magneto-dielectric function indicates a significant electric-magnetic coupling. Therefore, radical pairs present a new mechanism to generate electric-magnetic coupling towards the development of molecular metamaterials.

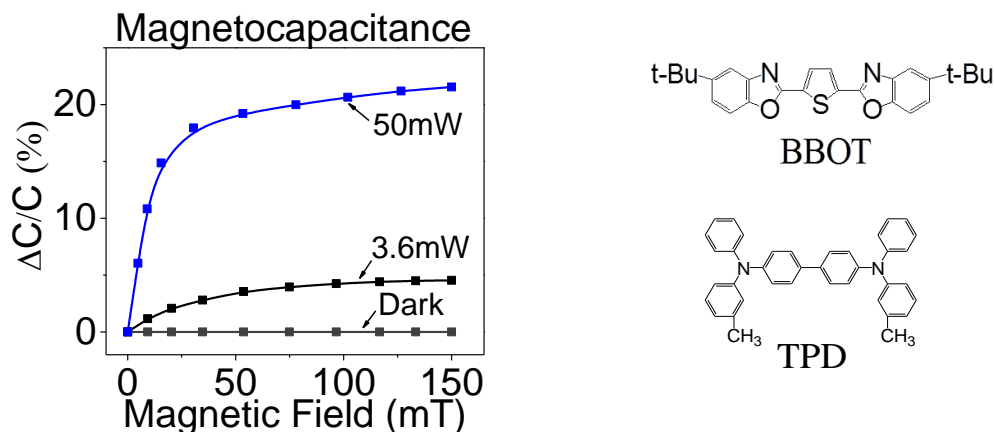


Fig. 3 Magnetocapacitance from optically-generated intermolecular excited states in semiconducting donor:acceptor (BBOT:TPD) composite.

2. New approach: Optically controlling magnetic properties by using charge-transfer states

- ◆ **Optically tunable magnetic properties through the interaction between intermolecular charge-transfer states** [*Adv. Mater* **26**, 3956-3961, 2014; *Physical Review B* **89**, 155304 (2014)].

We have found that the spin-exchange energy in intermolecular charge-transfer states can be manipulated by the photoexcitation through changing the Coulomb interaction spin interaction among the intermolecular charge-transfer states. Fig. 4 indicates that the magnitude and line-shape of magnetocapacitance and magnetophotoluminescence can be changed by increasing the photoexcitation. Consequently, the line-shape narrowing of magnetocapacitance and magnetophotoluminescence illustrates a new way to tune the magnetic properties by photoexcitation through the interaction between intermolecular charge-transfer states, leading a new method to realize the molecular metamaterials.

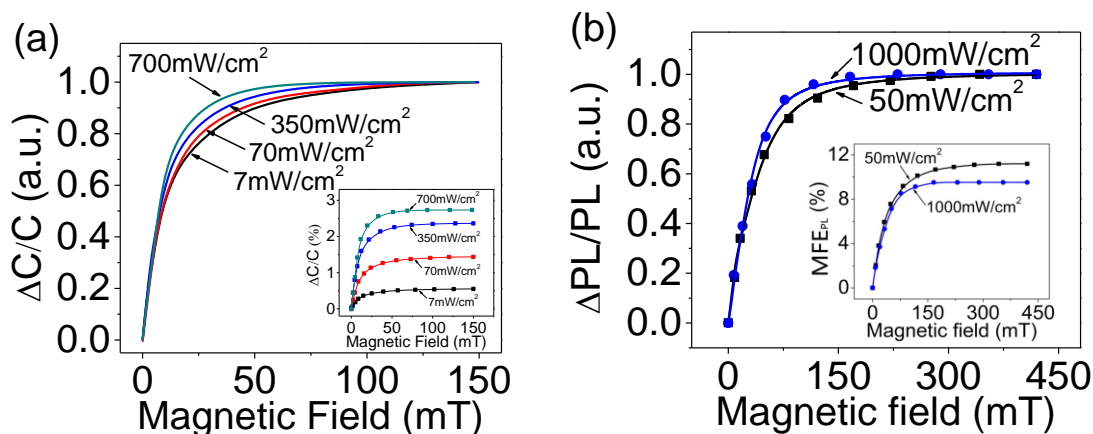


Fig. 4 (a) Magnetocapacitance in semiconducting donor:acceptor (BBOT:TPD) composite under different photoexcitation intensities. (b) Magnetophotoluminescence in semiconducting donor:acceptor (Pyrene:DMA) in DMF under different photoexcitation intensities.

