GREEN MATERIALS RESEARCH EDUCATION

UC-IDR Collaborative Lead Campus Component

Irvine, Davis and Riverside

MISSION STATEMENT: ***The mission of the proposed Lead Campus is to advance interdisciplinary research and education on the invention, assessment, and adoption of less-toxic "green" materials as alternatives to toxic substances currently used in consumer products.***

This is a forward-thinking mission that acknowledges, complements, and extends traditional discipline-based research and training related to toxic substances. It is an approach that will aid in finding interdisciplinary solutions to complex problems, including those arising from economic globalization, internationally distributed pollution, and the environmental burden of disease. This mission aligns well with strategies for maintaining California's and TSR&TP's leadership in developing innovative solutions for multifaceted societal concerns regarding environmental quality and human health.

A. PROGRAM FOCUS

The proposed three-campus collaboration (**UC Irvine**, **Davis**, and **Riverside**) on research and education in green materials (**UC-REGM**) will focus on innovative solutions to problems arising in the interface of manufacturing systems, toxic material uses, consumer preferences and concerns, and government regulatory policies. Comparative toxicity risk analysis, risk perception, risk communication, and risk management are germane to the focus of the program, and they will represent important components of the multidisciplinary framework of research and education under the auspices of **UC-REGM.** The program will be positioned to address toxicity risks associated with new materials and emerging technologies. The goals of **UC-REGM** will be accomplished by a distinguished group of participating faculty who are committed to training uniquely qualified graduate students through collaborative interdisciplinary research on critical questions within the **UC-REGM** scientific framework (Figure 1). In addition to sponsoring research through competitive awards, funding the development of innovative interdisciplinary courses, and establishing a forum for multidisciplinary collaboration on materials use science and policy, participants will work collaboratively to apply for sustaining extramural funding (e.g., National Science Foundation's Integrative Graduate Education and Research Traineeship) within the initial three-year funding period of TSR&TP support. **The ultimate goal is to become a *Center of Excellence in Green Materials and Pollution Prevention* within the six years of TSR&TP support.**

