Southern California Regional Technology Acceleration Program

Final Program Performance Report

October 1, 2010 – September 30, 2014

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Introduction

UC San Diego von Liebig Entrepreneurism Center is pleased to present the final report for award DOE-SC0005459 covering the period of October 1, 2010 through September 30, 2014.

The Center is excited to report outstanding accomplishments during this program period and we are thankful for the Department of Energy's support without which the Center would not have been able to serve the 71 faculty, PhD, and MBA students that participated in the Southern California Regional Technology Acceleration Program (SoCal rTAP).

Below is sampling of the success stories that this grant from the Department of Energy has made possible:

- Electrozyme team was admitted to the highly selective EvoNexus incubator; is negotiating with a multi-national beverage company to produce and distribute its technologies; and has had many other successes including:
  - Established strategic partnership with a Fortune 100 company that is interested in potentially incorporating Electrozyme technology into its existing products.
  - Raised $2M in follow on funding
    - $250,000 investment from strategic partner
    - $250,000 angel investment
    - $1,500,000 in National Institute of Health grants
  - Achieved proof of concept
  - Admitted to the highly selective EvoNexus incubator
  - Enormous success in entrepreneurial competitions including
    - 1st Place: Elevator Pitch Competition at the 2012 World's Best Technology Rady School of Management Student Venture Open
    - 2nd Place: Business Plan Presentation at the 2012 World's Best Technology Rady School of Management Student Venture Open
    - Finalist: 2012 California Institute of Technology Flow Competition
    - 4th Place: 2012 UC San Diego Entrepreneur Challenge
    - Finalist: 2013 California Dreamin' Investor & Fast Pitch Competition
    - Audience Choice in the BioTech/MedTech category: 2013 UC San Diego Entrepreneur Challenge
  - Recognized by the community including
    - CONNECT's Most Innovative New Product Award in Sports & Active Lifestyle
    - 2014 San Diego Venture Group Cool Company
  - Incorporated and hired 11 people to join the growing team
  - Holds five exclusive licenses from UC San Diego
  - Filed 12 patents
- Lyxia achieved enormous success in a relatively short period of time and now has international facilities and operations, has raised significant follow on funding, received accolades from the community, achieved proof of concept and success in entrepreneurial competitions. Highlights include:
  - Raised $18.7M in follow on funding
    - $17.1M investment for commercialization development of microalgae-based technology in China
    - $1.6M angel round funds from Venture Lender in April 2013
  - 2013 finalist for the Los Angeles Business Journal Patrick Soon-Shoing Innovation Awards
  - Top 10 at "Win the 21st Century" contest sponsored by the US-China Association of High Level Professionals
  - Regional finalist at the FLoW Competition
- GrollTex team has achieved exceptional success during this program and is poised for success going forward. Highlights include:
  - Raised $101,000 + in kind services in follow on funding

- Raised $61,000 + in kind services through entrepreneurship competitions to fund further commercialization efforts. Awards included:
  - 1st Place: 2013 UC San Diego Entrepreneur Challenge
  - 2013 UC San Diego Entrepreneur Challenge Audience Award in Tech/Innovation
  - 2nd Place at FLoW competition at Caltech on May 9, 2014
- Investment of $50,000 pending from CTO Forum participation

o Received NSF Graduate Research Fellowship in 2014
o Identified and successfully recruited a CEO
o Selected as one of the top 50 startups by Founder.org

The success stories above were made possible by the 84 faculty, advisors, program managers, PhD and MBA students that participated in the SoCal rTAP. The researchers – faculty, PhD student and MBA students – are working on technologies that will shape the future. The technologies are cutting edge and the researchers are innovative, motivated, and dedicated to solving current problems for future generations. Without grants such as the one the Center received from the Department of Energy, many of the innovations developed in university labs would never make it to market due to a gap in funding between research and commercialization. Funding, such this Department of Energy grant, is a critical component of the commercialization process and helps ensure that the most viable technologies developed have a chance to change the world. We are very thankful for the Department of Energy's support of our technology acceleration program. A list of the people whose research and, in some cases, entire lives have been shaped by the Department of Energy's support of this program can be found in Appendix III.

Final Comparison Table Phase III Program Milestones (Section 4)

Comparison of the accomplishments toward the goals and objectives established for Phase III which includes the no cost extension period.

Phase III	
Stated Goals & Objectives Year 3	**Accomplishments**
1. Graduate 3 von Liebig Fellowships. (Year 2)	**<u>Graduate Year 2 recipients of von Liebig fellowships</u>** • All awardees from year 2 have successfully completed the technology development program set for their projects and the final tranches of funding are being processed.
2. Collect 15+ applications for the Year 3 Energy Innovation Challenge.	**Execute Year 3 Energy Innovation Challenge program at the von Liebig Entrepreneurism Center** **<u>Launch virtual Energy Challenge in Year 3</u>** • Year 3 of the Southern California Clean Energy TAP was advertised online from early October 2012 until the application deadline 10+ universities and colleges in Southern California were targeted for a direct email campaign which included directly contacting administration and faculty to identify potential projects **<u>Selection of awardees:</u>** • 24 Statements of Intent received from 5 southern California universities • 13 invited to submit proposals after a review by expert advisers and program PIs • 11 finalists invited to present to an expert judge panel April 10-11, 2013 • 4 von Liebig advisers provided four weeks of mentoring to prepare finalists for the panel review in April • 11 panelists from the private sector, venture capital and the local entrepreneurial ecosystem

- 4 projects were selected by the expert review panel to participate in the 3rd year of the Technology Acceleration Program. The list of the four awardees is described in section five.
  - 14 graduate students were awarded von Liebig Fellowships to participate in the four projects
  - 2 PhD students from UC San Diego's Department of NanoEngineering
  - 2 PhD students from UC San Diego's Department of Mechanical and Aerospace Engineering
  - 1 PhD student from University of Southern California's Department of Chemical Engineering and Material Science
  - 6 MBA* students from UC San Diego's Rady School of Management
  - 3 MBA* students from San Diego State University's College of Business Administration

**MBA students are selected through a competitive process and join engineering and science teams to conduct market research studies prior to the team launching proof of concept studies*

Incorporation of Improvements for launching announcement and fellowship selection

- The current outreach campaign involves a combination of social media platforms: Facebook, Twitter, LinkedIn, the von Liebig website, and email blasts for dissemination of information about the Southern California Clean Energy TAP call for Statements of Intent.
- LinkedIn is now being used by the Center's staff
- Applicant interviews were conducted as a part of the project selection criteria to help determine the engineering and science fellow's interest level and commitment to the process
- Awardees attended a 9-week lean startup training program taught by Kim Davis King – venture capitalist and lecturer at the UC San Diego Rady School of Management – to help them develop a business model for their technology using Steve Blank's well respected customer development methodology

Distribute awards, execute projects, and track milestones.

- All Year 3 teams have completed their technology development and commercialization plan and submitted the corresponding milestone and budget documents for the award period of 7/1/13 to 6/30/14
- All Year 3 teams have submitted their third quarterly report
- All Year 3 teams have successfully completed the outlined in their milestone & budget document
- Three of the Year 3 teams has successfully completed all of the required milestones to date

One of the teams is delayed on the commercialization and technical milestones and has only partially completed the milestones required for this quarter

Continue to refine program's best practices as needed.

- Improvements to this year program are captured in the revised program scheduled below as indicated by the blue shading.

	Program Schedule **September 22, 2012 – October 22, 2012**: Longer time for program dissemination and outreach. **October 22, 2012**: Invitation & Guidelines for Application **October 22, 2012 – February 4, 2013**: More effective use of social media platforms to disseminate information about the program, application process and general outreach. **January 29, 2013**: Webinar on Application Process and Broader Impact followed by Q&A. Webinar posted on YouTube channel. **February 4, 2013**: Statement of Intent Applications Due **February 11, 2013**: Invitations to Complete Full Application **February 28, 2013**: Full Proposal Applications Due. **February 28, 2013 – March 2013**: Team interviews by Program leadership team to evaluate commitment of applicants to commercialization. **March 2013**: Finalist interviews telephone by PIs and von Liebig advisors. **March 2013**: Invitation to Present to Expert Review Panel **April 10-11, 2013**: Presentations to Expert Review Panel. **May 2013**: Funding Announcement **April-June 2013**: Participation on 9-week customer development workshop. Business Model Canvas development.
3. Deliver commercialization boot camp on-line to 100% of applicants.	**Incorporate on-line training** • The repackaged series of on-line webinars is available to all DoE awardees and the innovation ecosystem in the region. Partnerships with Wilson, Sonsini, Goodrich & Rosati law firm, CONNECT, University of San Diego EPIC program (http://www.sandiego.edu/EPIC/), WilderShares, and the California Center for Sustainable Energy have enabled the von Liebig Entrepreneurism Center to produce relevant content for the program. • The webinar series was completed in April 2013. • A partnership with the American Chemical Society and Blackbird ventures was structured to provide a series of nine webinars on technology entrepreneurship that are available online for free. This series was completed in October 2013 and is available online free of charge. **Incorporate Web 2.0 tools to provide interaction among participants and content providers** • The on-line platform Go-To-Webinar has enabled all webinars to accommodate flexibility of schedules of the presenters. • All attendees were sent a survey to solicit feedback after attending the live webinar. • Asynchronous availability of webinars can be found on the von Liebig You Tube Channel, "UCSD von Liebig Center" (http://www.youtube.com/user/UCSDEntrepreneurism) and on the Center's website (http://www.vonliebig.ucsd.edu). **Collect feedback and adjust the program as needed**