- ◆ **Optically tunable magnetic properties through the interaction between intermolecular charge-transfer states and spin dipoles** [Submitted to *Advanced Electronic Materials*].

We have discovered that the magnetic properties of intermolecular charge-transfer states in electric-magnetic nano-composite can be adjusted by photoexcitation through varying the Coulomb interaction between intermolecular charge-transfer states and magnetic spin dipoles. Fig. 5 depicts an interesting phenomenon of narrowing line-shape and increasing amplitude of magnetocapacitance with increasing photoexcitation intensities. As a consequence, this straightforward phenomenon clarifies a unique way to tune the magnetic properties through

changing the interaction between intermolecular charge-transfer states and magnetic spin dipoles with varied photoexcitation intensities.

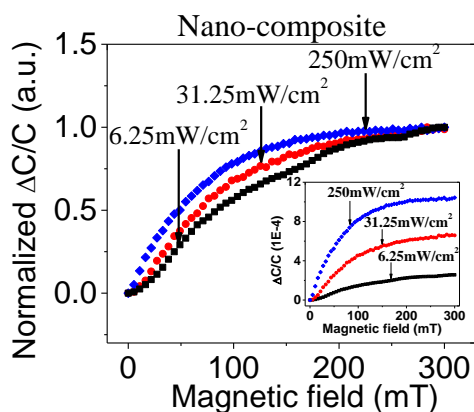


Fig. 5 Magnetocapacitance in electric-magnetic nano-composite under different photoexcitation intensities.

3. Discovery: New approach to realize optically tunable plasmonics [to be published]

We have discovered a new mechanism to separately control the magnetized charge-transfer states and photo-induced charge-transfer states through the coupling interaction between them. Fig. 6 shows the coupling interaction between magnetized charge-transfer states and photo-induced charge transfer states becomes stronger with the decreasing distance. This new phenomenon on one hand provides a unique way to magnetically control the photo-induced charge-transfer states. On the other hand, it predicts a method to optically tune the magnetic plasmonic response. Consequently, this new finding affords a new approach to coupling the electric, optic and magnetic properties for developing new metamaterials.

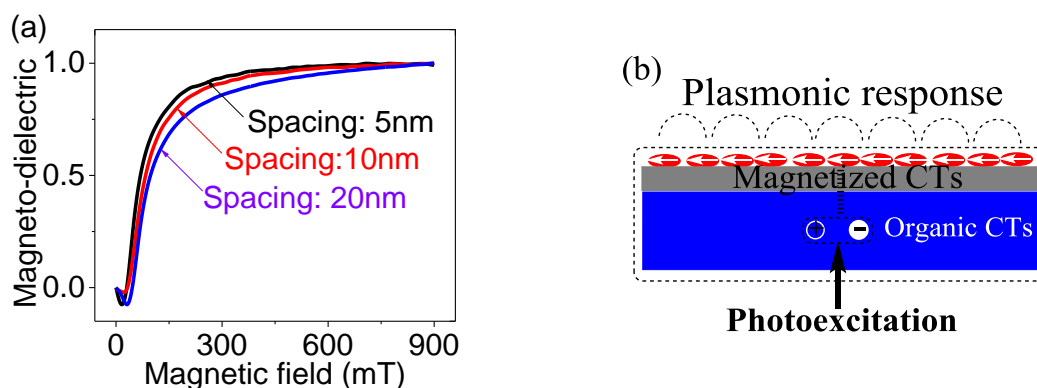


Fig. 6 (a) Magneto-dielectric property to show the coupling interaction between magnetized charge-transfer states and photo-induced charge transfer states. (b) Schematic for illustrating excitons-based plasmonics with optical tuning.

4. New mechanism to develop magneto-optic properties by combining Hall effects with spin radicals [Adv. Mater. 23, 2216-2220, 2011]

We have found a new mechanism to develop magneto-optic properties by combining Hall effects with spin radicals. This new mechanism has led to huge magneto-optic function based on organic spin radicals. Fig. 7 presents that the electroluminescence can be significantly changed up to > 400 % by a magnetic field at room temperature and low field (< 700 mT). This experimental discovery indicates a new mechanism to develop magneto-optic properties in liquid states.

