# Acquisition of Versatile Magnetic Property Measurement System

**PI: Michael Shatruk; co-PIs: Susan Latturner, Geoffrey Strouse (all FSU Chemistry & Biochemistry), Peng Xiong (FSU Physics), Komalavalli Thirunavukkuarasu (FAMU Physics)**

## 1. Scope: Description of the Instrument

We seek acquisition (Track 1) of a multi-user Magnetic Property Measurement System (MPMS) with a variety of options to address diverse research efforts in magnetic materials. The instrument will be housed in the materials characterization laboratory (MaCLab) in the Chemical Sciences Laboratory building (CSL).

***Instrument Description.*** Magnetism is a broad research area with strong traditions and long-lasting legacy at FSU. The shared instrument described herein is capable of addressing a variety of research problems:

(a) Determination of bulk magnetic moments of solid-state and molecular materials;
(b) Determination of critical parameters (temperature, pressure, irradiation intensity threshold, and magnetic field) for transitions between different magnetic phases;
(c) Investigation of magnetic anisotropy directions in single-crystal and thin-film samples;
(d) Detection of unconventional magnetic phases, such as spin glass and single-molecule magnet.

To enable such investigations, we seek to acquire a versatile Magnetic Property Measurement System equipped with a closed-cycle helium cryostat and a high temperature furnace, for operations in the range from 1.8 to 700 K, able to apply both direct-current (DC) and alternate-current (AC) magnetic fields, and supplied with additional attachments, such as a fiber-optic sample holder for photomagnetic measurements, a clamp cell and a diamond-anvil cell (DAC) for measurements under pressure, and an electric transport measurement option. Thus, the MPMS instrument will serve a variety of projects and support a diverse group of scientists carrying out cutting-edge research in chemistry, physics, and materials science. The lack of this instrument will severely impact NSF-funded research projects in the major and minor user groups.

The projects that are briefly outlined below represent only a small portion of research areas to be enabled by the proposed instrument. We also mention some minor users of this equipment.

***Itinerant (Intermetallic) Magnets.*** The Shatruk group (Chemistry &Biochemistry, hereafter C&B) carries out investigation of itinerant magnetism in various intermetallic systems, especially focusing on the materials with the $ThCr_2Si_2$ structure type. The magnetic behavior of these materials can be controlled by affecting their electronic band structures, which requires detailed understanding of correlations between electronic and magnetic properties and crystal structure. The MPMS is indispensable for the accurate measurement of magnetic phase transitions and critical parameters associated with such transitions. Over the last 10 years, the Shatruk group has published 43 papers on the topic of itinerant magnetism with the use of bulk magnetic measurements.

The Latturner group (C&B) studies complex metal carbides and nitrides prepared from metal fluxes. Many of them incorporate lanthanide and transition metal ions that cause magnetic ordering in these metallic or semimetallic materials. Besides magnetically ordered materials, the group also studies materials with spin-frustrating interactions that lead to the formation of spin-glass phases. The availability of AC measurement capability proposed for the new instrument is crucial to the detection of such phases. In the last 10 years, the Latturner group has published results of bulk magnetic measurements in 19 papers.

***Molecular Magnetic Materials.*** The Shatruk group carries out diverse research efforts in the area of molecular magnetism. These studies include not only characterization of temperature-dependent bulk magnetic properties of metal complexes and organic compounds, but also measurements of magnetic behavior under irradiation or under applied pressure, and characterization of magnetism in air-sensitive and liquid samples. The Thirunavukkuarasu group (FAMU Physics) investigates various magnetic molecules by magnetic resonance methods. Magnetic measurements to be afforded by the MPPS are indispensable for correlating the magnetic parameters established by the spectroscopic resonance techniques with the bulk magnetic properties of molecular materials. Both groups have published extensively in these research areas (>40 papers in the last 10 years), benefitting from the use of the current MPMS instrumentation.

***Magnetic Nanoparticles.*** The Strouse group in C&B and the Peng group in Physics have been working in the area of nanomaterials for many years. A large part of their research efforts has focused on nanoparticles of magnetic alloys and doped magnetic semiconductors. In particular, the proposed MPMS instrumentation will facilitate such research activities as (a) investigation of magnetic properties of Fe/Co and Fe/Ni nanoparticles produced by the collapse of Prussian-blue type coordination polymers and (b) chirality-induced spin selectivity achieved by conjugation of metal nanostructures with DNA templates. Over the last 10 years, both groups have published more than 30 papers that include results of MPMS measurements.

