UNIVERSITY OF MINNESOTA

Faculty Single Semester Leave

Route this form to:	U Wide Form
See Routing Instructions Below	UM 21
	Rev: 6/03

1. *Complete Faculty Single Semester Leave Form and submit to department head.*
2. *If request is recommended by department head/chair, submit form to college screening committee.*
3. *Forward request, with priority ranking, from college screening committee to the Dean/Vice Chancellor.*
4. *If request is approved, provide signed copies to: ☐ Dean/Vice Chancellor ☐ Department ☐ Employee Benefits*
5. *Enter approved leave information into PeopleSoft prior to the beginning of the single semester leave.*

For more information, see the Faculty Development Leaves Policy at http://www.umn.edu/regents/policies/humanresources/FacultyDevLeaves.html and the Administrative Procedures at http://www1.umn.edu/usenate/policies/facdevleaveadmin.html

Applicant Information

Name: Ted M. Pappenfus		Empl ID: 1661935	
Rank or Title: Assistant Professor		Job Code: 9403	
Department: Chemistry Discipline		College: Morris	
Requested Leave — Semester: Fall, Year: 2007		Official beginning and ending dates of requested leave: August 15 - December 20, 2007	
Annual Full-Time Base Salary	Basic Term of Appointment: LT	9 to 10 mo. term paid over 12: ☒ Yes ☐ No	Appointment Type: ☒ Probationary ☐ Tenured

Project to be Conducted During Leave - attach additional information if necessary

Title of Project	Institution or Location where project would be conducted
Collaborative research in materials chemistry between the Morris and Twin Cities campuses	University of Minnesota, Morris University of Minnesota, Twin Cities

Nature and significance of project in terms of scientific, scholarly, or artistic value, and/or practical application:

Materials chemistry is an interdisciplinary specialty area that encompasses traditional areas such as organic and inorganic chemistry. This field of chemical research focuses on fundamental properties of materials and their potential applications. Research in materials chemistry is growing at a rapid pace and its development is likely to continue throughout this century. New advances in materials chemistry continue to be reported and many of these discoveries have practical applications to our everyday lives. For example, materials chemists have found ways to promote bone tissue repair, modulate light for high-speed data transfer, and catalyze the breakdown of harmful chemicals in the environment.

This project includes proposed activities in the field of materials chemistry with an emphasis on fundamental research and materials design. Specifically, these activities include the study of materials for organic electronics. The objective of the project is to improve the performance of a class of materials recently published by a collaborative effort between faculty on the Morris and Twin Cities campuses. The scope of the project is in line with the strategic planning initiatives of the Morris campus as well as the University as a whole. If UMM is to contribute to the University's goal of becoming one of the top public research universities in the world, collaborative efforts such as this are essential.

Present state of knowledge or accomplishment on subject – General status:

Materials for organic electronics. A large emphasis of this project is the design and study of organic materials as semiconductors in transistors. Transistors are found in virtually all consumer electronics such as our cell phones, digital clocks and televisions. As a civilization, we have made more transistors than anything else on earth – more than bricks, nails, or hammers. For example, a single processor in a PC, such as Intel's® recent Core™ 2 Duo processor, contains an astonishing 290 million transistors![1]

A transistor is an electronic device capable of performing many functions including amplification and switching. The essential component of a transistor is the semiconductor – a material capable of conducting small amounts of current. Silicon is the principal component of most semiconductor devices. Certainly, it is hard to overlook the importance of this element (i.e. silicon) in terms of its impact on our everyday lives. Many believe that the advent of silicon electronics was one of the most important advances in the last half of the 20th century.[2]

Even the best technologies, however, have limitations and silicon is no exception. Silicon is similar to glass in the sense that although strong, it is very brittle and prone to chipping. Therefore, application of traditional silicon-based transistors in new technologies such as flexible electronics is difficult. A consumer product falling under the category of flexible electronics would be electronic paper. Most people envision this as a display device where one could simply download your daily newspaper on a flexible matrix each day rather than dealing with a paper copy. The electronic paper would be designed to be lightweight, flexible, and reusable.