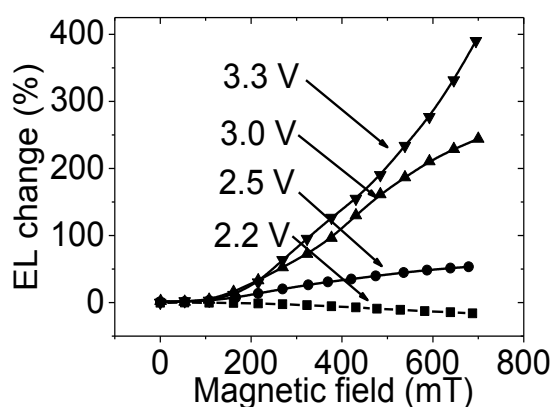


Fig.7 Electroluminescence from radical pairs as a function of magnetic field in triplet tris(2, 2'-bipyridyl) ruthenium(II)–tripropylamine.

5. Discovery: Optically induced ferromagnetic properties from radical pairs [Scientific reports 5, 2015]

We have discovered a new phenomenon that electrogenerated chemiluminescence can produce a magnetic property after removing the applied magnetic field. Fig. 8 shows an abnormal magnetic field effect on electrogenerated chemiluminescence: the electrogenerated chemiluminescence can still present a change even without a magnetic field. This unexpected phenomenon suggests that the activated charge-transfer [Ru(bpy)₃³⁺...TPrA•] complexes may become magnetized in magnetic field and experience a long magnetic relaxation after removing magnetic field. Therefore, this new discovery presents a new way to manipulate the magnetic property for developing new metamaterials.

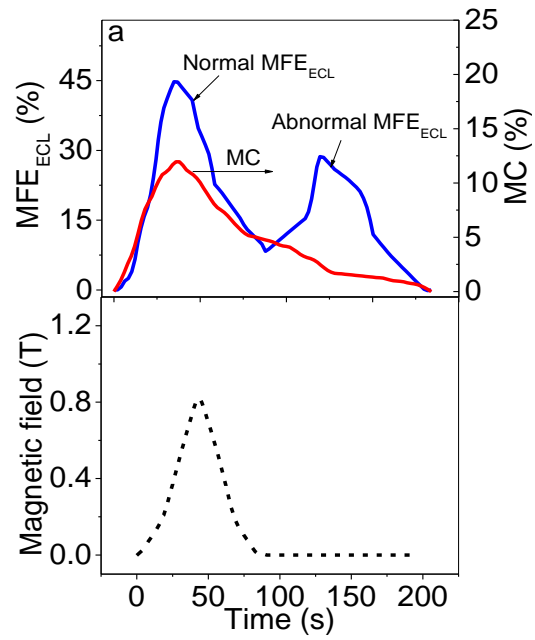


Fig. 8 (a) Magnetic field effect on electrogenerated chemiluminescence and magnetocurrent showing the magnetized charge-transfer states.

II. Thin-film based polymer thermoelectric devices

This research task has made the following five accomplishments including:

1. Rational design on polymer/conductor interface to develop high Seebeck effect based on vertical conductor/polymer/conductor thin-film devices [*Adv. Mater.* 23, 4120-4124, 2011]

We have discovered a new strategy to separately control electrical and thermal conduction by combining low thermal-conducting polymer and high electric-conducting metal in hybrid metal/polymer/polymer thin-film design. We can see in Fig. 9 that the hybrid Al/doped polypyrrole/Al thin-film device can exhibit a high Seebeck coefficient (100 ~ 200 $\mu\text{V/K}$). This high Seebeck coefficient implies a high-electric conduction and a low-thermal conduction existed in the Al/doped polypyrrole/Al thin-film device. In particular, this discovery presents a new design to separately control electric and thermal conduction by polymer/metal interface.