	• In response to questions about the program and solicitation process, a succinct programmatic webinar was delivered on January 29, 2013 about the DoE Clean Energy Program in general, the Southern California Clean Energy Program's outcomes and highlights, the fellowship technology validation period, and the application process • To date, webinars for this program are available on YouTube and have reached an audience of 195 people and cover topics such as the SoCal Clean Energy Program as well as overviews of new venture creation, intellectual property, and taking an introductory idea to innovation. • A partnership with the American Chemical Society allowed the production of a nine part webinar series on venture creation and entrepreneurship delivered by local entrepreneurs Neil Senturia and Barbara Bry. Recordings of these webinars are available online: http://acswebinars.org/chemical-entrepreneurship-2013
4. Award 3 von Liebig Fellowships. (Year 3)	• Successfully completed on July 1, 2013 • 14 von Liebig Fellows are participating in 4 projects selected to conduct concept studies, market research and business model development over a 12 month period • All four project teams finalized their milestone and budget proposals and the fellowship period started July 1, 2013.
5. Build an on-line community of at least 1,000 unique supporters.	**Launch Energy Innovation Challenge Virtualization and social media initiative** • **Engage social media experts and launch virtualization initiative.** The Center's website and social media platforms were updated by individuals with backgrounds in marketing in an effort to expand the Center's reach and allow for dissemination of calls for proposals. • **Execute virtualization initiative.** Facebook was primarily used to create followers for building awareness and creating community. LinkedIn and Twitter were used as complimentary platforms. The Center has focused more on LinkedIn to create a collaborative, professional atmosphere and to enhance the innovation ecosystem and give award recipients an opportunity to interact with the many experts, industry professionals and venture capitalists that engage with the von Liebig Entrepreneurism Center. • **Build on-line community of supporters.** After engaging business students to create social media platforms – Facebook, Twitter and LinkedIn – the von Liebig Entrepreneurism Center continues to evaluate the social media plan and connect with supporters. Currently there are 235 Facebook likes, 183 members of the LinkedIn group, 422 LinkedIn connections, and 164 followers on Twitter • **Develop a strategic plan and step-by-step timeline for social media strategy.** This objective is being currently implemented on a weekly basis and will seek advisory board approval once a longer-term plan has been finalized.
6. Secure commitments from 5+ supporters to provide funding for the program in Year 4 and beyond.	**Ensure continuous funding for the Proof of Concept process thru:** • **Support from Business Partners**. A corporate Technology Acceleration Program (TAP) package has been developed, which uses the current, successful TAP model to be proposed for funding to local, national, and global companies. The value proposition for this new development package is to provide an early stage pipeline for companies that want to invest in innovation. A meeting with Sempra (member of our advisory board) was held to gain feedback. Follow on meetings with other potential partners have been conducted and input is being integrated into the value proposition of the program. • **Technology Acceleration Fund.** The Triton Technology Fund (TTF), an early-stage investment/translational fund, was approved by the Jacobs School of Engineering (JSOE) and the Chancellor of UC San Diego. The JSOE has invested

	$1M in discretionary funding to launch a $15M fund to support commercialization of early stage technologies. The Center will source, evaluate, and develop commercializable technologies suitable for investment from this venture fund. Legal documents for the fund have been reviewed and approved by all parties. The initial $5M required to begin investments has already been raised and we are currently in the process of implementing the program. • **Rady Venture Fund**. The TAP participants were provided opportunities to pitch to the Rady Venture Fund and received feedback by venture capitalists and angel investors associated with the fund. The Rady Venture Fund is a venture philanthropy fund managed by the Rady School of Management at UC San Diego. • **Tech Coast Angles**. The TAP participants were introduced to the Tech Coast Angels (TCA), the largest angel investor group in the United States. Its members provide funding and guidance to a higher number of early-stage, high-growth companies in Southern California than any other investment group. TCA members invest in companies in a wide range of industries, including life sciences, biotech, IT, services, retail, Internet, financial, software, media, consumer products and tech startups. TCA members also provide counsel, mentoring and access to an extensive network of potential investors, customers, strategic partners and management talent. TCA has more than 250 members, including its venture capital affiliates, in five networks in Los Angeles, Orange County, San Diego, Westlake/Santa Barbara and the Inland Empire.
7. Release 2+ on-line reports/videos to disseminate best practices and lessons learned	• In progress.
8. Measure and review program progress	• **Identify and incorporate improvements.** Improvements have been made in the dissemination of information, interviewing of applicants and introduction of the lean startup methodology. • **Solicit feedback from program participants.** The program PIs and von Liebig staff will solicit informal feedback from program participants and reviewers during the project review meeting in the next 6 months. • **Evaluate impact.** Metrics table is included in Appendix I.

Discussion of Accomplishments (Section 5)

Summary

The four year Southern California Regional Technology Acceleration Program (SoCal rTAP) has been successful in helping to pull high quality technology out of university labs in the Southern California region and accelerating it toward the marketplace.

Due to widespread marketing and outreach efforts across the campuses of Southern California's most prestigious institutions the SoCal rTAP was successful in attracting high quality proposals. Over the course of this program a total of 82 applications were submitted for consideration from universities throughout the Southern California region. Each of the applications was reviewed by a group of experts including the program directors and von Liebig Business and Technology Advisors, additional due diligence was conducted as necessary and the 36 most promising applications were selected to present to expert review panels consisting of advisors, venture capitalists, and industry experts where the projects were reviewed against a common standard. These teams received business and technology advising from von Liebig advisors and the support of MBA students to prepare for their presentations. Eleven of the 36 finalists teams were selected to receive von Liebig

Fellowships. These 11 teams were teamed with a von Liebig Business and Technology Adviser and MBA students from either the UC San Diego Rady School of Management or the San Diego State University College of Business Administration for the duration of their 1 year program.

Program Highlights

- $27,726,000 in funding raised by the ecosystem in support of this program + undisclosed amounts for licensing agreements, royalties, and in kind services received by the program participants (includes follow on funding raised by companies)
- 95 patents and disclosures filed in conjunction with this program
- 84 highly qualified individuals* supported the successful outcomes of each of the 11 projects selected to participate in this program
- 11 projects were selected for this program
    - Lyxia (Enhanced oil and protein production of Botryococcus Braunii)
    - Reusable fuel source "lignocellulosic biomass"
    - Low-turbulence, low heat loss engines optimized for transient plasma ignition
    - Electrozyme (Flexible fuel cells)
    - Sky Imager (solar forecast tool)
    - GrollTex (novel production of high quality graphene)
    - Vertically Aligned Carbon Nanotube electrodes for High Power Density Capacitors
    - Structural Health Monitoring of Wind Turbine Blades Using Advanced Infrared Thermography,
    - Novel High-Efficiency and Mercury-Free Light Bulbs Based Semiconductor Nanowires
    - Novel 3D Organic Photovoltaic Solar Cells
    - Nanofoundry
- 48 graduate students participated in the successful completion of the 11 projects
    - 3 PhD students from UC San Diego's Department of NanoEngineering
    - 4 PhD students from UC San Diego's Department of Mechanical and Aerospace Engineering
    - 1 PhD student from University of Southern California's Department of Chemical Engineering and Material Science
    - 1 PhD student from UC San Diego's Dept. of Electrical and Computer Engineering
    - 1 PhD student form UC Los Angeles' Dept. of Biomedical Engineering
    - 1 PhD student from San Diego State University's College of Engineering
    - 1 PhD student from UC Los Angeles' Dept. of Aerospace and Mechanical Engineering
    - 1 PhD student from UC San Diego's Dept. of Structural Engineering
    - 1 M.Eng. student from San Diego State University's College of Engineering
    - 25 MBA students from UC San Diego's Rady School of Management
    - 8 MBA students from San Diego State University's College of Business Administration
    - 1 MBA student from University of Southern California's Marshall School of Business
- 14 PhD students received von Liebig Innovation Fellowships to act as entrepreneurial leads for the 11 selected projects
- 34 MBA students were selected, matched with the von Liebig Innovation Fellows and received stipends to support proof of concept and commercialization efforts by conducting market and business research
- 15 faculty advisors provided research support and guidance to the von Liebig Innovation Fellows for the duration of the program
- 7 von Liebig Business and Technology Advisors supported the von Liebig Innovation Fellows
- 6 program management team members provided guidance and executed program initiatives
- 8 unfunded research and commercialization team members supported the execution of the projects
- $5M in venture funding secured to launch Triton Technology Fund which will support technology development beyond proof of concept funding

*Details on all the team members including links to their professional profiles can be found in Appendix III.

Project Summaries

1. Lyxia (enhanced oil and protein production of *botryococcus braunii)*

Lyxia developed a novel method for enhancing the oil and protein production of *B.* braunii algae. When treated with the Lyxia's proprietary formula, the data shows that *B.* braunii has very consistent and reliable increases in cell growth and biofuel production enhancement including sharp increases in cell numbers and lipids. This technology is significant because with the successful scale up operations Lyxia predicts the capability of producing crude oil from a renewable source at a cost of approximately $23/barrel which almost 1/3 the current production cost - $61,86/barrel – of crude oil from *B. braunii*. The current world crude oil market is $3.2 trillion with an annual growth rate of 7.5% and the vast majority of production stems from non-renewable sources so the competitive advantages of this technology represent significant opportunities.

Successful completion of this project was reported in a previous report which also contained the final report for this project. Below are highlights of the team's commercialization accomplishments:

- Secured $18.7M in follow on funding
  - $17.1M investment for commercialization development of microalgae-based technology in China
  - Secured $1.6M angel round funds from Venture Lender in April 2013
- Two locations and 20 employees:
  - Lyxia Culver City, CA: continuing R&D of microalgae-based technology
  - Lyxia China: establishing a pilot scale plant in in the southern part of China
- Success in entrepreneurial competitions includes:
  - 2013 finalist for the Los Angeles Business Journal Patrick Soon-Shoing Innovation Awards
  - Top 10 at "Win the 21st Century" contest sponsored by the US-China Association of High Level Professionals
  - Regional finalist at the FLoW Competition
- Achieved proof of concept

Commercialization Team
Wei Yu, Project Lead, Founder Lyxia®, PhD candidate, Biomedical Engineering Dept., UC Los Angeles
Dan (Ryan) Zhang, Co-founder Lyxia®, MBA graduate, UC Los Angeles Anderson School of Management
Matthew Han, Partner, MBA graduate, UC Los Angeles Anderson School of Management.
Katrina Phruksukarn, MBA student, San Diego State University
Kevin Greene, MBA student, San Diego State University
John McMillan, MBA student, San Diego State University
Nick Moiseff, MBA student, San Diego State University
Chih Ming Ho, Project Faculty Adviser, Professor, Department of Bioengineering, UC Los Angeles
Jim Corlett, von Liebig Technology and Business Advisor, UC San Diego

2. Electrozyme (flexible fuel cells)

Electrozyme developed a novel fabrication concept for manufacturing miniature fuel cells whereby robust biofuel cells (BFCs) can be printed on a wide variety of rigid and flexible substrates for power generation using high-throughput and low-cost screen-printing techniques. Electrozyme wants to grow to be the world leader in the development of printed biofuel cells to power the 21st century lifestyle. Electrozyme's printed biofuels are capable of generating zero-emissions power from purely organic/biological fuels such as perspiration, urine, sewage, and wastewater.