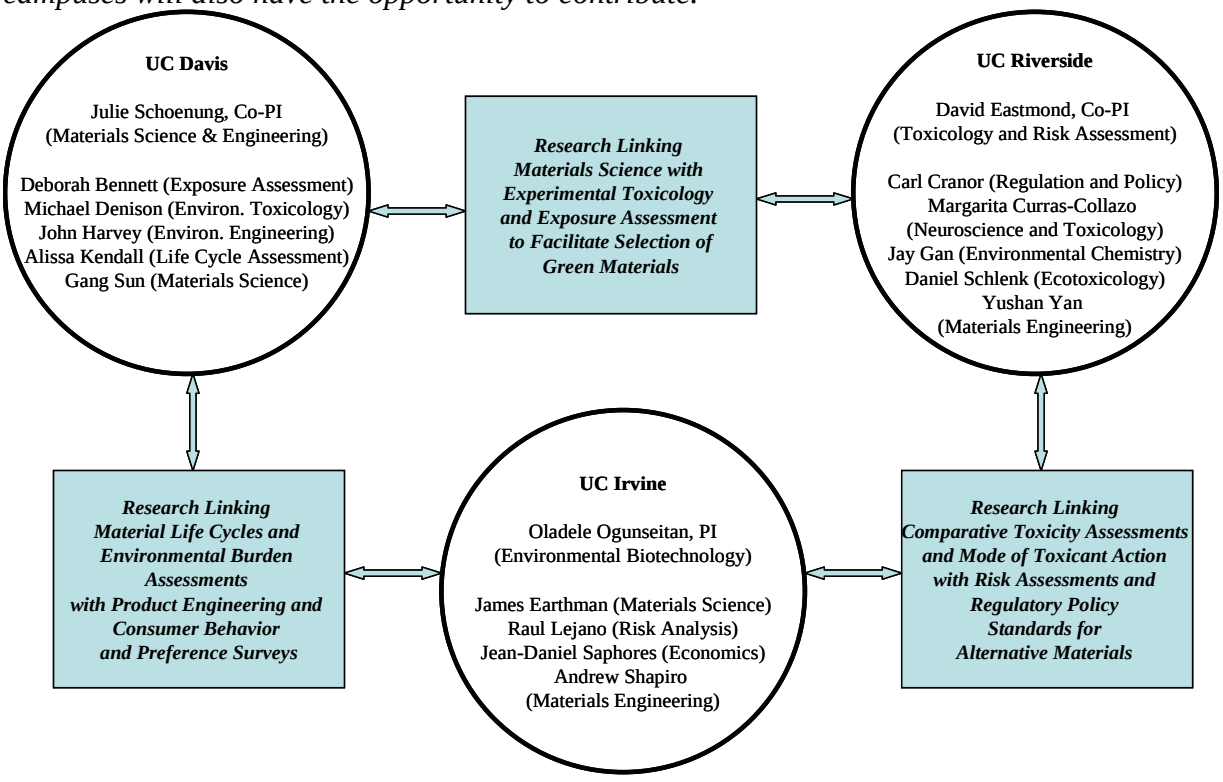
B. RELEVANCE TO THE UC TSR&TP

In recent years, there have been several situations where government initiatives, regulatory directives, or legislation based on public concern for health and environmental risks of consumer products have preceded the readiness of manufacturers to respond with new alternative "greener" products. Increasingly, these "policy primers" have originated from international domains, and the impacts of such foreign policies on domestic affairs have highlighted the declining hegemony of specific industrialized countries in setting the pace for innovation in material uses and product development. Invariably, **toxicity** is at the center of the debate, and research frameworks to identify alternative materials must address this as a fundamental issue (Figure 2). But the toxic characteristics of materials are often surrounded by complex issues of cost, product performance and reliability, energy demand, recyclability, and environmental fate.

The State of California, in part through the activities of the UC TSR&TP is committed to be a world leader in understanding these complex issues, and in producing innovative solutions that account for the various perspectives and trends at the local, national, and international levels. Two case studies will be used to illustrate the point.

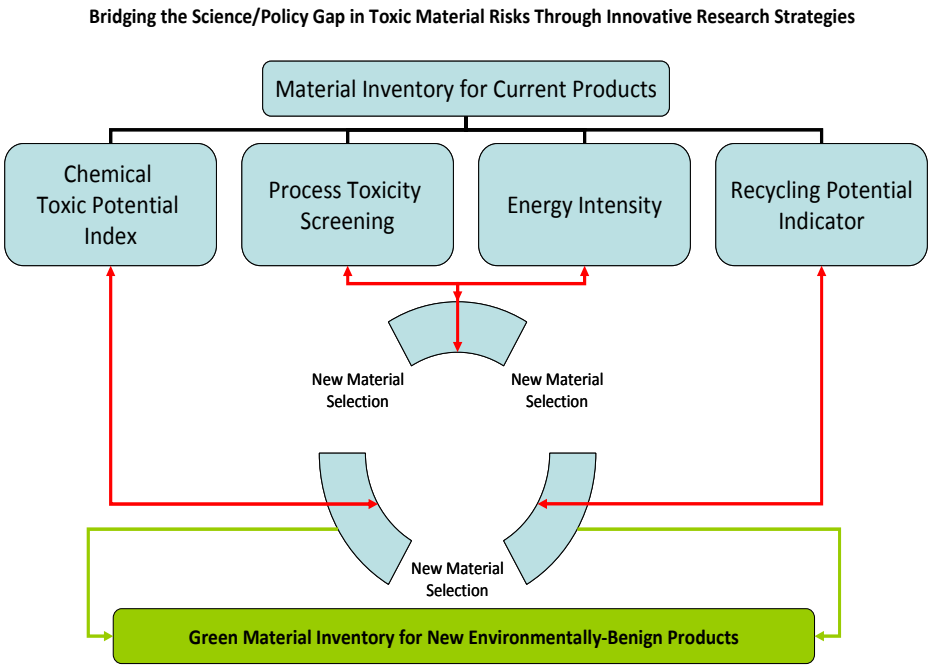
Hazardous Substances in Consumer Electronic Products – On July 1st, 2006, the European Union (EU) began to implement its so called RoHS Directive which involved "the restriction of the use of certain hazardous substances in electrical and electronic equipment." RoHS bans the placing on the EU market of new electrical and electronic equipment containing more than specified levels of lead, cadmium, mercury, hexavalent chromium, and polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants[1]. Similarly, the EU's Waste Electrical and Electronic Equipment (WEEE) Directive, which became law in February 2003 imposes the responsibility on manufacturers to manage the post-consumer fate of their products in order to minimize impacts on human health and the environment. These seemingly simple directives have managed to spurn a tremendous amount of research into alternative materials, and has revealed numerous policy differences across jurisdictional boundaries and knowledge gaps across many disciplines that still remain to be bridged in order to produce a comprehensive solution to the problem of electronic waste ("e-waste"), the fastest growing category of potentially hazardous solid waste in the U.S., and probably in the world. For example, the U.S. has no coherent national law against the use of toxic materials in electronic products, or against the disposal of e-waste.