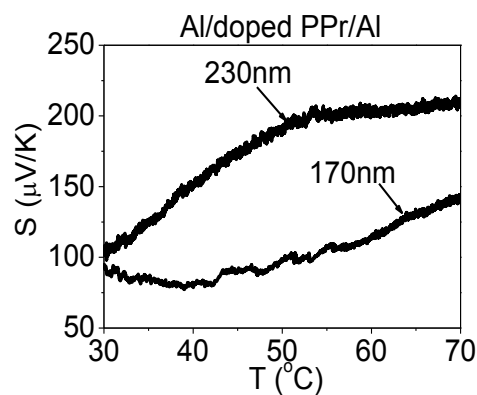


Fig. 9 Seebeck coefficients

2. New driving force of temperature-dependent surface polarization to cooperatively enhance Seebeck effect and electrical conductivity in vertical multilayer organic thin-film devices [*Phys. Chem. Chem. Phys.* 16, 22201-22206, 2014]

We have explored a new mechanism to develop Seebeck effects by using temperature-dependent surface polarization based on vertical multi-layer thin-film devices (Al/P3HT:PCBM/Al, & Al/MoO₃/P3HT:PCBM/Al). Here, the temperature-dependent surface polarization functions as an additional driving force, as compared with the traditional driving force from entropy difference, to diffuse the charge carriers under temperature difference towards the development of Seebeck effects. We have demonstrate simultaneously enhanced Seebeck coefficient and electrical conductivity by using dielectric interface through the temperature-dependent surface polarization to diffuse charge carriers in the Al/MoO₃/P3HT:PCBM/Al thin-film device (Fig. 10). This temperature-dependent surface polarization provides a new mechanism allowing a co-operative relationship between Seebeck coefficient and electrical conductivity.

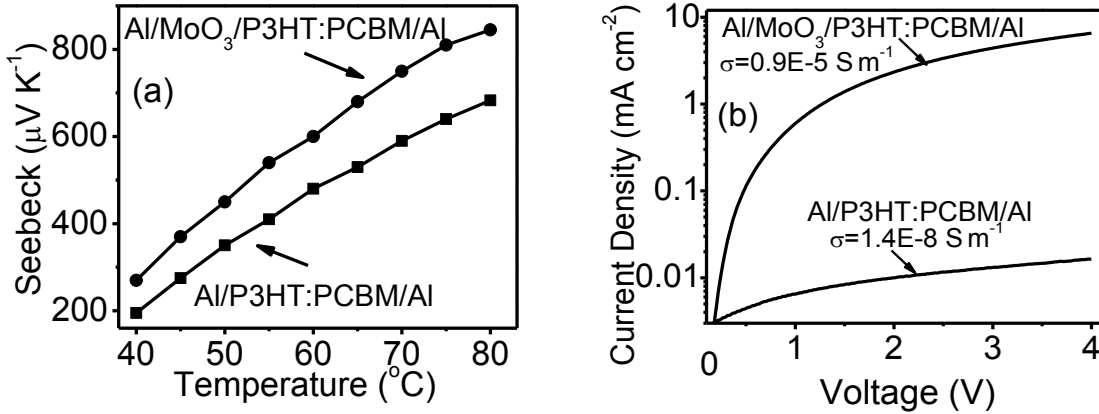


Fig. 10 (a) Seebeck coefficients in dark condition. (b) Electric conduction in dark condition.

3. Dual functions of Seebeck and cooling effects in organic thin-film devices [Submitted]

Here we have explored the possibilities of using temperature-dependent surface polarization as a new thermoelectric driving force to solve the conflicting requirement between electrical and thermal conduction in developing dual Seebeck and cooling effects based on the hybrid organic/inorganic Au/P(VDF-TrFE)/MoO₃/ITO thin-film device (Fig. 11). On one hand, the temperature-dependent surface polarization can lead to a temperature-dependent electrical field to drift charge carriers from high to low-temperature surface, generating a large Seebeck effect. On the other hand, the temperature-dependent surface polarization can absorb heat at the Au/organic interface through charge-phonon coupling by thermionic injection mechanisms when the charge carriers are injected upon applying an electrical bias, leading to a cooling effect. Essentially, the temperature-dependent surface polarization provides a mechanism to develop dual Seebeck and cooling effects through charge-phonon coupling based on thin-film electrode/organic/electrode devices.