Successful completion of the program was reported in a previous report which also contained the final report for this project. Below are highlights of the team's commercialization accomplishments:

- Established strategic partnership with a Fortune 100 company that is interested in potentially incorporating Electrozyme technology into its existing products.
- Raised $2M in follow on funding
    - $250,000 investment from strategic partner
    - $250,000 angel investment
    - $1,500,000 in National Institute of Health grants
- Achieved proof of concept
- Admitted to the highly selective EvoNexus incubator
- Enormous success in entrepreneurial competitions including
    - 1st Place: Elevator Pitch Competition at the 2012 World's Best Technology Rady School of Management Student Venture Open
    - 2nd Place: Business Plan Presentation at the 2012 World's Best Technology Rady School of Management Student Venture Open
    - Finalist: 2012 California Institute of Technology Flow Competition
    - 4th Place: 2012 UC San Diego Entrepreneur Challenge
    - Finalist: 2013 California Dreamin' Investor & Fast Pitch Competition
    - Audience Choice in the BioTech/MedTech category: 2013 UC San Diego Entrepreneur Challenge
- Recognized by the community including
    - CONNECT's Most Innovative New Product Award in Sports & Active Lifestyle
    - 2014 San Diego Venture Group Cool Company
- Incorporated and hired 11 people to join the growing team
- Holds five exclusive licenses from UC San Diego
- Filed 12 patents

Commercialization Team Members
Joshua Windmiller, Project Lead, PhD, Dept. of NanoEngineering, UC San Diego
Jared Tangney, PhD candidate, Dept. of NanoEngineering, UC San Diego
Drew Beal, MBA student, UC San Diego Rady School of Management
Joseph Wang, Project Faculty Adviser, Professor, Dept. of NanoEngineering, UC San Diego
Evgeny Katz, Project Faculty Adviser, Milton Kerker Chaired Professor, Dept. of Chemistry & Bimolecular Science, Clarkson University
John Watson, Project Faculty Adviser, Professor, Dept. of Bioengineering, UC San Diego
Kai Wenk-Wolff, von Liebig Technology and Business Adviser, UC San Diego

3. GrollTex (novel production of high quality graphene)

GrollTex developed an innovative process for manufacturing high quality graphene that eliminates all of the 10 tons of copper waste generated during the production of a gram of graphene using conventional manufacturing. This results in a cost of production that is a fraction of the current costs. Graphene is very strong, light, nearly transparent and an excellent conductor of heat and electricity. With these properties and low-cost, sustainable production, graphene can transform the market improving products ranging from ultra capacitors and electrodes to touchscreen displays, coolants and photovoltaics in solar panels.

Successful completion of this project was reported in a previous report which also contained the final report for this project. Below are highlights of the team's commercialization accomplishments:

- Successfully achieved proof of concept for non-destructive large-area graphene transfer for energy applications
- GrollTex signed an exclusive licensing agreement with the UC San Diego Technology Transfer office for the large-area graphene transfer technology (June 2014). This development allows the team to commence deliberations and negotiations with third parties (ex: LG Electronics).

- Provisional patents submitted to the USPTO on June 20, 2014.
- Raised $61,000 to fund further commercialization efforts through entrepreneurship competitions. Awards included:
  - 1st Place: 2013 UC San Diego Entrepreneur Challenge
  - Audience Award in Tech/Innovation: 2013 UC San Diego Entrepreneur Challenge
  - 2nd Place at FLOW clean tech competition at CalTech on May 9, 2014
- Investment of $50,000 pending from CTO Forum participation
- Received NSF Graduate Research Fellowship in 2014
- GrollTex has successfully identified and recruited a CEO
- Selected into top 50 startups by Founder.org

Commercialization Team:
Aliaksandr Zaretski, Project Lead, PhD candidate, Dept. of NanoEngineering, UC San Diego
Timothy F. O'Connor III, PhD candidate, Dept. of NanoEngineering, UC San Diego
Adam Printz, PhD candidate, Dept. of NanoEngineering, UC San Diego
David Eichorn, MBA student, Rady School of Management, UC San Diego
Yafei Ding, MBA student, Rady School of Management, UC San Diego
Tao Jiang, MBA student, Rady School of Management, UC San Diego
Darren Lipomi, Faculty Advisor, Professor, Dept. of NanoEngineering, UC San Diego
Rakesh Kumar, von Liebig Technology and Business Advisor, UC San Diego

4. Vertically Aligned Carbon Nanotube Electrodes for High Power Density Capacitors

This team is developing carbon nanotube super capacitors (CNTs) that combine the highest power associated with conventional super capacitors with the energy densities that batteries provide for a range of applications from personal electronics to electric vehicles and solar power. Capacitors are designed to store small amounts of energy and deliver it in short, powerful bursts as needed. By comparison, batteries are designed to deliver a steady stream of energy over a long period of time. The team's carbon nanotube super capacitor is designed to provide the best of each technology in one device, enabling electric cars, for example, with a long battery life and the higher power a driver needs to accelerate on demand.

The team focused on prototyping a device to grow CNTs on aluminum foil substrates which will reduce manufacturing expenses and resistance as well as increase power in comparison to traditional silicone substrates. The team performed cycling studies on the CNT capacitor and found that it maintained 90% of the capacitance up to 50,000 cycles. The team also pitched the technology to potential licensees and more than 10% of the companies contacted promptly expressed interest in the technology.

Successful completion of this project was reported in a previous report which also contained the final report for this project. Below are highlights of the team's commercialization accomplishments:

- Selected as a NSF I-Corps team which is accompanied by a $50,000 grant
- Received NSF grant CMMI 1246800 for Defect-engineered Nanocarbons for Electrochemical Energy Storage to further develop the technology
- Filed for patents (PCT No.: PCT/US11/59024, Publication No.: US 2013/0279076 A1)

Commercialization Team:
Rajaram Narayanan, Project Lead, PhD candidate, Dept. of Mechanical and Aerospace Engineering, UC San Diego
Wenfang Li, MBA student, Rady School of Management, UC San Diego
Ming Ming Wang, MBA student, Rady School of Management, UC San Diego
Prabakhar Bandaru, Faculty Advisor, Dept. of Mechanical and Aerospace Engineering, UC San Diego
Michael Elconin, von Liebig Technology and Business Advisor, UC San Diego

5. Novel 3D Organic Photovoltaic Solar Cells

This project focused on the scale up of novel, low-cost, flexible, organic photovoltaic cells through an innovative multi-DOF production line. The global photovoltaic market generates $82 billion a year in revenues with thin film photovoltaics projected to bring $19.5 billion in global revenue by 2015 and a year over year projected growth rate of 24%. The technology developed addresses the major concerns associated with photovoltaic cells including flexibility, transparency, weight, and aesthetic appeal. With enormous potential and a growing market, this technology is well positioned with several competitive advantages including competitive efficiency, 40% reduction in over existing thin-film technologies, and organic which negates disposability issues.

Successful completion of the program was reported in a previous report which also contained the final report for this project. Below are highlights of the team's commercialization accomplishments:

- Licensed the organic photovoltaic technology to South Korean based company Amotech, Inc. (license fees and royalties not disclosed) which resulted in:
    - Large royalty payment to San Diego State University
    - Payment in full for the significant patent prosecution expenses for the patent portfolio
    - Generated substantial cooperative research funding at SDSU campus and at the licensed company which is funding product development

Commercialization Team Members
Shanel Miller, Project Lead, M.Eng., College of Engineering, San Diego State University
Mieko Hirabayashi, M.S. Bioengineering, College of Engineering, San Diego State University
Beejal Mehta, M.S. Bioengineering, College of Engineering, San Diego State University
Mihir Parikah, M.S. Mechanical Engineering, College of Engineering, San Diego State University
Kadir Toksoy, M.S. Mechanical Engineering, College of Engineering, San Diego State University
Michael Mueller, MBA student, San Diego State University
Keith Allen, MBA student, San Diego State University
Sam Kassenge, Project Faculty Advisor, Professor of Mechanical Engineering, San Diego State University
Mike Krupp, von Liebig Technology and Business Advisor, UC San Diego

6. Structural Health Monitoring of Wind Turbine Blades Using Advanced Infrared Thermography

This technology monitors defects of wind turbines in the field using Pulsed Infrared Thermography where light strobes are used to impart thermal energy on turbines and variations in surface temperature are monitored using infrared cameras. This two-stage process involves low-pass filtering at the first stage and then multivariate outlier analysis to determine the size and depth of the defect. For windfarms this is a significant improvement over the currently available processes of defect detection because it does not require a contact medium, advanced operator training or test area disassembly making this process significantly more cost effective and efficient in defect detection. During prototype validation the team determined that the parameters used only accounted for 40% of known defects during testing therefore the project returned to the R&D phase to develop more robust parameters.

Successful completion of the program was reported in a previous report which also contained the final report for this project. Below are highlights of the team's accomplishments:

- Selected as a finalist at the FLoW Competition
- Successfully detected deeper defects that have been a persistent problem and remain undetectable by traditional inspection techniques
- U.S. provision patent granted
- Working prototype assembled and tested

Commercialization Team Members

Arun Manohar, PhD, Dept. of Structural Engineering, UC San Diego
Jung Hun Han, MBA student, Rady School of Management, UC San Diego
Antonio Aguiar, MBA student, Rady School of Management, UC San Diego
Francesco Lanza di Scalea, faculty advisor, Professor, Dept. of Structural Engineering, UC San Diego
Jim Corlett, von Liebig Business and Technology Advisor, UC San Diego

7. Novel High Efficiency and Mercury Free Light Bulbs Based Semiconductor Nanowires (Nanowire Light Bulbs)

The Nanowire Light Bulbs team focused on the development of highly efficient, low cost, environmentally friendly nanowire technology based LED light bulbs capable of using existing lamp sockets. The nanowire bulbs were projected to use less power 83% less power than incandescent bulbs while being 20% more efficient, 40% cheaper and consuming 16% less energy than traditional LED bulbs. This represents a significant cost savings to the $110B worldwide lighting market which uses 20% of electricity worldwide and is facing government regulations phasing out incandescent light bulbs due to inefficiency by 2018. In this environment companies that can deliver reliable, reasonably priced lighting alternatives to the incandescent bulb are poised for success.

The Initial prototype did not meet light emission expectations furthermore market analysis results indicated that the technology may be more suitable for the UV bulb market segment however the current specifications and costs were not competitive in that market. Successful completion of this project was reported in a previous report which also contained the final report for this project. Below are highlights of the team's commercialization accomplishments:

- UCSD patent disclosure 2011-177
- Prototype developed and tested

Commercialization Team Members
Muchuan Yang, Project Lead, PhD, Dept. of Electrical and Computer Engineering, UC San Diego
Nima Jafarian, MBA student, Rady School of Management, UC San Diego
Selina Lai, MBA student, Rady School of Management, UC San Diego
Deli Wang, Faculty Advisor, Professor, Dept. of Electrical and Computer Engineering, UC San Diego

8. Low-turbulence, low heat loss engines optimized for transient plasma ignition

This project was focused on developing a novel method of increasing the efficiency of internal combustion engines with minimal modifications. Currently internal combustion engines – the kind that power most of the cars on the road today – lose roughly 75% of all energy released through combustion in heat. The goal of this project was to redesign engine components to reduce turbulence in the cylinders, which will, in turn, reduce the head loss into the coolant and through the radiator while using transient plasma ignition (TPI) devices to maintain combustion speeds. Previously this technique would not have been feasible because combustion speeds drop significantly when turbulence is reduced but the development of TPI devices at University of Southern California allowed researchers to maintain combustion speeds while reducing turbulence. The team's goal was to achieve this redesign without affecting the drivability, emissions or performance and with no net increase in production costs for engine manufacturers. Achieving a modest 20% increase in efficiency, which this team identified as its target, has the potential to enormously effect on the combustion engine market, consumer transportation expenditures, reliance on crude oil, and the environment.