***Additional Users.*** Other users of the new MPMS instrumentation will include groups of such PIs as Schlenoff, Steinbock, Alabugin, Ma, and Hanson (C&B), Siegrist (Chemical & Biomedical Engineering), Hill (Physics), and Balicas (NHMFL).

***Choice of Instrument.*** The only commercially available system that conforms to all our requirements is the MPMS manufactured by Quantum Design (San Diego, CA). If the proposal is successful, we will work with the FSU procurement services to issue a request for bids, in order to see if any other competitive offers might be identified from other vendors.

## 2. Personnel Involved

The MPMS will be housed in the MaCLab facility in the CSL building. The instrument will be maintained by a facility manager, Dr. J. S. Raaj Vellore Winfred, who will be also responsible for user training and scheduling. All PIs on this project will be actively involved in the instrument usage, providing the general oversight and advice to the facility manager and student users of the SCXRD instrumentation. Two co-PIs on this proposal, Latturner and Shatruk, routinely teach the fundamentals of magnetism within their courses on materials and characterization techniques (Solid State Chemistry, Chemistry of Materials, Inorganic Chemistry). Moreover, Shatruk teaches a biennial graduate course on magnetism and magnetic materials, which attracts students from C&B, Physics, and MS&E programs. With the acquisition of the new instrument, which will be much simpler in usage, the course will begin to include hands-on exercises allowing the students to learn practical aspects of magnetic measurements. The instrument will be available for use by any FSU or FAMU researcher after they have received proper training from the facility manager, Dr. Winfred.

## 3. Existing Resources

The C&B department currently has a 20-year old MPMS XL system, which was last upgraded in 2011. Last year, the manufacturer of MPMS, Quantum Design, announced the termination of any support of such systems. This announcement is especially worrisome, since we have been experiencing more frequent and longer failures of the old instrument, which severely undermine our research productivity. The instrument downtime has increased from 30-45 days in 2017 and 2018 to ~60-80 days in 2019 and 2020, and to over 100 days in 2021. Importantly, when the instrument is operational, it is used on the 24/7 time schedule. Any prolonged or permanent failure of this instrument will lead to slow-down on a number of NSF-funded research projects. In its current state, this old MPMS instrument represents a very high risk of such a failure.

Moreover, over nearly two decades that have passed since the acquisition of this MPMS, the instrumentation has advanced substantially. First and foremost, the new system uses a closed-cycle helium cryostat, which dramatically reduces the consumption of this expensive cryogen (currently, we are spending ~$10,000 annually for liquid helium refills on the MPMS). Second, the new system is much more robust with respect to noise and, thus, offers much more sensitive and faster measurements. The new software interface is also in line with the modern operating systems. Our current software even cannot be upgraded to work properly with Windows 10, which causes security issues and impedes secure remote file transfer and instrument control. Addressing all these deficiencies will substantially enhance our research productivity. Besides, the new instrument will bring our measurement capabilities on par with the status of FSU as the top institution for the study of magnetic materials.

It should be added that there are two MPMS instruments currently available at the NHMFL, but they are intended to serve the facility users who come to the NHMFL from all over the world. Thus, these instruments are not accessible for our day-to-day operations. Moreover, the NHMFL instruments are rather basic and lack some measurement capabilities (the AC option, the fiber-optic sample holder, and the magnet reset option), which we plan to incorporate in the new instrument.

## ESTIMATED BUDGET

*Cost-Sharing Requirement*
Cost sharing of 30% is mandated by the program solicitation.

*Instrument Cost*
The instrument cost is ~$550,000, based on the preliminary quotation from Quantum Design. This is the only major expense associated with this proposal. The total amount of funding to be requested from the NSF-MRI program will be $385,000, which means the FSU cost share will be $165,000. The Department of Chemistry & Biochemistry has already pledged to provide $50,000 toward the cost-sharing contribution, and the Department of Physics has pledged to provide $5,000. We expect to receive the remaining cost-sharing contributions from the Office of Research and the College of Arts & Sciences.