Figure 1. *Research framework of **UC-REGM** as represented by participating faculty members. Graduate student research and REGM-team projects will build on existing strengths on each campus to focus on critical questions framed within the boxes. Participants from other UC campuses will also have the opportunity to contribute.*



Furthermore, individual States are beginning to pass legislation that may create domestic differences and international loopholes in reducing the hazards associated with e-waste. Since 2001, the Industrial Ecology Research Group, an interdisciplinary collaboration between faculty members at UC **Irvine** and UC **Davis** has studied the problem of e-waste from the California, U.S., and international perspectives. We have trained graduate students, postdoctoral fellows and visiting scientists, received major extramural funding from the National Science Foundation, and published highly visible papers [2,3,4,5,6,7]. In addition to the federal funds, over the past five years, we also received support from the TSR&TP for team research; from the California Policy Research Center; and through the AT&T Industrial Ecology Faculty Fellows program.

Figure 2. *Research and Teaching Framework for Green Material Selection.*



Transition from Incandescent Light Bulbs to Compact Fluorescent Tubes – In December 2007, the U.S. Congress passed a new energy bill that outlaws the sale of incandescent light bulbs (ILBs) by the year 2012. While the goals of energy efficiency and potential reduction of greenhouse gas emissions are laudable, there are uncertainties about the trade-offs on health impacts of alternative products because the most likely alternative to ILBs are Compact Fluorescent Tubes (CFTs) which contain small but concerning amounts of mercury. At present, there are limited studies on consumer participation in disposing of CFTs properly, their recyclability, and emergency response should they break in homes inhabited by children. The elimination of mercury from CFTs will become a priority, but it is not clear what set of criteria will guide the selection of alternative materials. Potential alternatives also include Light Emitting Diodes (LEDs), which are currently cost-prohibitive.

The **UC-REGM** framework as exemplified by these two case studies represent the tip of the iceberg for the kind of research needed to keep California from lagging economically and in

the protection of her citizens and environment from the impacts of potentially toxic substances used in manufactured products. We could write similar justifications for other products that have life cycles embedded in the use of toxic materials, and which will provide opportunities for innovation in materials research, toxicity profiling, exposure assessment, and ecotoxicology. For example, the role of pesticide use in fabric manufacturing is a major environmental problem, and the U.S. EPA is currently embroiled in controversies relating to continuing use of endosulfan, a nerve toxin on cotton agriculture[8]. Similarly, continuing use of carbofuran has left a legacy of toxicity accidents[9]. To top this line of argument, on January 24, 2008, a federal court upheld a California farmers' request through the Bush administration, to continue using methyl bromide, the sixth most commonly used pesticide in the State. Methyl bromide is a powerful pesticide, but it also has well documented environmental impacts at the global level with international concerns for its effects. Although research into an alternative "greener" version of methyl bromide has been funded for more than 10 years[10], some have continued to argue that there are no "greener" alternatives available without costing the economy up to an estimated $ 40 million annually[11]. In addition to these existing case studies, emerging products that promise to be widespread in manufactured products warrant investigation under the green materials framework. These include, for example, energy fuel additives[12,13], products manufactured with nanoparticles and radiofrequency identifiers (RFID tags), and the controversial issue of phthalates in plastics[14]. In addition, industrial processes such as cement production face complex life-cycle issues. In the State of California, limestone, the main raw material in cement manufacture, contains mercury, which is released during pyroprocessing[15]. There are unresolved toxicity and ecotoxicological research questions on mercury[16,17] that fall within the scope of **UC-REGM**. We will welcome well-conceived proposals from graduate students who wish to tackle these and other relevant issues, and we will encourage the establishment of faculty teams to extend the resources of **UC-REGM** through extramural research and training grants.

