Rec 10/9/15

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MTSU Clean Energy Initiative Project Funding Request

There are five (5) sections of the request to complete before submitting. See http://www.mtsu.edu/sga/cleanenergy.shtml for funding guidelines. Save completed form and email to cee@mtsu.edu or mail to MTSU Box 57.

1. General Information	
Name of Person Submitting Request **Ngee Sing Chong with Keying Ding as faculty co-sponsors**	
Department/Office **Chemistry/SCI 3067**	Phone # (Office) **898-5487**
MTSU Box # **Box 68, MTSU**	Phone # (Cell) **615-556-5509**
E-mail **nchong@mtsu.edu; Keying.Ding@mtsu.edu**	Submittal Date **10/9/2015**

2. Project Categories (Select One)			
Select the category that best describes the project.			
	Energy Conservation/Efficiency	**X**	Sustainable Design
	Alternative Fuels		Other
	Renewable Energy		

3. Project Information
a. Please provide a brief descriptive title for the project. **b.** The project cost estimate is the expected cost of the project to be considered by the committee for approval, which may differ from the total project cost in the case of matching funding opportunities. **Any funding request is a 'not-to-exceed' amount. Any proposed expenditure above the requested amount will require a resubmission.** c. List the source of project cost estimates. d. Provide a brief explanation in response to question regarding previous funding.
3a. Project Title **Equipping the New Science Building with Microwave Reactors to Enhance Student Laboratory Experience in Chemistry Courses**
3b. Project Cost Estimate **Total Amount Requested $29,560.00** **MARS Synthesis Reactor for Chemistry Laboratory**
3c. Source of Estimate **Price quote from CEM (Microwave Reactor Vendor) is attached.**

3d. If previous funding from this source was awarded, explain how this request differs?

The previous funding (Fall 2014) was for the purchase of a hydrogenation reactor intended to eliminate the use of hydrogen cylinder as a reactant source so that lab environment is safer without the high pressure cylinders of hydrogen gas which is explosive if it is leaked and accumulated to a high level. In this proposal, a microwave reactor will be used for student research or class experiments in order to (i) reduce energy usage, (ii) shorten reaction time, and (iii) improve safety by eliminating the traditional heating mantles or Bunsen flame burners.

4. Project Description

(Completed in as much detail as possible.)

a. The scope of the work to be accomplished is a detailed description of project activities.
b. The benefit statement describes the advantages of the project as relates to the selected project category.
c. The location of the project includes the name of the building, department, and/or specific location of where the project will be conducted on campus.
d. List any departments you anticipate to be involved. Were any departments consulted in preparation of this request? Who? A listing may be attached to this form when submitted.
e. Provide specific information on anticipated student involvement or benefit.
f. Provide information for anticipated future operating and/or maintenance requirements occurring as a result of the proposed project.
g. Provide any additional comments or information that may be pertinent to approval of the project funding request.

4a. Scope: Work to be accomplished

The MARS6-TA microwave reactor system include the reactor with the features of reagent stirring, fiber optic temperature control, and the option of doing open vessel synthesis. The GlassChem vessels for reactions have a working volume of 14 milliliters, heating range up to 180 C and can withstand about 200 psi and they can be used for sample extraction prior to chemical analysis. The MARS6-TA reactor will be set up for student use in SCI 3070 and its small size allows it to be moved to other laboratories if necessary. Faculty sponsors will do the installation of the reactor for student use.

4b. Scope: Benefit Statement

With the new microwave system, chemistry students will no longer heat flasks in the lab using older, less efficient methods such as heating mantles or Bunsen burners. Instead they will insert tubes with chemicals into the microwave system. The heat generated by the instrument will produce chemical reactions much quicker than before, with the added benefit of minimizing the production of byproducts and chemical waste. Students will also learn about modern microwave syntheses and will be better prepared in using the emerging microwave reactor technology that is being adopted by industry and the academia. The new microwave synthesis system is based on green chemical principles that include waste prevention, use of methods to minimize toxicity, using safer solvents, energy efficiency, and preventing accidents.

4. Project Description (continued)

4c. Location of Project (Building, etc.)

MTSU Department of Chemistry (Science Building Room 3070 and 3007)

4d. Participants and Roles

Ngee Sing Chong – Purchase and installation of the MAR6-TA microwave reactor; using microwave reactor in teaching and research; evaluating energy savings by switching from heating mantles and Bunsen burners to the microwave reactor.

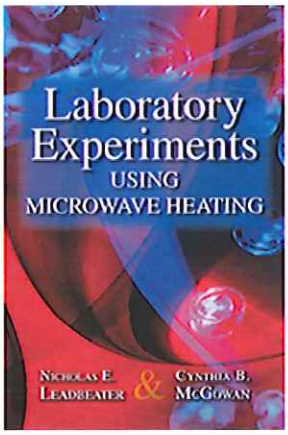
Keying Ding – Introduce students to the development of earth-abundant metal catalysts for organic transformations such as decarbonylation and deoxygenation which are particularly useful for biomass conversions to produce fuels and chemicals.