**Biographical Sketch**

**Michael (Mykhailo) Shatruk**

Florida State University | Department of Chemistry & Biochemistry
Phone: (850) 417-8417, E-mail: shatruk@chem.fsu.edu
http://www.chem.fsu.edu/~shatruk/

**Professional Preparation**

| | | | |
|---|---|---|---|
| Lomonosov Moscow State University | Moscow, Russia | Chemistry | B.S./M.S., 1996 |
| Lomonosov Moscow State University | Moscow, Russia | Chemistry | Ph.D., 2000 |
| Cornell University | Ithaca, NY | Materials Chemistry | Postdoc, 2001-2003 |
| Texas A&M University | College Station, TX | Inorganic Chemistry | Postdoc, 2003-2007 |

**Appointments**

| | | |
|---|---|---|
| Florida State University | Cottrell Family Professor | 2018-present |
| Florida State University | Professor | 2016-present |
| University of Valencia | Visiting Professor | 2016 |
| Florida State University | Associate Professor | 2013-2016 |
| Florida State University | Associate Chair for Graduate Studies | 2012-2015 |
| Florida State University | Assistant Professor | 2007-2013 |

**Honors, Awards, and Prizes**

Graduate Faculty Mentor Award, Florida State University (2021).
Cottrell Family Professorship, Florida State University (2018).
Nominated for Distinguished Teaching Award, Florida State University (2018, 2020).
Graduate Faculty Mentor Award, Florida State University (2015).
Nominated for Undergraduate Teaching Award, Florida State University (2014).
Developing Scholar Award, Florida State University (2014).
ExxonMobil Faculty Fellowship in Solid State Chemistry, American Chemical Society (2012).
Graduate Teaching Award, Florida State University (2011).
Nominated for Undergraduate Teaching Award, Florida State University (2011).
CAREER Award, National Science Foundation; Division of Materials Research (2009).
First-Year Assistant Professor Award, Florida State University (2008).
Best Publication Series, International Publishing Company "Nauka/Interperiodics" (2001).
Best Young Scientist Award, Department of Chemistry, Moscow State University (1999).

**Synergistic Activities**

- **Leadership:** FSU core university liaison to Oak Ridge National Laboratory (ORNL). Responsibilities: facilitating interactions and collaboration between the FSU and ORNL scientists, informing FSU faculty and students of collaboration and funding opportunities offered by various ORNL programs.
- **Professional Service:** Awards committee co-chair, Division of Inorganic Chemistry, American Chemical Society (January 2016 – current). Responsibilities: advertising the awards offered by the division; processing and ranking applications and nominations; award symposia organization.
- **Broadening Participation:** Providing research training to 6-7 FSU undergraduate students and 2 high-school teachers (NSF-RET participants) each year; running an outreach Materials Innovation and Discovery Lab (MINDLab) for high-school students.
- **Conference Organization:** Organizer of the symposium "Magnetism Across Length Scales" at the ACS National Meeting (April 2019) and co-chair of the Gordon Research Conference on Conductivity and Magnetism in Molecular Materials in Bryant University (August 2018).
- **Guest Editor:** A special issue of Dalton Transactions, *Frontiers in Coordination Chemistry and Its Applications* (August 2018).
- **Editorial Board Member:** ACS Materials Au, Polyhedron, Magnetochemistry