Results obtained by the team were consistent with predictions and the modifications demonstrated the effects that lowering turbulence of the measured cylinder – by redesigning the intake ports and valve seat area – had noticeable impact on combustion characteristics. The project is still underway and has now moved into a more in-depth modeling and testing phase to further optimize the modifications and engine control parameters. Successful completion of this project was reported in a previous report which also contained the final report for this project. Despite the setbacks, the team has promising outcomes that are highlighted below:

- Stock cylinder head was successfully modified with proposed changed

- Preliminary testing results consistent with the targeted 20% increased efficiency which will significantly impact the combustion engine market, consumer transportation expenditures, reliance on crude oil and the environment.

Commercialization Team:
Kanchana Gunasekera, Project Lead, PhD, Dept. of Aerospace and Mechanical Engineering, University of Southern California
Barrett Fisher, MBA student, Rady School of Management, UC San Diego
Paul Ronney, Project Faculty Advisor, Professor, Dept. of Aerospace and Mechanical Engineering, University of Southern California
Michael Elconin, von Liebig Technology and Business Advisor, UC San Diego

9. Reusable fuel source "lignocellulosic biomass"

The focus of this project was the development of a new and reusable source of fuel called "lignocellulosic biomass" that is derived from lignin which can be obtained from agricultural residues such as corn stover and bagasse as well as wood residue from pulp and paper mills. Lignin is an aromatic polymer well-known for resistance to microbial degradation, it is the second most abundant natural polymer in the world, surpassed only by cellulose and it is found in the walls of almost all dry land plant cell. These potential fuels sources are readily available and sustainable. Successful completion of this project was reported in a previous report which also contained the final report for this project. Highlights of this project's accomplishments include:

- Dr. Derek Butler was hired as a post doc by Archer Daniels Midland Company to conduct ongoing research in this area as a direct result of this project
- Archer Daniels Midland company is negotiating a research partnership between ADM and SDSU/UCSD
- Developed a catalyst for lignin degradation that is able to work properly on multiple sources of lignin which solves a persistent problem in current research on the degradation of lignin.

Commercialization Team:
Derek Butler, Project Lead, College of Engineering, San Diego State University
John McMillan, MBA Student, San Diego State University
Nick Moiseff, MBA Student, San Diego State University
Kevin Green, MBA Student, San Diego State University
Katrina Phruksukarn, MBA Student, San Diego State University (former)
Laurance Beauvais, Asst. Professor Inorganic, Bioinorganic, and Materials Chemistry, San Diego State University
Michael Elconin, von Liebig Technology and Business Advisor, UC San Diego
John Crockett, Adviser, Research Advancement Program Director, San Diego State University Research Foundation

10. Sky Imager (solar forecast tool)

The Sky Imager team developed a solar forecasting tool that provides in-depth future power output estimates of solar generators based on local sky imagery. This technology is a hybrid of advanced optical systems and software algorithms that detect a cloud's position and direction to compute its future location that results in highly accurate solar forecasts in durations that provide key information for solar plant operators to adjust their power output and distribution feeders.

Upon studying the energy market, making contact with major players, and discussing the needs and interests with regard to the product, the team learned that their initial customer targets (customers in the energy sector) were still determining their solar forecast needs. Though the energy customer segment was not ready, the Sky Imager team realized that moving higher up the value chain represented significant potential and has decided to market the Sky Imager system as a remote sensing device capable of sophisticated cloud observations and solar

power forecasting. Since making this pivot the Sky Imager team has contacted a number of original equipment manufacturers of solar metrology equipment.

Successful completion of this project was reported in a previous report which also contained the final report for this project. Highlights of Sky Imager's accomplishments include:

- Successfully licensed the technology to three organizations and is involved in ongoing licensing discussions with several other organizations.
    - Toyota Racing
    - EPRI
    - University of Hawaii
- Submitted a $1.576 million proposal to SDG&E to forecast solar power output in Imperial Valley
- ~$40,000 funding received from licensing agreements

Commercialization Team:
Bryan Urquhart, Project Co-Lead, PhD, Dept. of Mechanical and Aerospace Engineering, UC San Diego
Mohamed Ghonima, Project Co-Lead, PhD, Dept. of Mechanical and Aerospace Engineering, UC San Diego
Aimee Lim, MBA student, Rady School of Management, UC San Diego
Brett Scurfield, MBA student, Rady School of Management, UC San Diego
Jan Kleissl, Faculty Adviser, Assoc. Professor, Dept. of Mechanical and Aerospace Engineering, UC San Diego
Tim Rueth, von Liebig Technology and Business Advisor, UC San Diego

11. Nanofoundry

Nanofoundry focused on developing a scalable platform for manufacturing metal nanoparticle catalysts that are a critical and highly cost prohibitive component of fuel cell technologies. Nanofoundry aims at manufacturing metal nanoparticle catalysts at one-third of the cost compared to traditional chemistries. Nanofoundry's high-throughput, continuous-flow micro reactor devices are easily scalable via parallel operation to meet any demand. Current technologies use batch reactors to synthesize catalyst particles but this method suffers from slow heat and mass transfer due to uneven rates of mixing and gradients that form while trying to mix materials in large batches. Nanofoundry's technology alleviates these issues and the ionic liquid solvent system utilized by Nanofoundry minimizes waste and does not release toxic chemicals into the atmosphere. In a US$1.4B market that is expected to grow to US$15.7B by 2017, Nanofoundry's cheaper, smaller, and more consistent product is poised to create new industry standards.

This team received no-cost extension so the final technical outcomes of the project are reported below. Appendix II contains the final report for this project. Highlights of the team's commercialization accomplishments include:

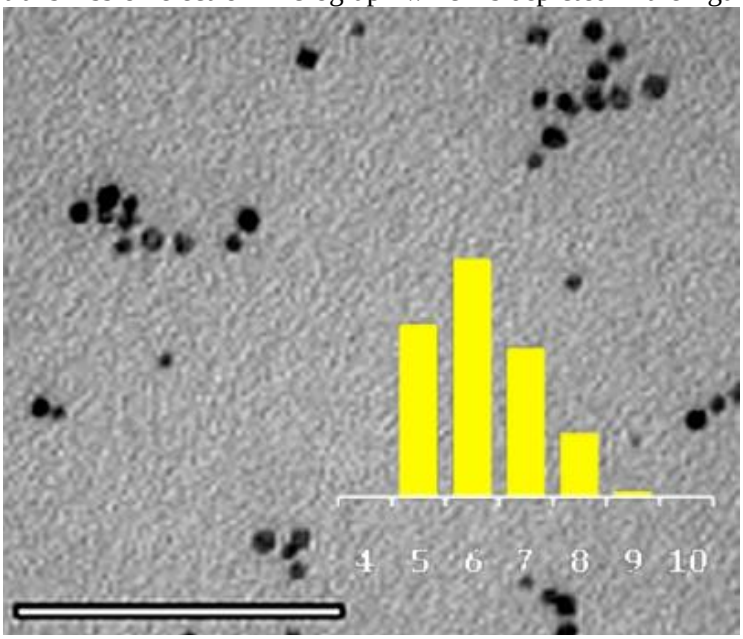
- Secured follow on funding from NSF (amount not specified)
- SBIR funding application pending submission
- The technology is generating industry interest and 3M has requested cost and performance comparisons and is considering some form of partnership

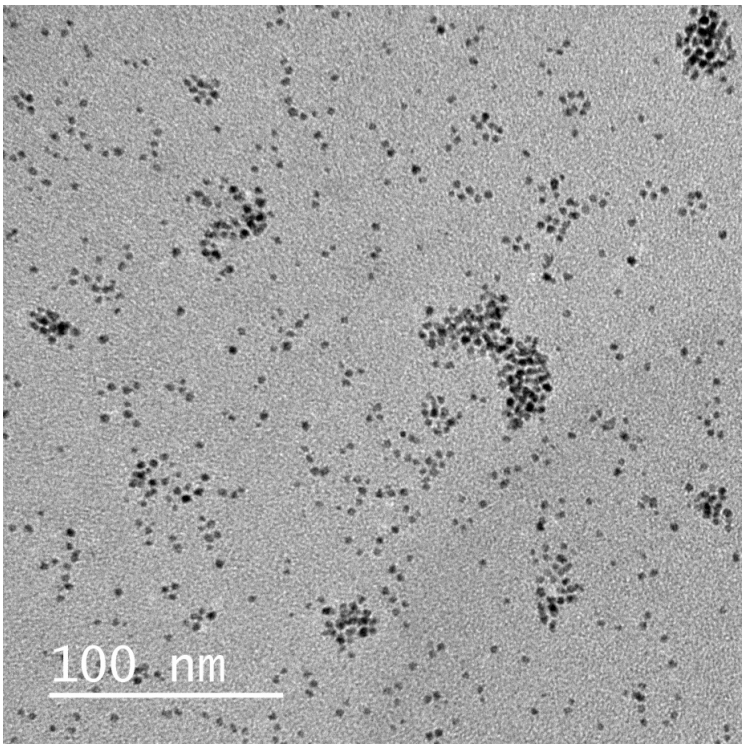
Commercialization Team:
Carson Riche, Project Lead, PhD candidate, Dept. of Chemical Engineering and Material Science, University of Southern California
John McMillan, MBA Student, College of Business Administration, San Diego State University
Victoria Cherkashina, College of Business Administration, San Diego State University
Alex Filler, MBA Student, Marshall School of Business, University of Southern California
Stacy Nease, MBA student, College of Business Administration, San Diego State University
Sarah Gonzalez, MBA/JD student, College of Business Administration, San Diego State University
Noah Malmstad, Faculty Adviser, Asst. Professor, Dept. of Chemical Engineering and Material Science, University of Southern California

Malancha Gupta, Faculty Adviser, Asst. Professor, Dept. of Chemical Engineering and Material Science, University of Southern California
Richard Brutchey, Faculty Adviser, Assoc. Professor, Dept. of Chemistry, University of Southern California
Rakesh Kumar, von Liebig Technology and Business Advisor, UC San Diego

Technical Accomplishments
The no-cost extension was productive for the research team who used the time to successfully complete its technical milestone: test platinum catalyst particles in rotating disk electrode, characterize catalytic activity, and demonstrate nanoparticle synthesis in the multi-channel device.

Test platinum catalyst particles in rotating disk electrode
The team developed a pathway to synthesizing platinum nanoparticles using ethylene glycol as a reducing agent. The scheme utilizes the reusable ionic liquid platform that the team developed and is covered under the filed patents. As a representative example of the nanoparticles produced using this chemistry, the team included a transmission electron micrograph which is depicted in the figure below.