Jessie Weatherly – Maintenance of the microwave reactor by periodic replacement of consumable parts.

Other Chemistry Faculty and Students – Use the reactors and record usage duration to help track the cost or energy savings compared to traditional heating methods.

4e. Student participation and/or student benefit

Students will be the main beneficiaries of the microwave reactor because they will learn a modern laboratory technique for synthetic reactions that will enable some of them to adapt to the modern industrial laboratory practice of using microwave reactors rather than traditional heating methods. Students will be able to follow existing microwave based chemistry experiments such as those described in the following lab manual.



Laboratory Experiments Using Microwave Heating
Nicholas E. Leadbeater & Cynthia B. McGowan
CRC Press 2013

Presents 22 modern experiments for the chemistry lab

- Cycloaddition reactions
- Esterification reactions
- Condensation reactions
- Rearrangements
- Metal-catalyzed couplings, metathesis, click chemistry, cyanation
- Coordination chemistry
- Determination of empirical formula
- Extraction of essential oils
- Digestion and analysis by atomic absorption

4f. Future Operating and/or Maintenance Requirements

The microwave reactor has few consumable parts other than the glassware, which can be purchased using funds from Chemistry Department. Jessie Weatherly, the Instrument Support Engineer in the Department of Chemistry, is in charge of maintenance for all laboratory equipment and will be able to take care of the maintenance and repair of the microwave reactor if the need arises.

4g. Additional Comments or Information Pertinent to the Proposed Project

1. **Efficiency and Selectivity of Microwave Reactors in Organic Chemistry;**
   http://www.chem.tamu.edu/rgroup/djd/chem483/Projects/Microwave%20Chemistry.pdf

2. **Controlled Microwave Heating in Modern Organic Synthesis**
   http://onlinelibrary.wiley.com/doi/10.1002/anie.200400655/pdf

3. **Chemists Crank Up Heat On Microwaves**
   http://cen.acs.org/articles/90/i39/Chemists-Crank-Heat-Microwaves.html

4. **Greening the organic chemistry laboratory: a comparison of microwave-assisted and classical nucleophilic aromatic substitution reactions**
   http://www.tandfonline.com/doi/pdf/10.1080/17518253.2015.1065010

5. **Microwave chemistry**
   https://en.wikipedia.org/wiki/Microwave_chemistry

6. **A critical assessment of the greenness and energy efficiency of microwave-assisted organic synthesis**
   http://140.123.79.90/~mash1225/images/microwave%20reference/c0gc00823k.pdf

7. **Microwave Chemistry—Out of The Lab and into Production**
   http://ctechinnovation.com/papers/Microwave-chemistry-out-of-lab-into-production.pdf

5. Project Performance Information

Provide information if applicable.

a. Provide information on estimated annual energy savings stated in units such as kW, kWh, Btu, gallons, etc.
b. Provide information on estimated annual energy cost savings in monetary terms.
c. Provide information on any annual operating or other cost savings in monetary terms. Be specific.
d. Provide information about any matching or supplementary funding opportunities that are available. Identify all sources and explain.

5a. Estimated Annual Energy Savings (Estimated in kW, kWh, Btu, etc.)

The energy savings vary greatly among different reaction conditions and should be evaluated on a case-by-case basis as pointed out in Reference 6 above. The comparison of the energy efficiencies of selected chemical reactions carried out using the microwave reactor and traditional thermal heating is provided by Yvonne Barton in Reference 7. The comparison and analysis of data are shown in the two tables below where (MW) refers to microwave-assisted reactions.

Table 1. Summary of results comparing microwave heating to conventional heating

Reaction	Time	Temperature	Yield
Suzuki coupling	2 h	120 °C	92%
	2 min (MW)	160 °C	99%
	1 min (MW)	155 °C	98%
Dihydropyrimidine	8 h	120 °C	35%
	4 min (MW)	145 °C	71%
Ionic liquid	4 h	130 °C	95%
	1 min (MW)	200 °C	95%

Table 2. Comparison of energy use in microwave reactor and batch reactor

Reaction	Energy/kg in MW	Energy efficiency	Energy/kg in batch (Croda)	% energy saving in MW
Suzuki	0.381 kWh/kg	57%	3.60 kWh/kg	89%
Cyclisation	3.84 kWh/kg	42%	3.60 kWh/kg	–
Ionic liquid	0.382 kWh/kg	39%	3.60 kWh/kg	89%

5b. Annual Energy COST Savings ($)

The savings in energy expenditure is 89% but the actual energy cost savings will depend on actual reaction conditions.

5c. Annual Operating or Other Cost Savings. Specify. ($)

Since the microwave reactor allows 14 chemical reactions to be performed simultaneously, this would amount to annual savings of about $5000 based on the capital cost of $2500 per heating mantle and control unit.

5d.Matching or Supplementary Funding (Identify and Explain)

Department of Chemistry will pay for the consumable cost of the additional glassware needed for the microwave reactor. This amounts to about $1500 per academic year.