**Representative Publications**


1. Gakiya-Teruya, M.; Jiang, X.; Le, D.; Üngör, Ö.; Durrani, A. J.; Koptur-Palenchar, J.; Jiang, J.; Jiang, T.; Meisel, M. W.; Cheng, H. P.; Zhang, X. G.; Zhang, X. X.; Rahman, T. S.; Hebard, A. F.; Shatruk, M. Asymmetric design of spin-crossover complexes to increase the volatility for surface deposition. *J. Am. Chem. Soc.* **2021**, *143*, 14563-14572; https://pubs.acs.org/doi/10.1021/jacs.1c04598.
2. Üngör, Ö.; Choi, E. S.; Shatruk, M. Optimization of crystal packing in semiconducting spin-crossover materials with fractionally charged $TCNQ^{\delta-}$ anions ($0 < \delta < 1$). *Chem. Sci.* **2021**, *12,* 10765-10779; https://pubs.rsc.org/en/content/articlelanding/2021/sc/d1sc02843j.
3. Clark, J. K.; Yannello, V.; Samarakoon, A. M.; Ross, C.; Uible, M. C.; Garlea, V. O.; Shatruk, M. Inelastic neutron scattering study of magnetic exchange pathways in MnS. *J. Phys. Chem. C* **2021**, *125*, 16183-16190; https://pubs.acs.org/doi/abs/10.1021/acs.jpcc.1c02956.
4. Romanini, M.; Wang, Y.; Gürpinar, K.; Ornelas, G.; Lloveras, P.; Zhang, Y.; Zheng, W.; Barrio, M.; Aznar, A.; Gràcia-Condal, A.; Emre, B.; Popescu, C.; Zhang, H.; Long, Y.; Balicas, L.; Tamarit, J. L.; Planes, A.; Shatruk, M.; Mañosa, L. Giant and reversible barocaloric effect in trinuclear spin-crossover complex $Fe_3(bntrz)_6(tcnset)_6$. *Adv. Mater.* **2021**, *33*, 2008076; https://onlinelibrary.wiley.com/doi/full/10.1002/adma.202008076.
5. Mann, D. K.; Wang, Y. X.; Marks, J. D.; Strouse, G. F.; Shatruk, M. Microwave synthesis and magnetocaloric effect in $AlFe_2B_2$. *Inorg. Chem.* **2020**, *59*, 12625-12631; https://pubs.acs.org/doi/10.1021/acs.inorgchem.0c01731.
6. Wang, Y. X.; Yannello, V.; Graterol, J.; Zhang, H.; Long, Y.; Shatruk, M. Theoretical and experimental insights into effects of Zn doping on magnetic and magnetocaloric properties of MnCoGe. *Chem. Mater.* **2020**, *32*, 6721-6729; https://pubs.acs.org/doi/abs/10.1021/acs.chemmater.0c02294.
7. Clark, J. K.; Tan, X.; Arico, A. A.; Ramirez, A. P.; Yannello, V.; Thompson, C. M.; Kovnir, K.; Garlea, O. V.; Shatruk, M. Reentrant spin glass state induced by structural phase transition in $La_{0.4}Ce_{0.6}Co_2P_2$. *Phys. Rev. Mater.* **2020**, *4*, 074412; https://journals.aps.org/prmaterials/abstract/10.1103/PhysRevMaterials.4.074412.
8. Mann, D.; Xu, J.; Mordvinova, N.; Yannello, V.; Ziouani, Y.; González-Ballesteros, N.; Sousa, J.; Lebedev, O.; Kolen'ko, Y.; Shatruk, M. Electrocatalytic water oxidation over $AlFe_2B_2$. *Chem. Sci.* **2019**, *10*, 2796-2804; https://pubs.rsc.org/en/content/articlelanding/2019/sc/c8sc04106g.
9. Dragulescu-Andrasi, A.; Filatov, A.; Oakley, R. T.; Li, X.; Lekin, K.; Huq, A.; Pak, C.; Greer, S. M.; McKay, J.; Jo, M.; Lengyel, J.; Hung, I.; Maradzike, E.; DePrince, A. E.; Stoian, S. A.; Hill, S.; Hu, Y. Y.; Shatruk, M. Radical dimerization in plastic organic crystal leads to structural and magnetic bistability with wide thermal hysteresis. *J. Am. Chem. Soc.* **2019**, *141*, 17989-17994; https://pubs.acs.org/doi/10.1021/jacs.9b09533.
10. Dragulescu-Andrasi, A.; Hietsoi, O.; Üngör, Ö.; Dunk, P. W.; Stubbs, V.; Arroyave, A.; Kovnir, K.; Shatruk, M. Dicyanometalates as building blocks for multinuclear Fe(**II**) spin-crossover complexes. *Inorg. Chem.* **2019**, *58*, 11920-11926; https://pubs.acs.org/doi/10.1021/acs.inorgchem.9b01121.
11. Yannello, V.; Guillou, F.; Yaroslavtsev, A. A.; Tener, Z. P.; Wilhelm, F.; Yaresko, A. N.; Molodtsov, S. L.; Scherz, A.; Rogalev, A.; Shatruk, M. Revisiting bond breaking and making in $EuCo_2P_2$: where are the electrons? *Chem. Eur. J.* **2019**, *25*, 5865-5869; https://onlinelibrary.wiley.com/doi/abs/10.1002/chem.201900244.
12. Hrudka, J. J.; Phan, H.; Jengyel, J.; Rogachev, A. Yu.; Shatruk, M. Power of three: incremental increase in the ligand field strength of *N*-alkylated 2,2′-biimidazoles leads to spin crossover in homoleptic tris-chelated Fe(**II**) complexes. *Inorg. Chem.* **2018**, *57*, 5183-5193; https://pubs.acs.org/doi/abstract/10.1021/acs.inorgchem.8b00223.
13. Ryan, K.; Lengyel, J.; Shatruk, M. Crystal structure prediction via deep learning. *J. Am. Chem. Soc.* **2018**, *140*, 10158-10168; https://pubs.acs.org/doi/10.1021/jacs.8b03913.
14. Tan, X.; Tener, Z. P.; Shatruk, M. Correlating itinerant magnetism in $RCo_2Pn_2$ pnictides (R = La, Ce, Pr, Nd, Ca; Pn = P, As) to their crystal and electronic structures. *Acc. Chem. Res.* **2018**, *51*, 230-239; http://pubs.acs.org/doi/10.1021/acs.accounts.7b00533.
15. Phan, H.; Hrudka, J. J.; Igimbayeva, D.; Lawson Daku, L. M.; Shatruk, M. A simple approach for predicting the spin state of homoleptic Fe(**II**) tris-diimine complexes. *J. Am. Chem. Soc.* **2017**, *139*, 6437-6447; http://pubs.acs.org/doi/abs/10.1021/jacs.7b02098.