Leading candidates for semiconductors in flexible electronics are organic materials. Most people, however, view organic materials (i.e. plastics) as being insulators rather than conductors of electrical current. For example, copper wire (an inorganic material) conducts electricity while being insulated by a plastic coating (an organic material). Advances in the later half of the 20th century, however, have shown that plastics are capable of conducting electricity. The discovery in the late 1970's that conjugated polymers can be made highly electrically conducting[3] has opened up many new possibilities for devices combining unique optical, electrical, and mechanical properties of plastics and conventional inorganic materials. In certain applications, organic materials may compete with conventional inorganic electronic materials. These plastics are attractive due to their low density, flexibility, and processibility over large coverage areas.[4]

In addition to polymers, small organic molecules are also able to act as semiconductors in electronic devices. My research has focused on the study of organic molecular-based systems as alternatives to traditional silicon-based systems. This project includes the exploration of similar materials to improve on the performance of molecules designed by UMM undergraduate students and me.

(1) Intel Corporation. Intel High-performance Consumer Desktop Microprocessor Timeline. http://www.intel.com/pressroom/kits/core2duo/pdf/microprocessor_timeline.pdf (accessed October 2006).

(2) Ratner, M.; Ratner, D. *Nanotechnology: A Gentle Introduction to the Next Big Idea*; Prentice Hall: New Jersey, 2003.

(3) Chiang, C. K.; Fincher, C. R., Jr.; Park, Y. W.; Heeger, A. J.; Shirakawa, H.; Louis, E. J.; Gau, S. C.; MacDiarmid, A. G. "Electrical conductivity in doped polyacetylene," *Phys. Rev. Lett.* **1977**, *39*, 1098-1101.

(4) Rogers, J. A.; Bao, Z. "Printed plastic electronics and paperlike displays," *J. Polym. Sci. Part A: Polym. Chem.* **2002**, *40*, 3327-3334.

Present state of knowledge or accomplishment on subject – Your background or activities in this area:

Organic semiconductors can be categorized into three main types: p-type, n-type, and ambipolar (possessing both p- and n-type behavior). The vast majority of organic-based semiconductors display hole-transporting (p-type) behavior in transistors. During my graduate work, I synthesized an organic molecule that displayed electron-transporting (n-type) behavior in a transistor. When published in 2001,[5] this represented a rare example of an organic molecule displaying n-type behavior. Later in 2003, we published the first example of an organic molecule displaying ambipolar behavior in a transistor.[6] As with any new discovery, there is a desire to see that others make similar observations. Fortunately, since 2003 ambipolar behavior has been reported by other investigators on similar materials, most notably by Prof. Tobin Marks at Northwestern University.[7]

Since beginning my appointment at UMM, I have focused on the design and synthesis of organic materials as candidates for n-type and ambipolar semiconductors. This work is part of a collaborative effort including contributions from faculty, staff, and graduate students on the Twin Cities campus and UMM undergraduate students under my direction. Faculty and staff from the Twin Cities campus that have participated in this collaboration include Dr. Michael Burand (Chemistry), Prof. Dan Frisbie (Chemical Engineering), Prof. Kent Mann (Chemistry) and Dr. Victor Young (Chemistry). Thus far, our collaboration has been successful as we have published six papers (many in leading chemistry journals) since my start date at UMM in 2003. In addition, our most recent work[8] includes four UMM undergraduate students as coauthors! I have made it a priority to include UMM undergraduate students in all aspects of my research.

(5) Pappenfus, T. M.; Chesterfield, R. J.; Frisbie, C. D.; Mann, K. R.; Casado, J.; Raff, J. D.; Miller, L. L. "A pi-Stacking Terthiophene-Based Quinodimethane Is an n-Channel Conductor in a Thin Film Transistor," *J. Am. Chem. Soc*. **2002**, *124*, 4184-4185.

(6) Chesterfield, R. J.; Newman, C. R.; Pappenfus, T. M.; Ewbank, P. C.; Haukaas, M. H.; Mann, K. R.; Miller, L. L.; Frisbie, C. D. "High electron mobility and ambipolar transport in organic thin-film transistors based on a pi-stacking quinoidal terthiophene," *Adv. Mater*. **2003**, *15*, 1278-1282.

(7) Yoon, M.-H.; DiBenedetto, S. A.; Facchetti, A.; Marks, T. J. "Organic Thin-Film Transistors Based on Carbonyl-Functionalized Quaterthiophenes: High Mobility N-Channel Semiconductors and Ambipolar Transport," *J. Am. Chem. Soc*. **2005**, *127*, 1348-1349.