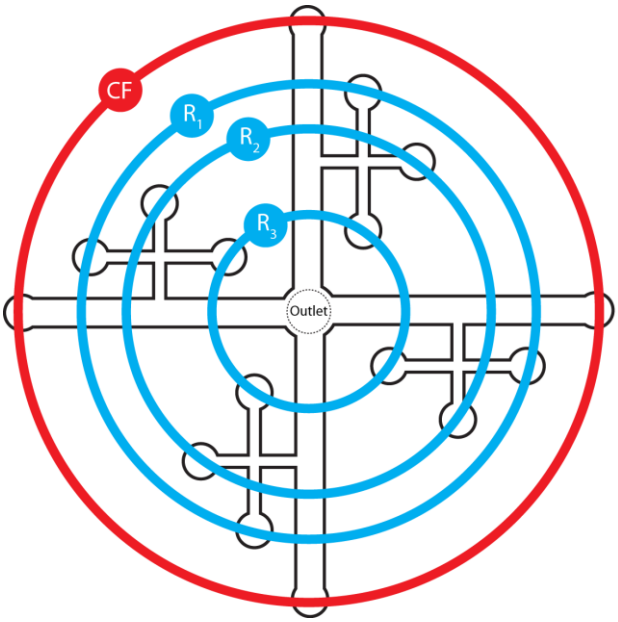
Transmission electron micrograph of rhodium (top) and platinum (bottom) nanoparticles synthesized in a microwave reactor at room elevated temperature. Scale bare indicated 100 nm.

Characterize catalytic activity

Single micro-reactor devices were fabricated and coated to allow flow of the ionic liquid solvents throughout the channel. Using these devices, the team has fine-tuned the gold nanoparticle size distribution through modulation of the input flow rates of the reagents. The size of the nanoparticles has been tuned to 4.28 nm based on analyzing nearly 60,000 particles imaged using transmission electron microscopy. This product has been fully characterized from a materials perspective and the team has developed a data sheet that outlines the specific size, absorption, and crystallinity properties of gold nanoparticles. The data sheet can be distributed with the product to customers as a validation of the product. The metrics are superior to the typical information provided by manufacturers on the team's list of available data sheets from over a half dozen gold nanoparticle manufacturers.

Demonstrate nanoparticle synthesis in the multi-channel device

The team has developed and operated parallel reactors using a new radial design, which is depicted in the figure below. This layout features a bottom layer of channels evenly distributed around a central outlet. A fluid distribution manifold is positioned above this layer to equally deliver the reagents to each of the channels. A circular design alleviates any difference in pressure drop across each of the channels and allows uniform droplet and reaction conditions in each of the branches.



Circular design for parallel device reactor

The team prototyped these devices by using soft polymer replication techniques. The molds for the replication were printed using a MakerBot Replicator 2x 3D printer. The mold surface was reflowed and made smooth upon exposure to acetone vapor. This process utilizes a low-cost 3D printer to do fast and efficient iterative optimization. In the future, the team plans to have a higher resolution device printed from a commercial printing facility such as FineLine Prototyping, Inc.

Commercialization Accomplishments

In addition to continued technical progress the team also completed its commercialization milestone for the quarter: develop a marketing/business plan based on research results and industry partnerships.

The commercialization team also continued the outreach process during this time focusing on nanoparticle users at universities, research institutions, and small business innovation research and technology transfer research (SBIR/STTR) recipients. The team used nanoparticle characterization results to initiate the discussions. In response to the absorbance curve having a slightly large wavelength spread, researchers believed the production device may need a bit more refinement to reduce the particle size distribution.

In addition to continuing device and nanoparticle refinement, the commercialization team has researched a variety of accelerator programs. The team has a positive outlook for raising funds through avenues including EvoNexus, LA CleanTech Incubator, IdeaLab, and Octane OC.

The team has also researched potential future funding sources from government agencies aimed at starting small businesses from technological innovations generated in research laboratories. Additionally, the team identified necessary IP considerations and steps to distribute the product through the university via a materials transfer agreement. Finally, the team is evaluating options for forming a corporation or partnerships. The team has included a summary of the different types of corporations as an appendix to their report, and this material will serve as a valuable resource for their next steps in their commercialization efforts.

Outcomes

Technical. The team has made excellent strides in validating the technology and proving proof of concept. The team successfully furthered the process of synthesizing platinum catalyst particles, and the results will be integrated into the data sheet that they also developed during Q4. The datasheet fully characterizes the properties of its synthesized gold nanoparticles and demonstrates metrics that are superior to typical information

provided by manufacturers. Finally, the team developed and operated a parallel reactor to demonstrate synthesis in a multi-channel device.

Commercial. The team used nanoparticle characterization results to initiate the discussions with potential customers and partners that include nanoparticle users at universities, research institutions, and small business innovation research and technology transfer research (SBIR/STTR) recipients. The team found that researchers believed the production device may need a bit more refinement to reduce the particle size distribution, as the absorbance curve has a slightly large wavelength spread. The team is continuing to refine its technology. The team's research on potential partnerships led to a positive outlook in raising funds through SBIR/STTR avenues and government agencies. The team also identified necessary IP considerations and evaluated options for forming a corporation or partnerships, which will be valuable in their continued commercialization efforts. The team also secured further funding to continue the technical and commercial aspects of the project beyond the DOE funding period.

Virtualization Efforts

The use of the von Liebig Entrepreneurism Center's online platform allowed the Center to focus its efforts in reaching a wider community and also better use of resources. The von Liebig Entrepreneurism Center created an organization wide LinkedIn page and group and has systematically invited all its current and former fellows to connect and join the group.

All the webinars in the series for the DoE fellows were completed in April 2013. Much of the webinar content is available online through the Center's website, below is a listing of webinars that were held as part of this program:

Webinar Topic	Presenter/Vehicle
Introductory: Idea to Innovation	YouTube
Intellectual Property Overview	YouTube
New Venture Creation	YouTube
Licensing University Technologies	YouTube
Regulatory Workshop Overview	YouTube
Partnerships & Alliances	CONNECT: Ruprecht Von Buttlar
Regional Resources	California Center for Sustainable Energy: Len Hering
Accessing Capital	Panel: TCA, von Liebig mentors, and CONNECT EIRs (Entrepreneurs in Residence)
Perspective on Entrepreneurship: The Stuff that Dreams are Made of Part 1	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
Perspective of Entrepreneurship: The Stuff that Dreams are Made of Part 2	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
From Academia to Entrepreneurship	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
Business Model Analysis: How will your company make money?	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
Building a Successful Social Enterprise	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
Marketing Issues and Challenges	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
Intellectual Property Today and the America Invents Act	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series
Bend Minds with your Bare Hands: Neil's Perspective	von Liebig Entrepreneurism Center and ACS

on Negotiation	partnered entrepreneurship webinar series
Interview with Life Science Serial Entrepreneur and Venture Capitalist Larry Bock	von Liebig Entrepreneurism Center and ACS partnered entrepreneurship webinar series

Sustainability Efforts

Several approaches are being pursued to ensure sustainability of the program beyond the third year of funding:

Secure sponsorship from sponsors through the TAP process and launch an early stage acceleration fund.

- Outreach to program partners for continued funding has indicated that more outreach to the small business community will be desirable to engage additional program sponsors.
- Launch of the Triton Technology Fund is underway and all legal documents have been approved and executed. Currently $5M in capital commitments have been secured and the Center anticipates that early stage investments will begin in mid-2014.

Connecting the program participants with potential investors in Southern California ecosystem.

- The participants are provided opportunities to pitch to the Rady Venture Fund, a venture philanthropy fund at the Rady School of Management at UC San Diego, and provided feedback by venture capitalists and angel investors associated with the fund.
- The participants are introduced to the Tech Coast Angels (TCA), the largest angel investor group in the United States. Its members provide funding and guidance to more early-stage, high-growth companies in Southern California than any other investment group. TCA members invest in companies in a wide range of industries, including the life sciences, biotech, IT, services, retail, Internet, financial, software, media, consumer products and tech startups. TCA members give companies more than just capital; they also provide counsel, mentoring and access to an extensive network of potential investors, customers, strategic partners and management talent. TCA has more than 250 members, including its venture capital affiliates, in five networks in Los Angeles, Orange County, San Diego, Westlake/Santa Barbara and the Inland Empire.
- On October 17, 2013 the Center held a Technology Showcase highlighting success stories including many projects that grew out of the DoE TAP. More than 100 individuals from the San Diego innovation ecosystem including technologists, faculty, venture capitalist, and investors participated in the showcase.

NSF I-corps Grant.

The von Liebig Entrepreneurism Center has been awarded a three year $300,000 grant by the National Science Foundation as an I-corps site. Each year, over the next three years, this award will allow the university to provide mentorship and up to $3000 in funding to 30 teams of students, faculty, staff and researchers interested in commercialization of their ideas. Focused commercialization training following the lean startup methodology will be provided to those teams selected. Although this program is not exclusively clean energy, the Center anticipates that clean energy technologies will also be part of the portfolio.

Cost Status (Section 6)

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment)	Page	of
U.S. Department of Energy	DE-SC0005459	1	1 pages

3. Recipient Organization (Name and complete address including Zip code)

University of California, San Diego Office of Post Award Financial Services, 0954 9500 Gilman Drive La Jolla, CA 92093-0954

4a. DUNS Number	4b. EIN	5. Recipient Account Number or Identifying Number (To report multiple grants, use FFR Attachment)	6. Report Type	7. Basis of Accounting
804355790	956006144	28472AB	X Quarterly ☐ Semi-Annual ☐ Annual ☐ Final	X Cash ☐ Accrual

8. Project/Grant Period From: (Month, Day, Year)	To: (Month, Day, Year)	9. Reporting Period End Date (Month, Day, Year)
10/1/2010	9/30/2014	6/30/2014

10. Transactions	Cumulative
(Use lines a-c for single or multiple grant reporting)	
Federal Cash (To report multiple grants, also use FFR Attachment):	
a. Cash Receipts	$961,081.70
b. Cash Disbursements	$968,172.96
c. Cash on Hand (line a minus b)	($7,091.26)
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	$1,044,412.00
e. Federal share of expenditures	$966,172.96
f. Federal share of unliquidated obligations	$2,221.74
g. Total Federal share (sum of lines e and f)	$970,394.70
h. Unobligated balance of Federal funds (line d minus g)	$74,017.30
Recipient Share:	
i. Total recipient share required	$321,002.00
j. Recipient share of expenditures	$208,464.48
k. Remaining recipient share to be provided (line i minus j)	$112,597.52
Program Income:	
l. Total Federal program income earned	$0.00
m. Program income expended in accordance with the deduction alternative	$0.00
n. Program income expended in accordance with the addition alternative	$0.00
o. Unexpended program income (line l minus line m or line n)	$0.00

11. Indirect Expense	a. Type	b. Rate	c. Period From	Period To	d. Base	e. Amount Charged	f. Federal Share
				g. Totals:			

12. *Remarks. Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:*

Contact Person: **Khanh Ha N. Pham (858) 822-0897 k3pham@ucsd.edu**

13. Certification: By signing this report, I certify that it is true, complete, and accurate to the best of my knowledge. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

a. Typed or Printed Name and Title of Authorized Certifying Official	c. Telephone (Area code, number and extension)
For Mark E. Cooper, Director Office of Post Award Financial Services	(858) 822-0897 d. Email address k3pham@ucsd.edu
b. Signature of Authorized Certifying Official	e. Date Report Submitted (Month, Day, Year) 7/30/2014
	14. Agency use only:

Standard Form 425
OMB Approval Number: 0348-0061
Expiration Date: 10/31/2011

Paperwork Burden Statement

According to the Paperwork Reduction Act, as amended, no persons are required to respond to a collection of information unless it displays a valid OMB Control Number. The valid OMB control number for this information collection is 0348-0061. Public reporting burden for this collection of information is estimated to average 1.5 hours per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0060), Washington, DC 20503.