# Michael Shatruk

**From:** Geoffrey Strouse
**Sent:** Tuesday, November 9, 2021 3:42 PM
**To:** Michael Shatruk
**Subject:** RE: NSF-MRI Cost Sharing Commitment

Dear Dr. Shatruk,
The department of Chemistry & Biochemistry is committed to the support of your NSF-MRI Proposal**: Acquisition of Versatile Magnetic Property Measurement System.** The department will contribute *$50,000* towards the instrument and will house the instrument in the *Chemical Sciences Laboratory*. The instrument will be maintained by Departmental staff and a recharge for usage to ensure continuous operation monitored by our Auxiliary. The source of the $50,000 will be assigned following approval of the pre-proposal.
Prof Geoff Strouse
Chair

## Michael Shatruk

**From:** Paul Eugenio
**Sent:** Wednesday, November 10, 2021 2:51 AM
**To:** Michael Shatruk
**Subject:** Re: NSF-MRI Cost-Sharing Commitment

**Follow Up Flag:** FollowUp
**Flag Status:** Flagged

Mike,
I confirm the Physics agrees to the cost-sharing commitment.

--
Paul Eugenio

> On Nov 9, 2021, at 3:35 PM, Michael Shatruk <shatruk@chem.fsu.edu> wrote:
>
> Dear Paul,
> Peng has informed me that you have graciously agreed to provide $5K in cost-sharing toward our MRI proposal to acquire a new MPMS system. I'm submitting the pre-proposal to FSU tomorrow, and I just would like to ask for a brief letter or email to confirm your cost-sharing commitment. I apologize about such a short notice. I hope you'll be able to send me the requested letter. I'm attaching a brief summary of the intended proposal.
> Best,
> Mike
> <Shatruk NSF-MRI_MPMS.docx>

**Pushing the Efficiency Limits of Solar Cells with Molecular Photon Upconversion**

**Summary:** The abundant and sustained nature of sunlight leaves little doubt that access to inexpensive solar energy conversion technology will play a pivotal role in future global health and sustainability. As such, it is necessary to generate less expensive cells and/or increase solar cell efficiencies in order to decrease module costs per energy generated ($/kWh). As a step towards this goal we have introduced an entirely new solar energy conversion strategy that incorporates molecular photon upconversion directly into a solar cell. Photon upconversion (UC)—combining low energy light to generate a higher energy light—is a strategy to efficiently utilize the previously unharnessed, low energy portions of the solar spectrum. Our efforts thus far have demonstrated that the mechanism is feasible but the proof-of-concept device efficiency is low. Here we propose the steps necessary to significantly increase device performance. If successful, this integrated upconversion solar cell will be a lower cost alternative to traditional silicon solar cells which could have far reaching global implication for the distribution and utilization of inexpensive renewable energy.

**I. Description of invention:** Dye-sensitized solar cells (DSSCs) are a promising alternative to traditional silicon solar cells because they can be generated using low cost, solution processable manufacturing. Since the mid-1990s the record DSSC efficiency has increased from 11% to 14.1%[1] through incremental variation in the composition of the materials but the photocurrent generation mechanism remains largely unchanged. The record efficiency, while impressive, falls short of the competitive commercialization goal of 15%.[2] Systems analysis indicate that harnessing photon upconversion via triplet-triplet annihilation (TTA-UC) can increase the maximum theoretical solar cell efficiency from 31% to greater than 43%.[3] Actual device performances are lower than the theoretical limit but successful implementation of TTA-UC could increase DSSC performance from the current 14.1% to upwards of 20% (well above the 15% commercialization goal) but with much lower manufacturing cost than current solar cell technologies. With this goal in mind, the Hanson research group has introduced self-assembled bilayers on metal oxide surfaces (Figure 1) as an effective strategy for combining TTA-UC molecules[4] and directly harnessing TTA-UC in a DSSC.[5] Our prototype bilayer TTA-UC film/device is composed of a high surface-area semiconductor, an acceptor molecule (blue in figure 1), a sensitizer molecule (red in figure 1), a redox mediator, and counter electrode. We have definitively established that bilayer films effectively harness sunlight and generate photocurrent via low energy light absorption by the sensitizer molecule, followed by triplet energy transfer, TTA-UC, and electron injection from the upconverted state.