CEM Corporation
3100 Smith Farm Rd. - Matthews, NC 28104 -
Phone: 800-726-3331 - Fax: 704-821-5185 - Email: sales@cem.com

QUOTE

	Quote #
07/21/10	CEMQ7733

MIDDLE TENNESSEE STATE UNIV
Dr. Ngee Sing Chong
Chemistry Dept
PO Box X067
Murfreesboro, TN 37130

Phone: 615-898-5487
Fax:

Please Provide Billing Information If Different Than Quote
Contact _____
Address _____
City _____ State _____
Zip _____
Phone _____ Fax _____

Ln #	Part #	Description	Qty.	Unit Price	Ext. Price
1	MARS-TA	**MARS Synthesis Academic Configuration** The MARS-TA is a specifically configured MARS for both open vessel and closed vessel Synthetic Chemistries in the Academic Marketplace. The MARS-TA includes the following part numbers; PN927060 (MARS), PN907540 (MARS Synthesis Option), PN565203 (Fiber Optic Temperature Option), and PN565305 (Reagent Stirring Option). These part numbers cannot be substituted and the final selling price incorporates Academic pricing.	1	$15,000.00	$15,000.00
2	565470-C	**Internal Pressure Control for MARS5 System** This option provides pressure control for the Mars System utilizing an internal Electronic Sensor for Pressure. This would be used for all 'plus' series vessel technologies. It includes one ESP-1500Plus sensor, pressure line and onboard instrument installed electronics allowing full pressure monitoring of the control vessel to 1500psi.	1	$3,600.00	$3,600.00
3	565731	**DuoTemp Control (includes TempGuard feature)** The option uses an infrared sensor in concert with the RTP-300 Plus to control program using the temperature of each vessel in the turntable. This reading is correlated to the control vessel temperature to provide a temperature reading for each vessel. Includes Program Disk, electronic application manual, 12 ft. null modem serial cable with RS-232 connectors and installation guide. Software program for PC installation which allows graphic representation of vessel temperatures and data acquisition and storage of time and temperature	1	$1,310.00	$1,310.00

Ln #	Part #	Description	Qty.	Unit Price	Ext. Price
		data. Program does NOT allow remote unit operation. Computer Requirement: IBM PC or compatible running Microsoft WindowsÖ 95 or WindowsÖNT or higher. **RTP-300 Plus must be purchased in order to take advantage of the new DuoTemp control option.**			
4	431783	**GreenChem Plus Vessel Accessory Set/Glass** The accessory set contains (13) GreenChem Plus Vessel Assemblies (glass liner), (1) GreenChem Plus Control Vessel (glass liner), Turntable Assembly, liner lifter tool, liner rack, liner weighing adapter and (2) thermowells.	1	$6,135.00	$6,135.00
5	907394	**GlassChem Vessel Starter Set, 24 place, 20 mL** The starter set contains (23) GlassChem vessels, (1) Vessel Rack and (1) 24- place turntable with (1) GlassChem Control Vessel Assembly. Fiber Optic capable system only.	1	$4,500.00	$4,500.00
6	907545	**MARS Synthesis Glassware Starter Kit** Kit includes an 11.5-inch connector adaptor with 24/40 ground glass joint, a 14.5-inch connector adaptor with 24/40 ground glass joint, a 3-liter round bottom flask with a 40/30 ground glass joint neck, a 5-liter round bottom flask with a 40/30 ground glass joint neck, a ground glass joint reducing adaptor (40/30 to 24/40), a single neck temperature probe adaptor, a double neck temperature probe adaptor to allow for overhead stirring, 2 oval rare earth stir bars (40 x 20mm), 2 oval rare earth stir bars (64 x 20mm), and 2 elliptical rare earth stir bars (70 x 20mm).	1	$2,300.00	$2,300.00
7	*99	**Academic Discount**	1	-$3,285.00	-$3,285.00
				Total	**$29,560.00**

Comments

Sales Rep	Terms	P.O. Number	Ship Via
Lee Daugherty	Net 30 Days		

Please sign here

Date

Note: This quote can be used as a purchase order by entering purchase order number and signing

Delivery is ***28*** days ARO

Quote expiration date: 9/30/2010

For information on leasing CEM products, contact Tammy Grimshaw at CEM Financial Services Phone 973-292-0025 X14

Terms

1. Payment - Make all checks payable to CEM Corporation and mail to Accounts Receivable at the address given below.
2. General - Net 30 Days FOB Matthews, NC. Freight is prepaid and added to invoice. Clerical errors are subject to corrections.
3. All orders subject to shipping and handling charges.
4. Taxes - All prices are quoted exclusive of any sales, excise, use or similar tax. The amount of tax applicable is the buyers responsibility.
5. Renters Casualty - Renter shall bear the risk of loss or damage to the equipment from delivery to customer site until it is returned to CEM.
6. Warranty - All instruments are warrantied against defects in workmanship or material for one (1) year from the date of shipment.
7. Returns - All returns must be authorized with an RMA# by the CEM customer Service Department. Call (800) 726-3331 for authorization.
8. Quantity - Any changes to quantities other than complete instruments will not effect the validity of this quote.