Schedule Status (Section 7)

Year 3 + No Cost Extension Schedule

Oct. 2012-Dec. 2012	Jan. 2013 –March 2013	April 2013- June 2013	July 2013-Sept. 2014
Task 13.0. Execute Year 3 Energy Innovation Challenge program at the von Liebig Entrepreneurism Center			
Year 3 - which extended into the no-cost extension period - of this program was successfully executed and concluded in September 2014. Improvements in outreach and solicitations were incorporated from the previous years and the program management team made more effective use of social media to reach potential applicants as well as to publicize the achievements of program participants throughout the year and online tools to help			
• Issued solicitation on-line • Solicited applications by using social media tools • Conducted outreach to southern California universities and institutions through social media and other tools	• Applications reviewed and finalists selected • PIs and von Liebig advisors interviewed finalists • Finalists invited to present to expert review panel	• Completed online seminars. • Conduct commercialization bootcamp on-line • Provide business mentoring and commercialization assistance via teleconferencing, on-line interaction and in person meetings. • Selected four teams to receive commercialization award for year three of the program. • Conducted 9 week workshop on lean startup /customer development	• Used social media to communicate program outcomes, highlights • Used social media platforms to disseminate best practices • Measured and review progress, solicit and collect feedback, evaluate impact, and continue to refine program's best practices as needed
Task 14.0 . Continue to execute Energy Innovation Challenge Virtualization plan			
Throughout the final year and no-cost extension period of this program the virtualization plan for this program continued to be implemented and enhanced. The team found that the creation of separate website and social media platforms for this program has unexpected adverse effects because it isolated program participants from the many connections and resources that are integrated into the main von Liebig platforms therefore the program management team worked to re-integrate the program's content and platforms into the main von Liebig platforms to give the program participants the full benefit of the von Liebig and San Diego ecosystem.			
• Continued implementing social media Strategy developed in Phase II to gain traction • Used von Liebig staff to execute social media strategy developed in Phase II.	• Conducted social media campaigns to increase interest and usage. • Assigned engineering student ambassador to create content	• Increased participation in social media platforms by driving content on the outcomes of the fellows • Created a plan for sustainability of social media platforms	• The von Liebig program management team took over management of the social media platforms as part of the regular activities of the Center

Task 15.0. Begin implementing Energy Innovation Challenge sustainability initiative			
Launch Technology Acceleration Fund and begin seeking financial commitments.			
• Secured the approval of the Translation Fund at the UCSD campus-wide level		• Sought initial financial commitments to the Translation Fund to support early-stage university discoveries	• Developed and seek approval for legal documents for translational fund creation and management
Pursue other sustainability avenues as planned in Phase I and II and begin seeking financial commitments.			
• Created a Value Proposition package for corporate sponsorship of the TAP model • Received feedback from SDG&E regarding impact report and TAP model.	• Solicited more feedback from regional corporate sponsors	• Tracked progress and adjust sustainability initiative as needed.	• Solicited feedback from corporate partners and program participants • The team continues to work toward securing additional commitments for future TAPs
Task 16.0. Prepare final report and disseminate best practices and lesson learned			
In preparation for this task the team solicited ongoing feedback from program participants in order to identify and incorporate improvements into the program. The program management team also conducted yearly program reviews with that year's program participants, MBA students and von Liebig business and technology advisors to identify and refine best practices.			
• Developed outreach platform with other universities in the region	• Prepare quarterly progress reports for DOE		• Requested no cost extension to complete three year projects. • Started collecting information for documentation of best practices

Changes in approach or aims with accompanied reasons (Section 8)

No changes.

Actual or anticipated problems or delays with resolution plan (Section 9)

No changes.

Any absences or changes in key personnel (Section 10)

No changes.

Description of any product produced or technology transfer activities (Section 11)

A. Publications. No Publications to date about the Southern California Clean Energy TAP.
B. Web sites or other Internet sites that reflect the results of this project

- von Liebig You Tube Channel, "UCSD von Liebig Center" (http://www.youtube.com/user/UCSDEntrepreneurism)
- von Liebig Entrepreneurism Center website (http://www.vonliebig.ucsd.edu)
- Specific to Southern California Clean Energy TAP
    1. https://twitter.com/socalie
    2. http://www.linkedin.com/groups/Southern-California-Innovation-Ecosystem

C. Networks or collaborations fostered
    - Clean Energy Alliance Membership
    - Rady Venture Fund
    - Tech Coast Angels
D. Technologies/Techniques
E. Inventions/Patent Applications
    - All finalists were required to file at least a provision patent to be able to present to the panel of expert judges
F. Other Products

Appendices

Appendix I. Metrics Table

Index	Proposed Metric	Elaboration
I. **Commercialization Milestones**		
1	Follow-on funding raised by startups nurtured by ecosystems	**Total Amount: $20,921,000** + undisclosed amounts pertaining to licensing agreements, royalties and in kind services **Electrozyme: Joshua Windmiller (UCSD)** $20,000 from entrepreneur competitions + in kind services $500,000 in investments from a strategic partner and an angel investor $1.5M NIH Grant **Lyxia: Wei Yu (UCLA)** $18.7M from private investors **New Heterogeneous Catalyst Toward the Biofuel Production of Lignocellulosic Biomass : Derek Butler (SDSU)** Partnership with ADM for further commercialization of the technology. Actual value is to be determined. **GrollTex: Alexander Zaretski (UCSD)** $61,000 combined cash winnings + in kind services from entrepreneurial competitions $50,000 investment from participation in CTO Forum **Novel 3D Organic Photovoltaic Solar Cells: Shanel Miller (SDSDU)** Licensing and royalty revenue generated from the commercialization of the proprietary technology licensed by Amotech Inc. **Vertically Aligned Carbon Nanotube Electrodes for High Power Density Capacitors:** $50,000 NSF Grant **Sky Imager: Bryan Urquhart & Mohamed Ghonima (UCSD)** ~$40,000 in licensing fees
2	Total number of startups incorporated	**4** (Nanofoundry, Electrozyme, Lyxia, GrollTex)
3	Number of jobs created	**34**
4	Number of technologies	**1. Electrozyme:** revenues undisclosed

Index	Proposed Metric	Elaboration
	licensed, revenues received	**2. Lyxia:** revenues undisclosed **3. Organic Photovoltaic Solar cells:** revenues undisclosed **4. Sky Imager:** >$40,000
5	Number of patents and disclosures filed	95
II. Entrepreneurial Services Provided		
1a	Total number of applicants to competitions	82 applications for fellowships from 7 institutions
1b	Total number of awardees from competitions, and amounts awarded to each winner.	To date 11 projects have been awarded a total of $645 000 plus the business & technology advisory services from a dedicated advisor and MBA student support for commercialization research.
2	Total number of ventures served.	36 teams
3	Total number of technologies vetted.	82
4	Number of mentors/Executives In Residence (EIRs) placed with clients	15 von Liebig business and technology advisors.
III. Ecosystem Development		
1	Number, amount, and source of funds raised by ecosystem	Total $27,726,000 Companies: $20, 921,000 (Lyxia, Electrozyme, GrollTex) Investors: $1.5M NSF I-Corps: $0.3M Triton Fund: $5M Local Law Firms: $5,000 + in kind services
2	Significant collaborations with other organizations/partners, whether a university, industry partner, non-profit, government agency, or otherwise.	CalTech FLoW competition; Wilson, Sonsini, Goodrich and Rosati; CONNECT; University of San Diego EPIC program (http://www.sandiego.edu/EPIC/); WilderShares; California Center for Sustainable Energy; and American Chemical Society; Founders Institute
3	Number of new outreach activities launched	• ACS Webinars by Barbara Bry & Neil Senturia • Completed the webinar series online • Lean Launchpad Commercialization workshop • 2013 von Liebig Technology Showcase
4	Target audience responses to outreach activities	• von Liebig Entrepreneurism Center Facebook page reach has grown 20%. • von Liebig Entrepreneurism Center LinkedIn has grown to 183 connections and 148 group members within 1 month of being started • LinkedIn Southern California Innovation Ecosystem group: 10 members. • SoCalie twitter handle: 160 Tweets and 16 followers. • 49 total individual views of the educational webinars of the program since they were posted by the Center.
5.	Press Coverage	• In progress
IV. Narrative Items		

Index	Proposed Metric	Elaboration
1	Testimonials/Success stories – Electrozyme, Lyxia, GrollTex	
2	To the degree that there are actual receipts of funds pooled across ecosystems: 0	
3	Failures/Case Studies: 0	

Appendix II. Project Reports

1. Carson Riche (USC): Nanofoundry

Vertically Aligned Carbon Nanotube Electrodes for High Power Density Capacitors

Date of Report 6/19/2014

Fellow's Name: Rajaram Narayanan

Campus: University of California, San Diego

Technology Advancement Team:
PI & Project Director: Dr. Prabhakar Bandaru, MAE, UCSD
vLC Advisor: Michael Elconin
MBA student(s): : Mingming Wang, Wenfang Li, Yi Zhao

Awarded from (06/2013) to (06/2014)

I. Table of Contents

II. Introduction

The growing global energy consumption has increased the demand for low emission energy sources. The future of clean energy sources such as Solar and Wind rely heavily on Electrical Energy Storage systems (EES). Supercapacitors are a class of such EESs which store and release energy by charge separation between electrode and electrolyte at the nanoscopic level. Supercapacitors are vital for power intensive applications in a variety of areas such as : transportation (e.g. Hybrid Electric Vehicles), Stationary Electrical energy storage (Transmission and distribution grids), portable power (consumer electronics) and military applications to name a few. In 2010, the global supercapacitor market generated revenues of over $375 million. By 2016, this number is expected to grow up to $2.75 billion. Such projections highlight the demand and commercial potential of Supercapacitors.

Designation	Team Members	email
Faculty Advisor	Dr. Prabhakar Bandaru	pbandaru@ucsd.edu
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Ideally, supercapacitor materials must possess a large surface area and high electrical conductivity. These two properties determine the key parameters (the desirable extent of which are in italics) that quantify the performance of a supercapacitor namely-

1) *High* Power Density- The amount of power delivered per mass of the material.

2) *High* Energy density- The amount of energy delivered per mass of the material.