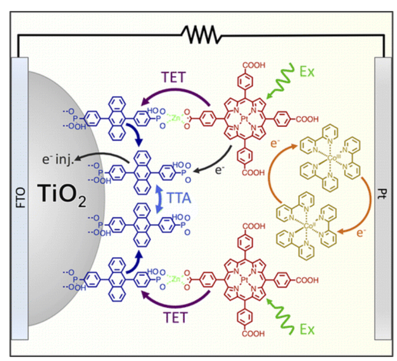

**Figure 1**. Schematic of the self-assembled TTA-UC DSSC.

**II. Importance in the area of science, environmental conservation, or patient care and experience:** The realization of an efficient TTA-UC could have a major impact on numerous applications, such as photodynamic therapy, photocatalysis, bioimaging, photoactuators, and, in particular, solar energy conversion. Access to low cost, renewable solar energy will 1) reduce

$CO_2$ emissions, 2) lessen the need for mining/fracking/drilling for fossil fuel, and 3) improve the quality of life for millions of people around the globe. The later point being particularly important in that inexpensive energy/electricity can be used for water and air purification, cooking, indoor lighting, recycling materials, as well as the production and distribution of medical equipment/technology.

**III. Stage of invention:** We have generated an integrated TTA-UC DSSC using self-assembled bilayers and have definitively supported that we are able to harness a new photocurrent generation mechanism via TTA-UC. Our first published TTA-UC DSSC efficiency is low ($\eta_{UC}$ = 1.6 × $10^{-5}$ %, $\eta_{total}$ = 7.0 × $10^{-3}$ %) but does demonstrate proof-of-concept. Now that we have established a mechanism we are positioned to significantly improve device performance by: 1) Incorporating near-IR absorbing sensitizer and acceptor pairs into the film to maximize solar spectrum overlap and UC solar cell efficiency, 2) generating multi-sensitizer bi- and tri-layer films to increase broad band light absorption, 3) modifying the acceptor molecule structure to maximize electron injection yield and cross-surface energy transfer/TTA rate, and 4) incorporating earth abundant sensitizer molecules into the TTA-UC DSSCs.

**IV. Current funding:** The research thus far has been entirely supported by start-up funds provided by the FSU Energy & Materials initiative. This startup account will be closed on August 2017. We currently have two pending grants (NSF-CHE-MSN and ONR-YIP) to gain fundamental mechanistic insights into the energy/electron transfer dynamics in the film. These pending proposals do not focus on increasing device efficiencies (although the insights gained will help in future materials design).

**V. Feasibility:** The extensive information already available on both DSSCs and TTA-UC indicate that a >15% efficient TTA-UC DSSC can be realized. The success of this effort requires a broad range of skills including synthesis, thin-film preparation, and device assembly/measurement. Based on our preliminary results, previous publications, and instrumental capabilities we are confident that we have the plan, skill, and know-how to achieve this goal.

**VI. Approach for measuring progress during the grant term:** Progress in developing this technology can readily be monitored using the device efficiency (current and voltage) relative to the prototype device as well as a control cell that are known to reach 11% in a manufactured device (the same architecture is ~4% efficient in our lab).

**References**

1) Kakiage, K.; Aoyama, Y.; Yano, T.; Oya, K.; Fujisawa, J.; Hanaya, M. *Chem. Commun.*, **2015**, 51, 15894-15897.
2) Qin, Y.; Peng, Q. *Int. J. Photoenergy* **2012**, 2012, 291579.
3) Cheng, Y. Y.; Fückel, B.; Khoury, T.; Clady, R. l. G. C. R.; Tayebjee, M. J. Y.; Ekins-Daukes, N. J.; Crossley, M. J.; Schmidt, T. W. *Journal of Physical Chemistry Letters* **2010,** 1, 1795-1799.
4) Hill, S.P.; Banerjee, T.; Dilbeck, T.; Hanson, K. *J. Phys. Chem. Lett.* **2015**, 6, 4510-4517.
5) Hill, S.P.; Dilbeck, T.; Baduell, E.; Hanson, K. *ACS Energy Lett.* **2016**, 1, 3-8.

**<u>Budget (spreadsheet available upon request):</u>**

**A. Senior Personnel (Total: $39,855)**

One month of summer salary is requested for the PI, Kenneth Hanson, who will devote 1.0 calendar-months effort to this project per year ($10,832). Funds are requested to cover fringe benefits at a rate of 19.03% for faculty. A 3% annual salary increase has been included.

