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Rank: Assistant Professor  Chair/Professorship: 

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Start Date: 12/01/2011  Completion Date: 06/15/2012

Title of Project: Advanced Transport Property Measurements on Carbon Nanotubes and Carbon Aerogel

Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Carbon Nanotubes</td>
<td>$1,150.00</td>
</tr>
<tr>
<td>2. Flash-Dry Components</td>
<td>$850.00</td>
</tr>
<tr>
<td>3. IR Temp Sensor</td>
<td>$240.00</td>
</tr>
<tr>
<td>4. Misc. Supplies</td>
<td>$355.00</td>
</tr>
<tr>
<td>5. Student Worker</td>
<td>$600.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$3195.00</strong></td>
</tr>
</tbody>
</table>

Budget Justification:

Multi-wall carbon nanotubes (7 grams): $1050.00

Heater system and fabrication parts for the thin-film flash-dry deposition system (2200 W IR lamp, track and drive motor system, speed controller): $850.00

IR temp sensor required to measure sample temperature (non-contact method): $240.00

Miscellaneous supplies (surfactants, electrical controls, wiring, sample substrates, conductive epoxy, etc.): $355.00

(1) Undergraduate student worker (60 hrs. @ 10.00/hr): $600.00

Total: $3195.00
Where would the results be published, exhibited or performed? Materials Research Society Conference Presentation, Paper and Poster (April 2012) and possibly Journal of Applied Physics.

What other sources of funding (internal and external) have you identified for this project? This is a small experimental project required to leverage larger external sources of funding such as LA EPSCoR and NSF opportunities.

List years and amounts of prior Loyola University faculty grants (for the last three years): 2010/2011 faculty grant $3455, resulted in PI/student poster presentation at LaSPACE conference.

Introduction

Materials science investigates, predicts and measures the fundamental properties and characteristics of materials at both molecular and bulk scales. One of the most important and foremost research areas of materials science entails how energy (such as heat and electricity) is transported in advanced material systems. Energy transport is important because material behavior is dependent upon temperature, electrical current and combined thermoelectric conditions. Examples of advanced materials include nanoscale semiconductors, nanocomposite photovoltaics and compounds exhibiting complex crystalline structure. The accurate measurement and characterization of thermal, electrical and thermoelectric transport properties of any material can pose many challenges given the wide range of material size, geometry and behavior under varying conditions. Perhaps due to this fact, over the past several decades, there have been relatively few advances in fundamental experimental methods used to measure transport properties. This situation contrasts the surge in new materials research driven by extensive micro and nanoscale material fabrication, advanced synthesis techniques and powerful theoretical predictions due to increased computational resources. Subsequently, the synergy that has developed with the collaboration of theory, synthesis and fabrication has not fully encompassed fundamental experimental theory and methodology. Therefore, there is a critical need to advance our methods and range of transport property measurements in order to facilitate the development and application of new and technologically important materials.

Current Research Status and Project Intent

The PI is focusing on the pioneering development of Dynamic Electron Scattering (DES) which is a perturbation-free technique to measure electronic transport properties on materials ranging from simple metals to advanced material systems. The term “perturbation-free” means that electrical or thermal gradients are not required during the experimental measurement process. The subject material is kept in complete equilibrium resulting in one of the primary advantages of DES over every other comparable experimental method. Additionally, this fact explains the ease of DES measurements on complex materials. Basically, DES departs from traditional transport property measurement techniques by approaching the problem from a spectroscopic viewpoint. While in complete equilibrium, the electrons in materials are known to fluctuate at finite temperatures. This phenomenon, commonly referred to as Johnson/Nyquist noise, may be experimentally measured through voltage or current fluctuations. The fluctuation spectrum carries a great deal of information about the underlying transport properties of the relevant material. The DES technique experimentally measures transport property information through careful extraction and processing of charge and energy information from the fluctuation spectrum. Currently, DES has been rigorously validated on 11 metals and 3 semiconducting materials. Peer reviewed publications [1-3] and conference presentations [4,5] have helped stimulate several collaborations with other groups (Stokes and Malkinski at UNO, Chen at MIT and Minnich at Caltech) and Loyola is recognized as the originating university for this novel experimental technique. This proposal is an integral part of the PI’s plan to advance his research to the national collaboration and funding level. Measuring transport parameters without thermal or electrical gradients is a fundamentally new approach that may drastically change traditional experimental techniques. It is expected that such basic change of well-established experimental methods will meet certain lack of understanding in the community of transport property researchers, including grant reviewers for state and federal institutions. This can be overcome only by providing clear and convincing evidence of the validity and usefulness of DES. High quality rigorously obtained data is needed to support applications for state and federal funding, especially since the PI lacks a history of previous federal funding and the research approach
proposed here can be viewed as “low risk, high payoff.” The PI has also begun the patent process on DES to further ensure that Loyola remains the anchoring research site. Additionally, the PI has been selected to attend the highly sought after NSF CAREER workshop with mentoring and oversight from the NSF condensed matter program director who is the relevant contact person from the NSF for the PI’s research. This project incorporates student involvement. It will provide a range of experimental and theoretical experience thus helping to prepare students to face challenges presented by modern research practice.

Research Plan

The next logical step in the development of DES is to begin the experimental validation process on advanced materials. The PI proposes the validation of DES on carbon nanotubes and carbon aerogel. The motivation behind the selection of carbon nanotubes is based upon widely available published values of transport property data for comparative analysis. Carbon aerogel has been selected due to the complex platelet structure, immediate technological applicability potential and available published transport property data. Therefore, this project seeks to complete experimental validation work on important materials truly qualifying as advanced materials via nanoscale dimensions and exhibiting complex structure. The experimental methodology and techniques for DES are well developed [1-3] and the PI’s lab is ready to initiate a DES project immediately. The estimated timeline to complete this project is approximately 12 weeks. For this study, the PI proposes to fabricate carbon nanotube samples in a thin film configuration [6]. Therefore, funds are requested to purchase carbon nanotubes. The fabrication technique requires a flash dry heating system which also requires funds requested by this proposal. The carbon aerogel will be acquired and supplied by the PI. Surface microscopy will then be performed to characterize the carbon nanotubes and carbon aerogel surface structure integrity. The PI shall supply the microscopy study through the use of an atomic force microscope via collaboration with Leszek Malkinski and Kevin Stokes at the Advanced Materials Research Institute at the University of New Orleans. Traditional electrical resistivity measurements will be made on the fully characterized samples in order to establish a redundant validation control data point for comparative analysis. The PI shall supply all equipment and supplies required to obtain the electrical resistivity data. DES transport property measurements shall then be made on the samples. The resulting data will then be submitted to a comparative analysis study utilizing both electrical resistivity results and published data. The expected outcome is multi-fold. First, the results of the study shall be presented at the Materials Research Society Conference (April 2012) in oral, paper and poster form. This conference is funded by the Dean’s office and is an excellent forum for further collaborations, opening up new avenues of materials research and most importantly, dissemination of the results to the relevant scientific audience. Furthermore, DES also acquires measurements of the electronic thermal conductivity which has not yet been reported in the literature base. The PI anticipates possible publication of electronic thermal conductivity results in a peer-reviewed journal upon successful completion of this project. Finally and most importantly, this project will provide important foundational research on two advanced materials. The results will be used to expand the scope and applicability of DES which lends additional rigor to research proposals the PI plans to submit to the LA Board of Regents and the National Science Foundation.