



AFRL-AFOSR-VA-TR-2016-0013

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**Designing Microstructures/Structures for Desired Functional Material and Local Fields**

**Liping Liu**  
**RUTGERS THE STATE UNIVERSITY OF NEW JERSEY**

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**12/02/2015**  
**Final Report**

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14. ABSTRACT <p>The investigations have focused on the predictive modeling and optimal design of multifunctional materials/structures as proposed. Along the line of predictive modeling, the PI, supported students and collaborators have (i) established an atomistic model for surface elasticity, (ii) derived a new type of Maxwell stress in soft materials due to quantum mechanical-elasticity coupling and elucidated its ramification in engineering multifunctional soft materials, and (iii) demonstrated the possibility of concurrent magnetoelectricity and piezoelectricity in soft materials.</p> <p>Concerning local field in heterogeneous structures, we have shown designs of thermoelectric composites and the feasibility of large-scale power plants based on thermoelectric effects. we achieve designs of structures that can amplify static electric/magnetic fields or temperature gradient. These designs can be used to improve sensitivity of telecommunication receivers and efficiency of heat engines / thermoelectric generators. We also show optimal geometries of minimum field concentration that may be used to mitigate fatigue damage and improve reliability and life-span of structures.</p>					
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Subject: Final Project Report to Dr. Byung L. Lee

Contract/Grant Title: (YIP 12) - Designing Microstructures/Structures For Desired Functional Material And Local Fields

Contract/Grant # FA9550-12-1-0349

Reporting Period: 1 July, 2012 to 31 July 2014

Project accomplishments: The investigations have focused on the predictive modeling and optimal design of multifunctional materials/structures as proposed.

Along the line of predictive modeling, the PI, supported students and collaborators have (i) established an atomistic model for surface elasticity [3], (ii) derived a new type of Maxwell stress in soft materials due to quantum mechanical-elasticity coupling and elucidated its ramification in engineering multifunctional soft materials [1,2], and (iii) demonstrated the possibility of concurrent magnetoelectricity and piezoelectricity in soft materials [6].

Concerning local field in heterogeneous structures, we have shown designs of thermoelectric composites and the feasibility of large-scale power plants based on thermoelectric effects [4, 5]. We achieve designs of structures that can amplify static electric/magnetic fields or temperature gradient. These designs can be used to improve sensitivity of telecommunication receivers and efficiency of heat engines / thermoelectric generators. We also show optimal geometries of minimum field concentration that may be used to mitigate fatigue damage and improve reliability and life-span of structures.

Archival publications derived from the project:

1. X.B. Li, L.P. Liu and P. Sharma. A New Type of Maxwell Stress in Soft Materials due to Quantum Mechanical-Elasticity Coupling, *J. Mech. Phys. Solids*, In review.
2. X.B. Li, L.P. Liu and P. Sharma. Geometrically nonlinear deformation and the emergent behavior of polarons in soft matter (6pg, Communication). *Soft Matter*, In press.
3. L.X. Hu and L. P. Liu. *From atomistics to continuum: effects of a free surface and determination of surface elasticity properties (10pg). Mechanics of Materials, 90, 202-211, 2015.*
4. F. Ahmadpoor, L. P. Liu and P. Sharma. Thermal fluctuations and the minimum electrical field that can be detected by a biological membrane (13 pg). *J. Mech. Phys. Solid, 78, 110-122, 2015.*
5. L. P. Liu. Feasibility of Large-scale power plants based on thermoelectric effects. *New Journal of Physics, 16, 123019, 2014.*

6. Z. Alameh, Q. Deng, L. P. Liu and P. Sharma. Using electrets to design concurrent magnetoelectricity and piezoelectricity in soft materials. *Journal of Material Research*, 30:93-100, 2015

Principle Investigators:

Liping Liu     Department of Mathematics and Department of Mechanical & Aerospace Engineering, Rutgers University

Contributors to the Project:

Hanxiong Wang and Lixin Hu(supported Ph.D. students)

Project highlights:

- [1] Accomplish a systematic continuum theory for multifunctional materials that can be used for predictive modeling of magneto-electro-elastic materials of any geometry and boundary conditions.
- [2] Discover and elucidate a universal mechanism, i.e., the Maxwell stress, that can be utilized to engineer multifunctional soft materials for multi-sensing, multi-actuating, human-machine interfaces.
- [3] Establish a theoretical framework and numerical tools for designing structures/materials with desired functionality and local fields.

Planned Continuing Work: Future work will focus on multifunctional soft materials for their unique multifunctionality and biocompatibility. The strength of the PI lies in rigorous continuum-mechanics and multiscale approach to the predictive modeling of multifunctional materials. In particular, the PI will explore the microscopic statistical mechanics models of typical soft materials and means to improve their functional properties, establish a self-consistent continuum theory for electro-magnetic-elastic materials, derive the asymptotic theories of soft composites, curved rods and membranes, and optimize a specified functionality via numerical and analytical efforts.

1.

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**Grant/Contract Number**

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Liping Liu

**Program Manager**

The AFOSR Program Manager currently assigned to the award

Byung Les Lee

**Reporting Period Start Date**

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**Reporting Period End Date**

07/01/2015

**Abstract**

The investigations have focused on the predictive modeling and optimal design of multifunctional materials/structures as proposed.

Along the line of predictive modeling, the PI, supported students and collaborators have (i) established an atomistic model for surface elasticity, (ii) derived a new type of Maxwell stress in soft materials due to quantum mechanical-elasticity coupling and elucidated its ramification in engineering multifunctional soft materials, and (iii) demonstrated the possibility of concurrent magnetoelectricity and piezoelectricity in soft materials.

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