**B. Other Personnel (Total: $478,968)**

This proposal requests support for one postdoc, three graduate students, and three undergraduate student over the 3-year funding period. The postdoc will be paid at a rate of $47,500 with 2.75% fringe with $15,000 per year for health insurance. Each grad students will be paid at a rate of $23,494.00 for the first year and a 3% yearly increase to account for inflation with 1.3% for fringe benefits as well as $1,662 per year per student subsidy the university-sponsored health insurance plan. Three undergraduate summer research students will be paid at a rate of $5,000 each summer with 1.3% for fringe benefits

**C. Travel (Total: $42,000)**

We request $8,000 per year in domestic travel costs and $6,000 per year for international travel costs. Funds are requested for the PI, postdoc, and students to attend four domestic conference each per year ($2000 per trip per person) and two international conference ($3000 per trip per person). Example rates are shown below:

| <u>Domestic:</u> | | <u>International:</u> | |
|---|---|---|---|
| Airfare: | $500.00 | Airfare: | $1500.00 |
| Registration: | $1,000.00 | Registration: | $1000.00 |
| Lodging: (3 nts @ ~$120/nts) | $356.00 | Lodging: (3 nts @ ~$120/nts) | $356.00 |
| Meals: (4 days @ $36/day) | $144.00 | Meals: (4 days @ $36/day) | $144.00 |
| ====== | | ====== | |
| TOTAL/TRIP: | $2,000.00 | TOTAL/TRIP: | $3,000.00 |

**D. Materials, Supplies, and Instrument time (Total: $82,810)**

We request $34540, $29761, and $24846 in years one, two, and three respectively for materials and supplied to conduct the research. These funds will be partitioned 70% materials and supplies (chemicals, glassware, lamps, etc.) and 30% instrument time (NMR, MS, spectrometers, etc.).

**E. Tuition (Total: $100,029)**

Funds for tuition costs are requested for 27 credit hours per year per graduate research assistant (9 hours/semester during the fall, spring and summer term). The 2017-18 academic year cost is $11004 and is anticipated to increase by 1%/year in subsequent years.

**F. Equipment (Total: $0)**

No funds are requested for equipment. All equipment necessary to perform the research described in this proposal are already available in our lab or in user facilities at FSU.

**G. Indirect (Total: $75,000)**

The grant does not allow for indirect costs as a percentage of the funding. However, FSU will receive a total of $75,000 ($25,000 each year) to offset costs associated with grant management.

**Total Requested Funding** = $750,000 + $75,000 **= $825,000**
(direct) (indirect) **(TOTAL)**

# Kenneth Hanson

Department of Chemistry and Biochemistry • Florida State University • Tallahassee, Florida 32306-4390
Phone: 850.645.0479 • E-mail: hanson@chem.fsu.edu

**Education/Experience**

| | | |
|---|---|---|
| Florida State University | Assistant Professor | 2013-present |
| UNC-Chapel Hill | Postdoctoral Researcher<br>Research Advisor: Prof. Thomas J. Meyer | 2010-2013 |
| University of Southern California | Inorganic Chemistry<br>Research Advisor: Prof. Mark E. Thompson | Ph.D., 2010 |
| St. Cloud State University | Chemistry | B.S., 2005 |

**Publication/Patent Metrics**

| | | |
|---|---|---|
| Total Publications: 56 | Patents: 9 (1 provisional) | h-index: 25 |
| Independent Publications: 20 | Citations: 1668 | i10-index: 36 |

**Independent Grants/Awards**

| | |
|---|---|
| 2016 | DOE-EFRC: Center For Actinide Science (PI: Thomas Albrecht-Schmidt) |
| 2015 | AAAS Early Career Award for Public Engagement with Science (Top 4 Finalist) |
| 2015 | NSF-Major Research Instrumentation Grant |
| 2015 | Selected as 1 of 50 "Not to miss" presentations at the Fall 2015 National Meeting of the American chemical Society |
| 2015 | C&EN's ChemPics Tumblr Blog Chemistry Photo of the Year |
| 2014 | Army Research Office-Young Investigator Program Award |
| 2014 | American Chemical Society-Petroleum Research Fund |

**Five Example Publications**

1) Hill, S.P.; Dilbeck, T.; Baduell, E.; Hanson, K. Integrated Photon Upconversion Solar Cell via Molecular Self-Assembly at Hybrid Interfaces. *ACS Energy Lett.* **2016**, 1, 3-8. http://pubs.acs.org/doi/abs/10.1021/acsenergylett.6b00001.