C. PROPOSED PROGRAM

Introduction and Rationale

The global economy is sustained by material transactions. California, as the world's sixth largest economy, is both a source and sink for manufactured products with material components that remain poorly characterized with respect to potential impacts on human health and environmental quality. The increasing globalization of material life cycles and the penetrating effects of associated toxic substances have invigorated desires for "greener" consumer products with demonstrably lower burdens on societal resources and human health. However, identifying alternative materials as "green" or "greener" requires multidisciplinary, innovative approaches that account not only for relative toxicity and ecotoxicity, but also for exposure assessment and risk management. It is also important to account for potential burdens exerted throughout the entire life cycle of materials, and to quantify trade-offs in **performance**, **toxicity**, **consumer preferences**, and **regulatory constraints**. It is this level of quantitative assessments and deliberative community engagement that can command the attention of product designers and manufacturers who must have access to the information necessary to truly transform our currently dominant toxic material society into a green material society. The goal of the proposed Lead Campus program is to transform the research education of a new cadre of graduate students trained to approach materials science, toxicology, environmental science and engineering, and

social sciences through selective engagement in interdisciplinary collaboration. We will build upon existing collaborative research and course development across the participating campuses to implement the following specific objectives:

1. Support original interdisciplinary research involving either focused graduate student research or the establishment of REGM teams to develop innovative solutions to the problem of toxic substance use in specific manufactured consumer products of importance in California.
2. Implement a team-taught course that introduces students to multidisciplinary perspectives on the selection of materials used in product manufacturing.
3. Expand existing seminar and other courses to include speakers and topics addressing issues related to material science, life cycle assessment, toxicology, risk assessment, environmental health and international policy.
4. Establish a network of researchers, manufacturers, and policy makers through targeted symposia and workshops to address new trends in the rapidly developing areas of material discovery, use, toxicity, recycling, and disposal.

The solid foundation for this lead campus has been under development for some time as collaborations between individuals and research groups under the industrial ecology framework at **Irvine** and **Davis**, and under the toxicology and ecotoxicology framework at **Riverside**. We strongly believe that it is now time to pull these strengths together under the collaborative framework of green materials. This proposal represents our collective vision of how we can work together to reach the next level of productivity and prominence in an increasingly urgent aspect of TSR&TP's programmatic goals. Specifically, we identified gaps in the previous scope of research that warrant bringing in additional faculty participants on all three campuses, and organizing the research and education effort under a single organizational structure. For example, we believe that collaboration among the various expertise represented by participating faculty members is needed to reveal solutions to long-standing research questions such as:

a. Intuitive measures for comparative toxicity of alternative materials that includes objective and subjective measures of population health impacts, including occupational hazards, and the assigning of appropriate "weights" to these measures.
b. Assessment of trade-offs among material toxicity indices, product performance and reliability, economic costs, component recyclability, and potential ecological impacts.
c. Inclusion of geographical, national, and consumer behavior differences and valuation of toxicity into the assessments of material life cycle impacts on the environment and human health.

We envisage that individual graduate student research and REGM-teams activities will fall within the scope of issues described in Figure 1. Examples of urgently needed research topics include:

I. Review and comparison of toxicity rating or classification schemes that link materials science with experimental toxicology and exposure assessment so that engineers, product designers, and policy makers are better able to choose and recognize 'greener' alternative materials.