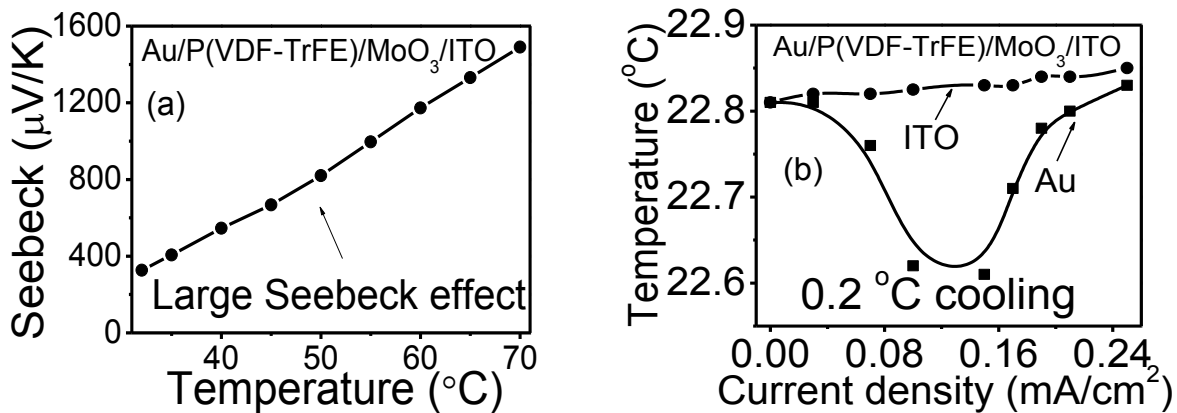


Fig. 11 (a) Seebeck coefficients. (b) Cooling effects with small injection currents.

- Excited-states based Seebeck effect with decoupled three key parameters of Seebeck coefficient, electrical conductivity, and thermal conductivity [*J. Phys. Chem. C*, 117, 10264-10269, 2013]

Recently, we have discovered a new mechanism to further separately control electrical and thermal conduction by using photoexcitation. *Traditionally*, doping has been largely used to control thermoelectric functions. But, doping can cause conflicting phenomena: increasing electrical conductivity but decreasing Seebeck effect. This leads to a big challenge for simultaneously increasing electrical conductivity and Seebeck coefficient to enhance thermoelectric functions. Now, we have discovered that photoexcitation can lead to an increased Seebeck effect in the organic semiconducting system (MEHPPV) (Fig. 12). The observed increased Seebeck effect implies that using photoexcited states can develop a separate control on electrical and thermal conduction towards the development of high-efficiency thermoelectric devices. Essentially, excited states can provide three unique properties to develop Seebeck effect. First, the excited-states can generate high electrical conductivity; second, the excited-states can lead to tunable electron-phonon coupling; third, the excited states can provide a mechanism of phonon-trapping to trap thermal transport in bulk polymer films during charge transport.

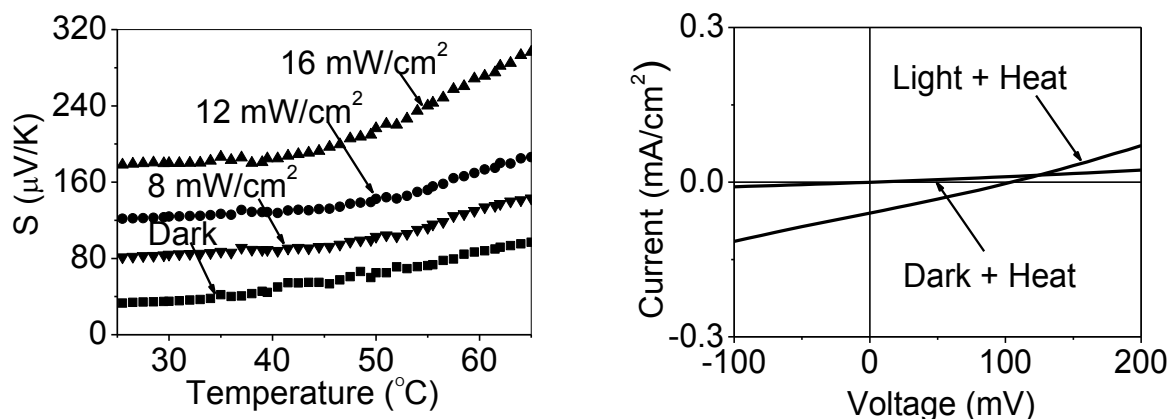


Fig. 12 (a) Seebeck coefficients for photoexcitation and dark conditions. (b) Electric conduction for photoexcitation (16mW/cm^2) and dark conditions. The system is based on ITO/MEH-PPV/Au devices.

- New mechanism to generate magneto-Seebeck effect by applying Hall effect on organic thin-film devices [Submitted]

Hall effect can generate magneto-transport phenomenon in organic thin-film devices, and vertical organic thin-film devices can lead to large Seebeck effect. Therefore, combination of Hall effect and vertical organic thin-film devices can lead to a new mechanism to generate magneto-Seebeck effect. Here we have discovered giant magnetic field effects on Seebeck coefficients by applying Hall effect on vertical multi-layer ITO/PEDOT:PSS/Au thin-film

devices (Fig. 13). This discovery demonstrates a magnetic approach to control the thermoelectric properties in organic thin-film devices.