Carbon nanotubes (CNTs) are a unique class of materials with excellent electrical, thermal and optical properties as a result of their unique one dimensional geometry. CNTs when fabricated as electrodes offer extremely high surface area ~ 1000m^2/gram. CNTs with their high electrical conductivity and surface area are touted to be ideal materials for Supercapacitor fabrication. Additionally, CNTs can also be modified with defects and functionalities offering tremendous potential for optimization.

III. Milestone Progress

a. Milestone Chart

	Task Description	Duration	Anticipated Start Date	Anticipated End Date	*For vLC Staff only* Date Funded	Funded Amount
1	Technical Milestone: 1) Process Design [13 Weeks] a) Carbon Nanotube (CNT) growth protocol: • The catalyst of choice for CNT growth on Aluminum foil is Iron (Fe) and Cobalt (Co) nanoparticles. The efficiency of these catalysts will be evaluated in terms of deposition uniformity and control on thickness. A reference catalyst , Fe alone will used to gauge these parameters. [6 Weeks]. • Growth pressure and temperature ramp rate and their influence on CNT growth will be monitored and compared with reference pressure (atmospheric pressure) and temperature ramp rates (650 deg C at 50 deg C/minute). [6 Weeks] b) Electrolyte choice: Electrolyte choice dictates the operating voltage of the CNT capacitors. The efficiency of organic electrolytes, Acetonitrile and Propylene Carbonate with reference to aqueous (water based) electrolytes will be researched and optimal electrolyte concentrations will be evaluated. [1 week]	3 mos	6/1/13	8/31/13		
	Commercialization Milestone: The milestone at this stage will mainly be research on the two alternative markets that can be considered: One is product application in electric vehicle industry; the other is its application in smart phone industry. For the product's application in **electric vehicle (EV)**, the research will cover: Week 1: The performance of current batteries in EVs, their limitations, and	1 mo	6/1/13	6/30/13		

	current technology pain point; 2) Week 2: What aspects/performance characteristics that need to improve for current battery technology in EV industry; 3) Week 3: For the above found performance aspect, what our current product already has and what still need to be improved in order to have the competitive advantage. 4) Week4-5: research findings and recommendations; combine with the smart phone industry part. For the product's application in **smart phone**, the research will cover: Week 1: The performance of current batteries in smart phones, their technology pain point; 2) Week 2: What aspects/performance characteristics that need to improve for current battery technology in smart phone industry; 3) Week 3: For the above found performance aspect, what benchmark the current products already have and what figures our SuperCap need to achieve in order to have the competitive advantage. 4) Week4-5: research findings and recommendations. The focus of the research will be the third point as it is directly related with our go-to-market strategy. The research mythology will be a combination of primary (talk to industry professionals, customers, and also possibly EV manufactures in this industry) and secondary research (website searching, database research, industry journal research)					
	Education Milestone: Complete the 9 session LEAN startup on-ground course (Tuesdays @ 6pm now-June 11) The learning Objectives of the LEAN startup workshop are to: • Indentify potential markets for early stage technology • define customer needs and market size of	1 mo	6/1/2013	6/11/2013		

	the opportunity • apply models of technology and market assessment in conducting technology based market research • utilize existing database and other tools for conducting technology based market-research • prepare a business model canvas and PowerPoint for a new venture					
	Report: Quarter 1	Due on 10/7/13				
2	Technical Milestone: 2) CNT growth and Preliminary Testing [13 weeks] • Aluminum foils of high purity (~99.9% purity) and of different thicknesses (16 to 50 microns) will be evaluated as substrate candidates. The processes parameters will be continuously varied against the established base values. The optimality of CNT growth along with the mitigation substrate melting will be continuously monitored and reported to the Center. [6 weeks] • Preliminary electrochemical testing will be conducted using the existing 3- electrode set-up. The performance parameters such as energy/power densities, rate capability and contact resistance will be recorded and duly reported. Modifications to the growth protocol maybe made based on the test data.[7 weeks]	3 mos	9/1/13	11/30/13		
	2) Commercialization Milestone: The team will further research markets of interest, including consumer and medical devices and transportation. This will require that the marketing fellows acquire a thorough grounding in the characteristics of capaicitors vs batteries and in the relative advantages of this technology vs other commercially available capacitors. The team will then reach out both capacitor manufacturers and the companies they sell to to identify specific needs in this space. The goal of the second quarter is to identify specific "low hanging fruit"	3 mos	9/1/13	11/30/13		

	applications where the new technology will uniquely deliver a high value solution to an existing problem.					
	Report: Quarter 2	Due on 1/7/14				
3	Technical Milestone: 3) **Defect Introduction and Electrochemical Characterization [13 weeks]** • **Defects will be introduced CNTs grown on Al foil using Argon Plasma irradiation. [10 weeks** • **Electrode stability will be monitored for different mechanical curvatures** • **Electrochemcial and Raman spectroscopic characterization will be performed on defect introduced samples to evaluate significant enhancement due to defects. [3 weeks]**	3	12/1/13	2/28/14		
	3) Commercialization Milestone: In Q3, the team will develop market data for the applications identified during Q2, locate personal contacts with relevant customers and potential partners and licensees, and initiate discussions with them to identify the technical issues they need to have resolved to get their serious interest.	3	12/1/13	2/28/14		
	Report: Quarter 3	Due on 4/5/14				
4	Technical Milestone: 4) Customer Validation [13 weeks] • Cycling Studies will be performed on the CNT capacitor in order to verify if it can indeed maintain its performance over several 1000s of cycles.	3	3/1/14	5/31/14		
	4) Commercialization Milestone: Arrange technology discussions and demonstrations, follow-up with potential partners and licensees. Develop a business model and business plan.	3	3/1/13	5/31/14		
	4) Marketing Milestone: Till now, the marketing research has covered: • Three kind of companies that could potentially be licensees: Companies which manufacture or developing) supercaps; Battery	3	3/1/14	5/31/14		

	manufacturers working on specialized batteries with super-cap properties; Electronics components manufacturers who might be interested in adding a supercap to their product line-up (45 related companies found) • 8 companies that manufacture large electrochemical capacitors • Maxwell Technologies' competitors research • Supercap market research, including global sales, growth, trends, application, competitive environment, etc. Get the general idea of industry layout (8 strong competitors for Maxwell Technologies from sales data)					
	Report: Final	Due on 6/6/14				
5	5) Marketing Milestone: Till now, the marketing research has covered: • The competitive advantage of supercapacitor in consumer electronic products • Trends of consumer electronics industry • Market size for supercapacitor in consumer electronics industry • Supercapacitor in industrial applications and update about Maxwell in Korea rail system • Effort in getting ~40 potential supercapacitor licensee companies information • Communication inside of team and get the technology part of the pitch message to the potential licensees • Reaching out to the potential licensees and getting more than 10% of them have interest to speak with us and see the commercialization opportunity					

Current Technical Milestone Progress:
Cycling performance of CNT capacitors

Progress:

Cycling stability is an important parameter by capacitors in the inductsry are judged. One of the key attributes of Electrochemical Double layer Capacitors (EDLC) is their ability to charge and discharge quickly over several thousands of cycles. This is precisely why EDLCs have a larger lifetime over conventional batteries.

Typically, EDLCs possess cycling stability over several tens of thousands of cycles. The industry standard may vary from 10^5-10^6 cycles without significant performance degradation. Some common reasons for failure after a prescribed number of cycles are : (a) electrochemical degradation of current collectors (b) degradation of electrolyte (c) active material inaccessibility due to pore blockage.

In order to evaluate the cycling stability of the developed CNT based supercapacitor electrode, cycling studies were done by repeatedly cycling the capacitor for several cycles at 1 V/s scan rate i.e. 1.5 s charge discharge times. The cyclic voltammogram and a plot of the reported cycling stability is shown in figure 1a and 1b respectively.

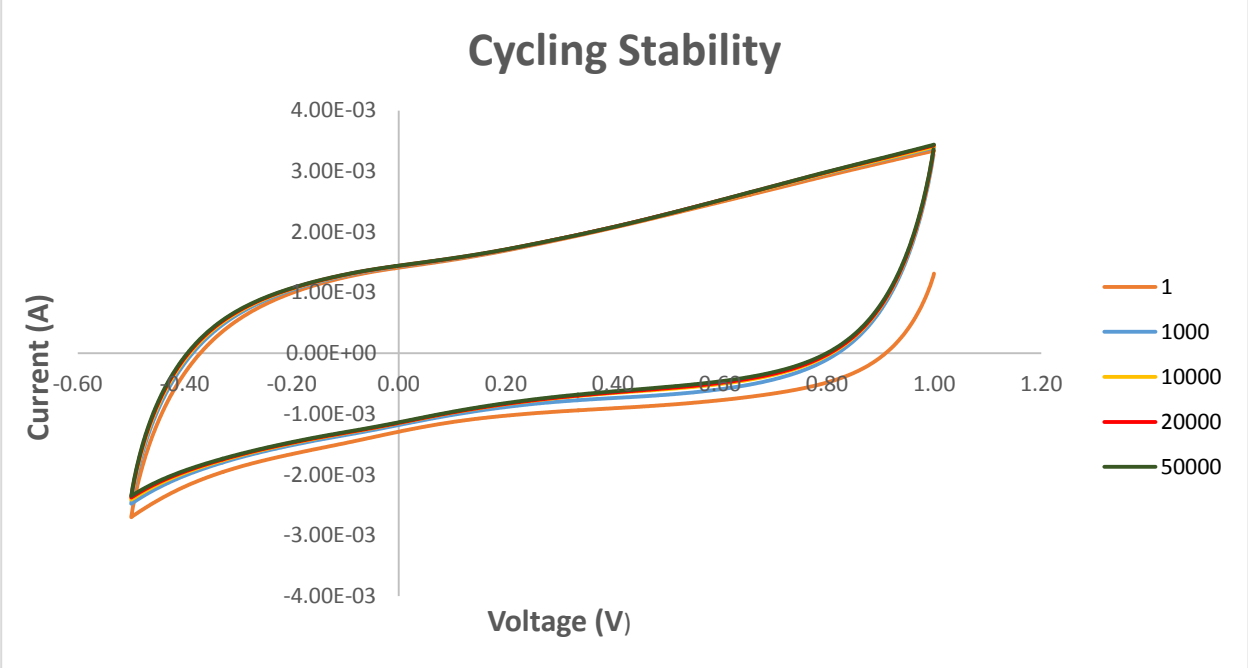

Figure 1a: Cyclic Voltammograms (current vs. potential plot) for various cycle numbers

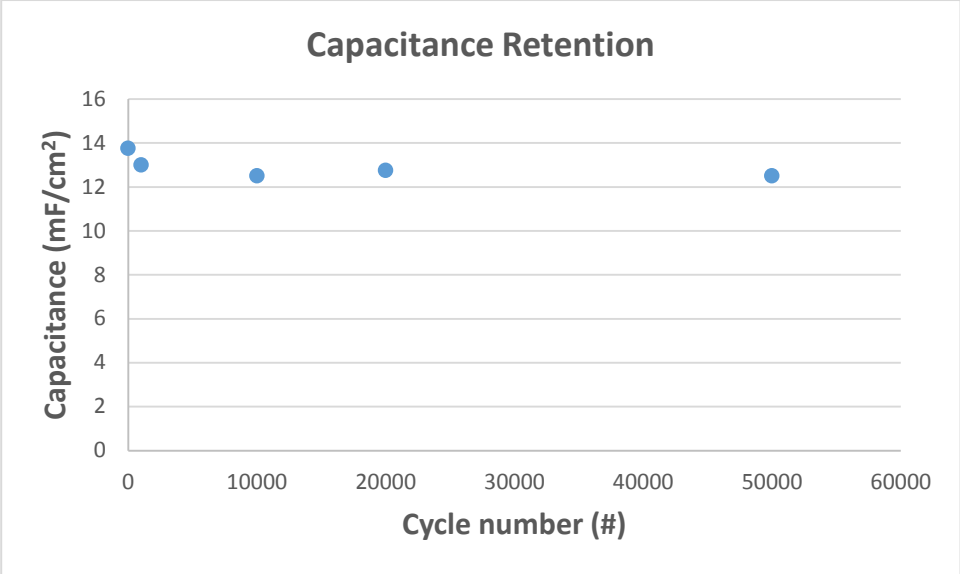

Figure 1b: Capacitance retention for various cycles numbers.