II. Evaluation of the toxic effects of high production volume chemicals (> 1 million lbs per year) to characterize, through experimentation, biomedical informatics database mining, and modeling, the potential risks associated with new, alternative materials being developed in the laboratory as potential green alternatives.

III. Identification of the different modes of action by which chemicals cause pathologies, focusing on linear or non-linear approaches needed to make informed decisions about low dose exposures relevant for legacy chemicals and their greener alternatives used in consumer products.

IV. Developing methods to integrate indices of material life cycle impacts so that technical product design engineers can simultaneously evaluate the environmental burden and technical feasibility of new materials.

V. Developing strategies to integrate information on consumer behavior and declared preferences with the formulation of public policy to evaluate the effectiveness of alternative legislative or regulatory methods.

Enhancement of Graduate Student and Postdoctoral Training through Education and Research in Green Materials

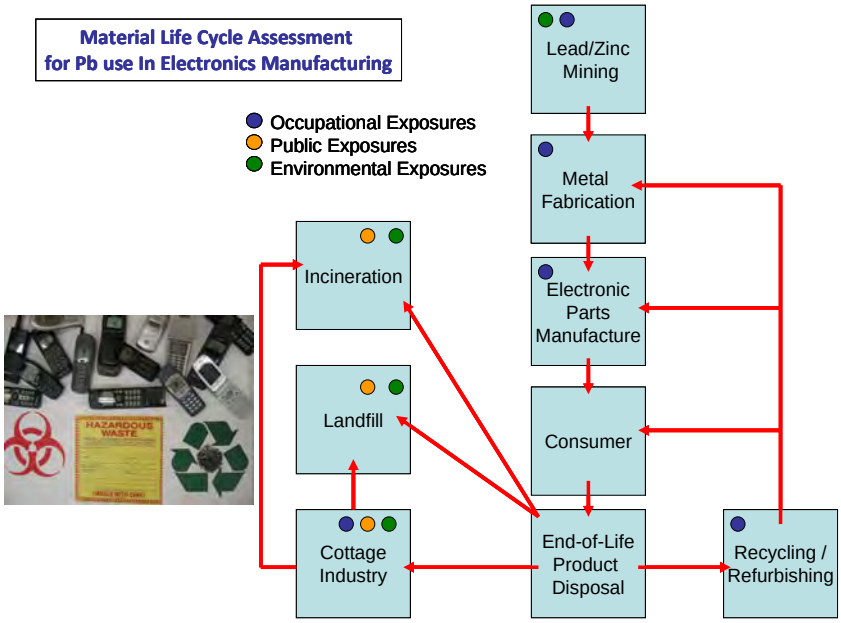
The purpose of **UC-REGM** is not to train generalists, but to inculcate, through targeted cross-fertilization of ideas, a deeper understanding of the overarching context for individual research contributions on toxic substances. Shared understanding is the best strategy for innovation, for translating the outcome of research findings to material inventions with specific uses, and for developing policies that encourage the adoption of greener products that pose minimal risks to human health and the environment. We believe that TSR&TP is in the position to spearhead the kind of interdisciplinary research and education that is crucial for proactive, rather than reactive training of students to deal with these emerging technologies and legislation.

For example, the breadth of issues surrounding the e-waste problem demands a multidisciplinary approach and different scales of analysis. In spite of this, it has been possible to delineate specific research projects suitable for focused doctoral dissertations. For example, four recent Ph.D. graduates (2 at UC Irvine and 2 at UC Davis) conducted their dissertation research within the framework described for this specific topic (Table 1). As these examples show, dissertation research on specific topics can be conducted within an interdisciplinary framework. These include the invention of new materials that eliminated the use of **toxic brominated flame retardants**, the assessment of consumer preferences for **toxic lead-free products**, comparative evaluation of **legislative initiatives**, and development of new **methods for materials life cycle assessment**. In addition to these dissertation-level works, collaborative research also addressed various aspects of the material life cycle; including simulation of toxic substance releases in landfills (Figure 3). Our graduate students also benefited from interactions with postdocs and visiting professors who brought additional expertise in environmental toxicology (e.g., Dr. Amrit Bhuie), environmental economics (e.g., Dr. Yuki Takatsuka) and chemical engineering (Dr. Tak Hur).