(8) Casado, J.; Delgado, M. C. R.; Merchan, M. C. R.; Hernandez, V.; Navarrete, J. T. L.; Pappenfus, T. M.; Williams, N.; Stegner, W. J.; Johnson, J. C.; Edlund, B. A.; Janzen, D. E.; Mann, K. R.; Orduna, J.; Villacampa, B. "Optical, redox, and NLO properties of tricyanovinyl oligothiophenes: comparisons between symmetric and asymmetric substitution patterns," *Chem.-A Eur. J.* **2006**, *12*, 5458-5470.

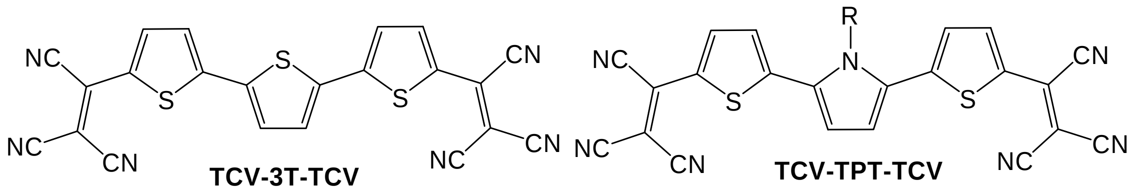
Description of research design or project plan (include specific information on approach to the project, methods to be used, potential results, and why the Single Semester Leave will facilitate this activity):

In Spring 2004 in our Introduction to Research course (Chem 2321), UMM students and I focused on making new organic molecules as candidates for organic semiconductors. Over the course of that semester and subsequent summer, the students were successful in preparing new molecules with interesting physical properties. These molecules were further characterized by graduate students on the Twin Cities campus in the research groups of Prof. Kent Mann (Chemistry) and Prof. Dan Frisbie (Chemical Engineering). In short, these materials display reasonably good n-type behavior, but relatively poor ambipolar behavior. The results of our efforts were recently published in two independent articles.[8,9]

(9) Cai, X.; Burand, M. W.; Newman, C. R.; da Silva Filho, D. A.; Pappenfus, T. M.; Bader, M. M.; Bredas, J.-L.; Mann, K. R.; Frisbie, C. D. "N- and P-Channel Transport Behavior in Thin Film Transistors Based on Tricyanovinyl-Capped Oligothiophenes," *J. Phys. Chem. B* **2006**, *110*, 14590-14597.

Description of research design or project plan (continued):

Although our results thus far are promising in terms of transistor performance, we feel the materials can be improved with careful design. For example, our best material thus far, **TCV-3T-TCV** (shown below), contains sulfur atoms in each of the five-membered rings. Our current objective is to simply replace one or more sulfur atoms in these materials with nitrogen-containing groups to create molecules such as **TCV-TPT-TCV**. Previous investigators in Japan have shown that this relatively small chemical change has a tremendous impact on the properties of the molecules.[10] Enhanced properties include improved solid state morphologies and more desirable electronic properties. To our knowledge, however, these investigators have yet to apply the molecules as organic materials in transistors. As such, this is a current objective of our research and will be the major focus of this project.



S = Sulfur; N = Nitrogen; C = Carbon; R= Carbon-containing group

<u>Plan of work (pre-leave)</u>
Spring 2007 – We began preliminary work on the organic materials project in the summer of 2005. Four UMM undergraduate students assisted in the synthesis of the nitrogen-containing analogs. The synthesis is not yet complete and will be completed in the spring of 2007 in our Introduction to Research course and with the assistance of a UROP student (proposal pending).
Summer 2007 – I have been asked to work on hydrogen projects with Twin Cities faculty during this summer under the auspices of the Initiative for Renewable Energy and the Environment (IREE). Plans are to explore the use of lithium nitride as a hydrogen storage material as well as a material for ammonia synthesis. As a result, I will not have time this summer to devote to the organic materials project.

<u>Plan of work (leave)</u>
August to November 2007 – I have received permission from Prof. Dan Frisbie (UMTC Chemical Engineering) to work in his lab and prepare transistors with organic materials prepared at UMM. I will spend this time learning the appropriate techniques and will collect and analyze data. Previously, UMM undergraduate student Jacob Melby was able to obtain the necessary skills for fabricating transistors over a ten week period. This was accomplished as part of a summer research program in 2006. Thus, a ten to fifteen week period in a semester is a suitable amount of time to investigate the device performance of our new materials.