From Figure 1a and 1b it is clear that 90 % of the capacitance is maintained up to 50000 cycles. Since a device could not be fabricated, there were some practical consideration like electrolyte evaporation from electrochemical cell that precluded testing up to 10^6 cycles. Clearly, should the electrode be tested in a hermetically sealed cell, one should be optimistic of observing this sort of capacitance retention for several more cycles.

Vertically aligned CNTs have a very uniform pore size distribution i.e. they have no micro-pores along on which pore blockage due to bubble formation is possible. Also, CNTs have excellent mechanical and electrical properties that prevent their degradation after several cycle number.

Educational Milestones:
No Educational milestones were required this quarter.
Educational milestone Results:
No Educational milestones completed this quarter

c. Key Research Accomplishments

Overall summary and accomplishments:

1. Vertically aligned CNTs were grown on Aluminum foils in order demonstrate their unique capacitive properties. The growth on such metal foils was undertaken for 2 reasons (a) mechanical flexibility enabling potential wearable supercapacitors (b) CNT growth on conducting substrates like Aluminum foil was expected to increase the overall conductivity of the electrode. CNTs were grown on Aluminum foils using chemical vapor deposition. Process parameters like temperature, temperature ramp rate, pressure and growth time were optimized to achieve CNT growth with density ~ 5 x 10^9 CNT/cm^2.
2. The grown CNTs were continuously monitored using Scanning Electron Microscopy (SEM) and Raman spectroscopy. It was inferred from these techniques that vertically aligned CNTs were of ~ 50 micron length and 40 nm diameter.
3. One of the key motivations behind this project was to explore ways to increase the specific capacitance of the existing CNT electrode. To that end plasma processing was performed using Reactive Ion Etching (RIE) to create defects on pristine CNTs. It was observed that such defects, due to their edge plane like characteristics, increased the specific capacitance by 350 % due to increased charge density at these sites. Parameters like Plasma power, gas flow rate and ion flux were optimized to achieve such a large enhancement of capacitance.
4. Finally, the developed capacitor electrode were cycled up to 50000 cycles in order to monitor their stability and capacitance retention. It was observed that no visible mechanical or chemical degradation of the electrode was observed and ~ 90 % of the capacitance was retained after cycling up to 50000 cycles.
5. However, there were problems in device fabrication in that the actual samples were no more than 0.25 sq.cm in area making it difficult to construct devices. The main problem arose from foil melting during CNT growth. Even though the growth temperatures were maintained well below the melting point of aluminum, some inherent impurities the foil caused such melting. Foil melting was alleviated by using 99.99 % pure aluminum foil, however, it was not possible to completely eradicate this problem.

d. Key Market Analysis Progress from the Project

For marketing research, I have regular meeting with Mike every week to discuss the progress and research direction. The process of marketing research would focus on finding out potential licensees, getting the contact information of these licensees, and reaching out to them to brief our CNT supercap technology. Finally we discuss with those companies which are interested in our technology and reach our goal to license/commercialize CNT supercap technology. Now the list of potential licensees, supercap ecosystem and industry layout are being researched. We've got a much bigger picture about the industry and players.

I analyzed the market from consumer electronics segment and industrial segment. There are data about the market size, trends, and real world applications for supercapacitors. In addition, we have a sense about the industry layout. Based on that information, I can get the direction which companies would be our potential licensees. Then I spent much time on searching the R&D information of the potential licensee companies. As most companies don't put their R&D department or contact people info. publicly, we decide to try to reach out the contact info. of sales team, customer service, or inquiry page. Finally I got ~40 pieces of contact information. After the communication with Raj and Mike, I finalize our pitch information and reach out to our potential licensees. In a short time, more than 10% of the companies replied and expressed interest.

Commercialization Progress:

There was no commercialization progress during the course of this milestone.

IV. Reportable Outcomes & Conclusions

- Outcomes and Conclusion: We have successfully grown CNTs on Al foil with minimal foil melting during growth.
- Key electrochemical parameters were evaluated under defect introduction and under mechanical deformation.
- No licensing agreements or companies have been formed yet.
- No additional funding recieved.

V. Next Steps

The observed power density of the CNT supercapacitor ~ 1000 W/Kg which is very competitive compared to commercially available supercapacitor cf. Maxwell PC 10 series. However, the observed energy density was ~ 0.1 Wh/Kg. In this report, the reported Energy and Power densities are with respect to the weight of the substrate, the CNTs and the mass of the electrolyte. Considering the packaging that might come with a commercially packages device i.e. the sealant, contact leads etc., the density values are expected to drop by a factor determined by the packaging design. Therefore, it is important to improve upon the energy density of the CNT electrodes.

In order to improve the gravimetric and volumetric energy densities, it is important to grow CNTs of sufficiently high density (~ 10^{12} CNTs/cm^2). The number density reported here is ~ 10^9 CNTs/cm^2. Since density was directly co-related to growth temperature, the applied temperatures in this work was not high enough owing to the fact that the substrate (Al foil) melts at 660 deg. C.

Therefore, other growth mechanisms like Plasma Enhanced CVD must be undertaken to grow CNTs of sufficient density at lower temperatures. In Plasma Enhanced CVD, the energy required for the carbon atoms to diffuse through the catalyst and crystallize out into CNTs is provided by radio frequency Plasma unlike thermal energy. Therefore, CNT growth is possible on any substrate at temperatures much lower than the melting point of the substrate. This approach would also result in CNTs of very high number densities.

The next step would be to try and further optimize the growth process parameters in order to achieve high CNT density growth. The size of the substrates obtained in this work were rather small owing to difficulties posed by the thermal CVD approach. Therefore, with further improvement in growth techniques, the next step would be to fabricate a prototype device that would highlight the salient features of this work on a more realistic scale.

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VI. Conclusion

CNT based supercapacitor electrodes were cycled repeatedly at charge discharge times ~ 1.5 s for up to 50000 cycles. No visible mechanical or chemical degradation was observed and 90 % of the capacitance was retained up to 50000 cycles.

We've not undertaken CNT growth vis PECVD due to lack of equipment. However, here we've demonstrated an approach to improve the energy density of CNT based electrode by ~ 350% using a proprietary plasma processing technique. We've also been able to cycle these electrodes at very high power and for several cycles without any losses.

The growth of CNTs on flexible and electronically conductive foil in conjunction with plasma processing resulted in high energy , highly flexible supercapacitor electrodes that also posses very good power capabilities.

Metrics Chart

Index	*Proposed Metric*	*Elaboration*
I. Commercialization Milestones		
1	Follow-on funding raised by startups nurtured by ecosystems	None
2	Total number of startups/licenses incorporated	None
3	Number of jobs created	None
4	Number of technologies licensed, revenues received	None
5	Number of patents and disclosures filed	The Regents of the University of California along with the inventors, Dr. Prabhakar Bandaru and Dr. Mark Hoefer have filed for an international patent. International Application Number: PCT/US2011/059024
6	News articles, stories from the press, presentations, etc	**"Clean Energy Program Accelerates the Commercialization of University Technologies to the Market"** - UCSD News Center

Appendix III: Team Members

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- Wei Yu, Founder of Lyxia®, PhD candidate, Biomedical Engineering Dept., UC Los Angeles
- Derek Butler, Reusable fuel source "lignocellulosic biomass", College of Engineering, San Diego State University
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- Carson Riche, Nanofoundry, PhD candidate, Dept. of Chemical Engineering and Material Science, University of Southern California
- Arun Manohar, Structural Health Monitoring of Wind Turbine Blades Using Advanced Infrared Thermography, PhD, Dept. of Structural Engineering, UC San Diego
- Muchuan Yang, Novel High-Efficiency and Mercury-Free Light Bulbs Based Semiconductor Nanowires, PhD, Dept. of Electrical and Computer Engineering, UC San Diego
- Shanel Miller, Novel 3D Organic Photovoltaic Solar Cells, M. Eng., San Diego State University
- Rahul Kapadia, Energy Conversion via Polymers, PhD, Dept. of Mechanical and Aerospace Engineering, UC San Diego

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- Francesco Lanza di Scalea, Structural Health Monitoring of Wind Turbine Blades Using Advanced Infrared Thermography, Professor, Dept. of Structural Engineering, UC San Diego

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- Jim Corlett
  - Structural Health Monitoring of Wind Turbine Blades Using Advanced Infrared Thermography
  - Lyxia
  - Energy Conversion via Polymers,
- Mike Krupp: Novel 3D Organic Photovoltaic Solar Cells
- Rakesh Kumar:
  - GrollTex
  - Nanofoundry
- Michael Elconin
  - Vertically Aligned Carbon Nanotube electrodes for High Power Density Capacitors,
  - Reusable fuel source “lignocellulosic biomass”,
- Tim Rueth: Sky Imager
- Kai Wenk-Wolff: Electrozyme

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- An Wang, Rady School of Management, UC San Diego
- Mengju Wu, Rady School of Management, UC San Diego
- Zhao Li, Rady School of Management, UC San Diego
- Ryan Zwilling, Rady School of Management, UC San Diego
- Antonio Aguiar, supported Structural Health Monitoring of Wind Turbine Blades Using Advanced Infrared Thermography, Rady School of Management, UC San Diego

*MBA students not assigned to a specific project received stipends to conduct general program support initiatives including outreach/sourcing of potential projects to apply to the program, help review applications, conducting due diligence during the application phase and support the technologists with business plan development prior to presenting to the selection panel.

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- John Crockett, director of researcher project development, San Diego State University Research Foundation