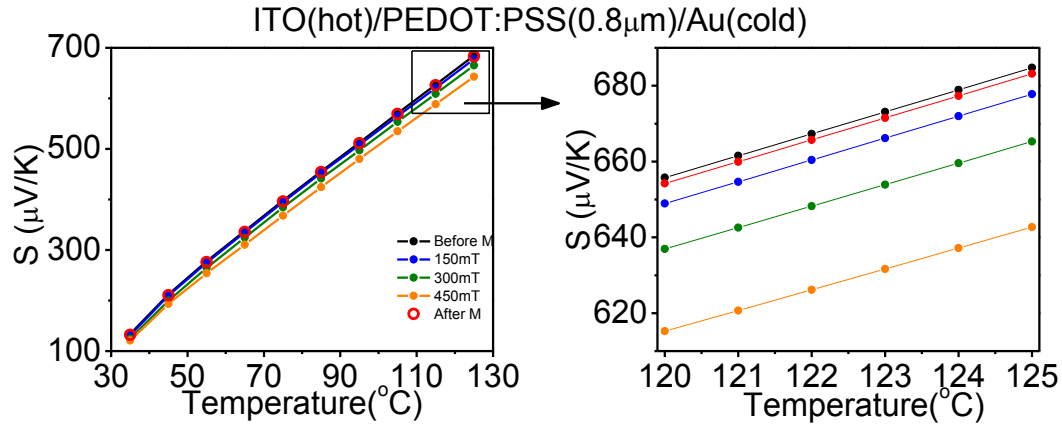


Fig. 13 Seebeck coefficient as a function of temperature under different magnetic field when magnetic field is perpendicular to temperature gradient.

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Ming Shao, Liang Yan, Li Mingxing, Ivanov Iliia, and Bin Hu*
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19. “Changing Inter-molecular Spin-Orbital Coupling for Generating Magnetic Field Effects in Phosphorescent Organic Semiconductors”
 Liang Yan, Ming Shao, Carlos F. O. Graeff, Ivo Hummelgen, Dongge Ma, Bin Hu
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 Raghavendra Hegde, Nathan Henry, Ben Whittle, Huidong Zang, Bin Hu, Jihua Chen, Kai Xiao, Mark Dadmun
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 21. “High Seebeck Effects from Hybrid Metal/Polymer/Metal Thin-Film Devices”
 Liang Yan, Ming Shao, Hsin Wang, Doug Dudis, Augustine Urbas, and Bin Hu*
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 Huidong Zang, Yongye Liang, Luping Yu,* and Bin Hu*
Adv. Energ. Mater. **1**, 923, 2011
 23. “Giant Magnetic Field Effects on Electroluminescence in Electrochemical Cells”,
 Ming Shao, Liang Yan, Ilia Ivanov, Bin Hu* ,
Adv. Mater. **23**, 2216-2220, 2011.
 24. “Effects of single walled carbon nanotubes on the electroluminescent performance of organic light-emitting diodes”, Ming Shao, Matthew Garrett, Xinjun Xu, Ilia Ivanov, Stanislaus Wong, and Bin Hu* ,
Organic Electronics, **12**, 1098-1102, 2011.
 25. “Electrical dipole-dipole interaction effects on magnetocurrent in organic phosphorescent materials”,
 Ming Shao, Yanfeng Dai, Dongge Ma, and Bin Hu
Appl. Phys. Lett. **99**, 073302, 2011
 26. “Magnetoconductance responses in organic charge-transfer-complex molecules”
 Tsung-Hsun Lee, Jhen-Hao Li, Wei-Shun Huang, Bin Hu, J. C. A. Huang, Tzung-Fang Guo, and Ten-Chin Wen
Appl. Phys. Lett. **99**, 0733097, 2011