Although we can make the organic materials at UMM, we do not have the facilities or equipment for preparing transistors. A single semester leave, therefore, is essential to the success of this project since the leave will allow me to test our materials in the Twin Cities. Furthermore, this area of research is highly competitive and includes investigators from across the globe in both academia and industry. As a result, a single semester leave is needed for a timely completion of this project.

November to December 2007 – At this time I will return to UMM and focus on writing a manuscript based on the results of the nitrogen-containing organic materials. If the preliminary results are not promising, I will return to my lab and explore alternative strategies for improving the device performance of the materials.

(10) For example, see the following and references therein: Ogura, K.; Ooshima, K.; Akazome, M.; Matsumoto, S. “Formation of metal-lustrous organic crystals from 2-aryl-1-(4-methoxyphenyl)-5-(5-tricyanoethenyl-2-thienyl)pyrroles,” *Tetrahedron* **2006**, *62*, 2484-2491.

List up to five of your recent personal publications or accomplishments (or equivalents) which may be related to the project:

(1) Cai, X.; Burand, M. W.; Newman, C. R.; da Silva Filho, D. A.; Pappenfus, T. M.; Bader, M. M.; Bredas, J.-L.; Mann, K. R.; Frisbie, C. D. "N- and P-Channel Transport Behavior in Thin Film Transistors Based on Tricyanovinyl-Capped Oligothiophenes," *J. Phys. Chem. B* **2006**, *110*, 14590-14597.

(2) Casado, J.; Delgado, M. C. R.; Merchan, M. C. R.; Hernandez, V.; Navarrete, J. T. L.; Pappenfus, T. M.; Williams, N.; Stegner, W. J.; Johnson, J. C.; Edlund, B. A.; Janzen, D. E.; Mann, K. R.; Orduna, J.; Villacampa, B. "Optical, redox, and NLO properties of tricyanovinyl oligothiophenes: comparisons between symmetric and asymmetric substitution patterns," *Chem.-A Eur. J.* **2006**, *12*, 5458-5470.

(3) Pappenfus, T. M.; Burand, M. W.; Janzen, D. E.; Mann, K. R. "Synthesis and characterization of tricyanovinyl-capped oligothiophenes as low-band-gap organic materials," *Org. Lett.* **2003**, *5*, 1535-1538.

(4) Chesterfield, R. J.; Newman, C. R.; Pappenfus, T. M.; Ewbank, P. C.; Haukaas, M. H.; Mann, K. R.; Miller, L. L.; Frisbie, C. D. "High electron mobility and ambipolar transport in organic thin-film transistors based on a pi-stacking quinoidal terthiophene," *Adv. Mater*. **2003**, *15*, 1278-1282.

(5) Pappenfus, T. M.; Chesterfield, R. J.; Frisbie, C. D.; Mann, K. R.; Casado, J.; Raff, J. D.; Miller, L. L. "A pi-Stacking Terthiophene-Based Quinodimethane Is an n-Channel Conductor in a Thin Film Transistor," *J. Am. Chem. Soc*. **2002**, *124*, 4184-4185.

Plans for publication or other outcome as a result of this project:

As mentioned above, I will write a manuscript based on the results of the nitrogen-containing organic materials. Regardless of the device performance of the materials, I am confident a report on these materials will be well received by scientists in this area. In addition, if the device performance of these materials is promising, I will write one or more proposals to secure external funds with UMTC faculty to further explore the materials.

Dates of previous leaves in the past 10 years

Single Quarter/Semester	Sabbatical	Summer Faculty Research Appointment	Other

☒ I will submit a report on my semester leave to the department head/chair and college dean/campus vice chancellor within three months of returning.

☒ In the event that I do not return to the University of Minnesota for a period at least equal to the period of the leave, I agree that:

1. I will reimburse the University of Minnesota for any salary paid during the semester leave, and
2. I will reimburse the University of Minnesota for its share of the retirement contributions and insurance premiums paid during the semester leave.

☒ I will not accept any other salary or compensation for services while on semester leave.

Requested in accordance with the Board of Regents Policy on Faculty Development Leaves and the corresponding Administrative Procedures.

Signature	Date
Prepared By	Date
Campus Address	Phone Number

Recommended – Provision for the applicant's work will be made within the funds of the department

Division Chair Signature	Date
Comments	

College Screening Committee

Rank or priority given this application	Total number of applications from this college	
Comments		
Signed		Date

Approved – Dean/Vice Chancellor	Date