2) Hill, S.P.; Banerjee, T.; Dilbeck, T.; Hanson, K. Photon Upconversion and Photocurrent Generation via Self-Assembly at Hybrid Interfaces. *J. Phys. Chem. Lett.* **2015**, 6, 4510-4517. http://pubs.acs.org/doi/abs/10.1021/acs.jpclett.5b02120.

3) Ogunsolu, O.O.; Murphy, I.A.; Wang, J.C.; Das, A.; Hanson, K. Energy and Electron Transfer Cascade Self-Assembled Bilayers for Application in Dye-Sensitized Solar Cells. *ACS Appl. Mater. Interfaces* **2015**, 7, 27730-27734. http://pubs.acs.org/doi/abs/10.1021/acsami.6b09955.

4) Das, A.; Ayad, S.; Hanson, K., Enantioselective Protonation of Silyl Enol Ether Using Excited State Proton Transfer Dyes. *Org. Lett.* **2016**, 18, 5416–5419. http://pubs.acs.org/doi/abs/10.1021/acs.orglett.6b02820.

5) Das, A.; Banerjee, T.; Hanson, K., Protonation of Silylenol Ether via Excited State Proton Transfer Catalysis. *Chem. Comm.* **2015**, 52, 1350-1353. http://pubs.rsc.org/en/content/articlelanding/2015/cc/c5cc08081a#!divAbstract.

**Synergistic Activities**

1) Reviewer: *Journal of the American Chemical Society, Journal of Physical Chemistry, ACS Photonics, Advanced Materials Interfaces, Sensors, Chemistry of Materials, Physical Chemistry Chemical Physics, ACS Applied Materials & Interfaces, Inorganic Chemistry, Journal of Graphics and Modeling, Inorganic Chemistry, Polymer Chemistry, Langmuir, Dalton Transactions, Chemical Sciences, ACS Nano, Angewandte Chemie, Materials Technology: Advanced Performance Materials, Applied Surface Science, Journal of Materials Chemistry A.*
2) Panelist for SCIENCE 2034 Live (Washington, DC): A United State Senate and House Congressional briefings on the importance of funding basic science and its implications for life in the future. (Hosted by the Science Coalition)
3) Founder and Organizer of the monthly First Friday, *Ask a Scientist* event in Railroad Square, Tallahassee
4) Regular contributor of scientific content to www.chemistry-blog.com, twitter.com and www.reddit.com/r/chemistry/.

**Students/Postdocs**

*Postdoctoral Associates:* Tanmay Bannerjee(2014-2016), Anjan Das (2014-current), Sahan Salpage (2016-current)

*Graduate Students:* Jamie Wang (2013-current), Sean Hill (2013-current), Omotola Ogunsolu (2014-current), Tristan Dilbeck (2014-current), Suliman Ayad (2016-current), Yan Zhou (2016-current)

*Undergraduate Students:* Ian Murphy (2013-2016),Enric Baduell (2014-2016), Bryan Casale (2014-2016), Catherine Kent (2014-current), Kyle Violette (2015-current), Victoria Posey (2016-current), Justin Silver (2016-current), Alex Braun (2016-current)

**Awards and Honors Received by Students**

| | |
|---|---|
| 2016 | Tristan Dilbeck, 2nd place graduate poster, Florida Inorganic/Material Symposium |
| 2016 | Kyle Violette, 1st place undergraduate poster, ACS Florida Meeting and Exposition |
| 2016 | Tristan Dilbeck, Ford Foundation Fellowship (honorable mentioned) |
| 2015 | Omotola Ogunsolu, FSU Art in Stem Competition (runner-up) |
| 2015 | Jamie C. Wang, NSF-Graduate Research Fellow |
| 2015 | Omotola Ogunsolu, P.E.O. International Peace Scholarship |
| 2015 | Ian Murphy, 1st place undergraduate poster, ACS Florida Annual Meeting and Exposition |
| 2015 | Sean Hill, 2nd place graduate poster, ACS Florida Annual Meeting and Exposition |
| 2015 | Jamie C. Wang, 1st place graduate poster, Florida Inorganic/Material Symposium |
| 2015 | Sean Hill, 3rd place graduate poster, Florida Inorganic/Material Symposium |
| 2015 | Ian Murphy, 1st place undergraduate poster, Florida Inorganic/Material Symposium |
| 2015 | Catherine Ken, 2nd place undergraduate poster, Florida Inorganic/Material Symposium |
| 2014 | Omotola Ogunsolu, Reverie Innovation Scholarship |
| 2014 | Jamie C. Wang, 2nd place graduate poster, Florida Inorganic/Material Symposium |