Interactions and Transitions:

a. Presentations at Conferences

Invited Presentation from July 01 2011 to December 31 2014

- (1) **Magneto-Optical Studies on Organic and Perovskite Solar Cells**
 Bin Hu

- Asian Conference on Organic Electronics, National Cheng Kung University, Tainan, Taiwan, November 12-15, 2014
- (2) **Magneto-Dielectric Effects Generated by Charge-Transfer States in Organic Semiconductors**
Bin Hu
5th Topical Meeting on Spins in Organic Semiconductors, Himeji, Japan, October 14-17, 2014
 - (3) **New Magnetic Field Effects in Organic Semiconductors**
Bin Hu
2014 International Symposium on Materials for Enabling Nanodevices, National Cheng Kung University, Tainan, Taiwan, September 03-06, 2014
 - (4) **Magneto-optic properties in organic materials**
Bin Hu
AOARD conference on magnetic nanomaterials, University of Maryland, June 16-17, 2014
 - (5) **Organic spintronics, organic solar cells, and organic thermoelectrics**
Bin Hu
E-MRS, Lille, France, May 26-30, 2014
 - (6) **Magneto-optic properties in organic materials**
Bin Hu
US-Taiwan Air Force Conference, Hualien, Taiwan, May 13-15, 2014
 - (7) **Magneto-optic studies of photovoltaic processes at D:A interface and electrode interface in organic solar cells**
Bin Hu
Indo-US Joint Workshop on Organic Solar Cells, Kanpur, India, March 20-22, 2014
 - (8) **Interface enhanced photovoltaic and Seebeck effects in organic solar cells and thermoelectric devices**
Bin Hu
ACS Annual Meeting, Dallas, TX, March 16, 2014
 - (9) **Multiferroic Effects from Intermolecular Excited States in Organic Semiconductors**
Bin Hu
Brazil-MRS meeting, Campos do Jordao, September 30 – October 04, 2013
 - (10) **Magneto-Optic, Magneto-Electric, and Magneto-Thermoelectric Effects in Organic Semiconductors**
Bin Hu
BES Program Review for the CNMS at Oak Ridge National Laboratory, September 24-26, 2013
 - (11) **Organic Thin-Film Thermoelectric Devices**
Bin Hu
Flexible Thermoelectric Workshop organized by AFOSR, Arlington, VA, July 09-10, 2013
 - (12) **Effects of Intermolecular and Dielectric-layer Interfaces on Internal Photovoltaic Processes in Organic Solar Cells**
Bin Hu

- Indo-US Joint Workshop on Organic Solar Cells, National Reviewable Energy Laboratory, Golden, Co, June 24-25, 2013
- (13) **Magneto-optical Studies on Internal Photovoltaic Processes in Organic Solar Cells**
Bin Hu
2013 TechConnect World, National Innovation Summit and National SBIR Conference, Gaylord Hotel, National Harbor, Maryland, May 13-16, 2013
- (14) **Magneto-Dielectric Functions Developed by Intermolecular Excited States**
Bin Hu
MRS Meetings, San Francisco, CA, April 01-05, 2013
- (15) **Departmental Seminar: Organic Spintronics**
Bin Hu
National Taiwan University, Taipei, Taiwan, December 11, 2012
- (16) **Workshop on Organic Spintronics**
Bin Hu
Intermolecular Excited States-Based Organic Spintronics
National Cheng Kung University, Tainan, Taiwan, December 06-07, 2012
- (17) **Effects of Intermolecular and Dielectric-layer Interfaces on Internal Photovoltaic Processes in Organic Solar Cells**
Bin Hu
International Symposium on Organic and Dye-Sensitized Solar Cells 2012 (IS-OPVDSC 2012), Taipei, Taiwan, November 24-29, 2012
- (18) **Electric-Magnetic Coupling in Organic Sintronics**
Bin Hu
9th National Conference on Organic Solids Electronics, Yangzhou, China, November 10-12, 2012
- (19) **Magneto-optical studies on internal photovoltaic processes in organic solar cells**
Bin Hu
Workshop on key scientific and technological issues for development of next-generation organic solar cells
Arlington, VA, September 20 – 21, 2012
- (20) **Multi-Ferroic Functions Developed by Inter-molecular Excited States**
Bin Hu
4th Topical Meeting on Spintronics in Organic Semiconductors, London, UK, September 10 – 14, 2012
- (21) **Excited States-Based Organic Spintronics**
Bin Hu
International Workshop on Novel Nano-Magnetic and Multifunctional Materials 2012
Seoul, Korea, June 11-14, 2012
- (22) **Magneto-Optical Studies of Internal Photovoltaic Processes in Organic Solar Cells**
Bin Hu
Departmental seminar at Department of Materials Science and Engineering, University of Florida, Gainesville, FL, April 04, 2012
- (23) **Organic Molecular Metamaterials**
Bin Hu
Organic Metamaterials Workshop, Army Research Laboratory, March 02, 2012

- (24) **Characterization and Understanding on Internal Photovoltaic Processes in Organic Solar Cells**
Bin Hu
International Photonics Conference – 2011, Tainan, Taiwan, December 07-08, 2011
- (25) **Organic Spintronics: Magnetic Field Effects**
Bin Hu
International Symposium on Organic Dye Sensitized Solar Cells, Tainan, Taiwan, December 08-10, 2011
- (26) **The Role of Inter-molecular Electron-Hole Pairs in Magnetic Field Effects in Organic Materials,**
Bin Hu
61st Annual Meeting of Japan Coordination Chemistry Society, Okayama, Japan, September 17-19, 2011
- (27) **Characterization and Understanding on Charge Dissociation, Transport, Collection in Organic Solar Cells**
Bin Hu
Workshop on Sustainable Energy Future: Focus on Organic Photovoltaics, Oak Ridge National Laboratory, September 21 – 23, 2011
- (28) **Electromagnetic and Thermoelectric Responses from Inter-molecular Excited States: Radicals Pairs**
Bin Hu
8th US-Taiwan NanoScience Workshop, Seattle, Washington, April 05-06, 2011

b. Consultative and advisory functions

None.

c. Transitions

None.

New Discoveries

Four experimental discoveries have been made. They include:

- (1) New strategy to couple semiconducting π electrons and magnetic d electrons for development of molecular metamaterials
- (2) New mechanism to use intermolecular excited states for realizing electric-magnetic coupling towards development of molecular metamaterials
- (3) New method to use spin radicals for realizing electric-magnetic coupling towards radicals-based metamaterials
- (4) New mechanism to develop significant magneto-optic properties by combining Hall effect with spin radicals
- (5) New strategy to separately control electrical and thermal conductivities by using interfacial polarization

Honors/Awards:

Research Achievement Award – April 2014

College of Engineering
University of Tennessee

Research Fellow Award – April 2012

College of Engineering
University of Tennessee

1.

1. Report Type

Final Report

Primary Contact E-mail

Contact email if there is a problem with the report.

bhu@utk.edu

Primary Contact Phone Number

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865-974-3946

Organization / Institution name

The University of Tennessee

Grant/Contract Title

The full title of the funded effort.

Exploring Electrical and Magnetic Resonances from Coherently Correlated Long-Lived Radical Pairs towards Development of Negative Refractive-Index materials

Grant/Contract Number

AFOSR assigned control number. It must begin with "FA9550" or "F49620" or "FA2386".

FA9550-11-1-0082

Principal Investigator Name

The full name of the principal investigator on the grant or contract.

Dr. Bin Hu

Program Manager

The AFOSR Program Manager currently assigned to the award

Dr. Charles Lee

Reporting Period Start Date

06/01/2011

Reporting Period End Date

12/31/2014

Abstract

The research efforts have made following major breakthroughs:

1. Developed new strategy to couple pi-d electrons for the development of molecular metamaterials [J. Am. Chem. Soc. 134, 3549, 2012]
2. Explored new mechanism to utilize intermolecular excited states for realizing electric-magnetic coupling towards developing molecular metamaterials [Adv. Mater. 23, 2216, 2011]
3. Developed new method to use radicals for electric-magnetic coupling towards radicals-based metamaterials [Adv. Mater 26, 3956, 2014]
4. Discovered a novel mechanism to generate magneto-optic properties by establishing spin-exchange interaction in electron-hole pairs in ferroelectrically semiconducting materials [Advanced Materials, DOI: 10.1002/adma.201405946, 2015]
5. Developing new strategy to separately control electrical and thermal conductivities by using interfacial polarization [Adv. Mater. 23, 4120, 2011]

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Change in AFOSR Program Manager, if any:

Extensions granted or milestones slipped, if any:

AFOSR LRIR Number

LRIR Title

Reporting Period

Laboratory Task Manager

Program Officer

Research Objectives

Technical Summary

Funding Summary by Cost Category (by FY, \$K)

	Starting FY	FY+1	FY+2
Salary			
Equipment/Facilities			
Supplies			
Total			

Report Document

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Appendix Documents

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