Table 1. *Recent UC Dissertations on "Green Materials" in Electronics.*

Name	Campus	Discipline	Degree, date	Dissertation Title
John Lincoln	UC Irvine	Materials Science	Ph.D., 2007	New Materials for Electronic Product Design-for-the-Environment: Balancing Performance Characteristics, Renewable Resources, and Toxicity Potential for Printed Wiring Boards
Hilary Nixon	UC Irvine	Social Ecology	Ph.D., 2006	Electronic Waste Management in California: Consumer attitudes toward recycling, advanced recycling fees, "green" electronics, and willingness to pay for e-waste recycling
Hai-Yong Kang	UC Davis	Materials Science and Policy	Ph.D., 2006	Comparative Hierarchical Decision Framework on Toxics Use Reduction Effectiveness for Electronic and Electrical Industries
Xiaoying Zhou	UC Davis	Materials Science	Ph.D., 2007	Life Cycle Thinking and Assessment Tools on Environmentally-Benign Electronics: Convergent Optimization of Materials Use, End-of-Life Strategy and Environmental Policies

Figure 3. *Opportunities exist for focused disciplinary work addressing toxicity issues in various components of materials life cycle assessment; a necessary precursor to innovative identification of alternative, greener materials. This example is related to the continued use of Tin-Lead solder in electronics sold in the U.S., whereas Pb-free solders have been adopted elsewhere.*



Interdisciplinary Training Component

The principal investigators and participating faculty members share the common understanding that interdisciplinary collaboration in education and research is necessary to transform the *status quo* of industrial manufacturing strategies into a system that prioritizes the reduction of risks associated with toxic materials. Almost a decade of collaboration among members of the participating faculty has deepened this understanding, and we have embedded the training of our graduate students and postdoctoral fellows in the framework of interdisciplinarity as articulated through the tenets of "industrial ecology". As two-time recipients of the AT&T Industrial Ecology Faculty Fellowships, we have had time to develop innovative strategies for interdisciplinary collaboration in research and education, and we have been able to reflect on what works well and what doesn't. Furthermore, we have achieved national prominence and we routinely publicize our work in industrial ecology as a quintessential interdisciplinary endeavor (see http://www.industrial-ecology.uci.edu). A brief introduction to the foundation of industrial ecology as an interdisciplinary training paradigm is informative:

In the seminal article published in a 1989 issue of *Scientific American*, Robert Frosch and Nicholas Gallopoulos envisioned an integrated model of industrial activity that would be environmentally sustainable, locally and globally[18]. The publication led to a National Academy of Sciences symposium that is generally considered the foundation of industrial ecology as an academic discipline[19], and subsequent key publications[20,21,22]. Industrial ecology has grown rapidly, now having its own peer reviewed journal (*Journal of Industrial Ecology* published jointly by Yale University and MIT Press), its own professional society (International Society for Industrial Ecology) and so-named graduate degree programs. In its original form, industrial ecology focused on understanding the threats from toxic substances and waste generation through an interdisciplinary approach that drew parallels between industrial systems and natural ecosystems. Thus ecotoxicology provided the springboard for industrial ecology, but the discipline evolved quickly to encompass *Design for the Environment* (DfE), now a major initiative under the U.S. Environmental Protection Agency; materials *Life Cycle Assessment* (LCA); and Sustainable Development Initiatives (SDI) through pollution prevention, resource recovery, energy conservation, and process optimization; and policy analysis for the governance of toxic material uses and toxic waste management. Risk communication is a central vein in industrial ecological assessments, and the multidisciplinary endeavor of quantifying trade-offs between economic benefits and toxic risk management are essential for guiding decision making processes which represent the ultimate outcome of protective policies (Ehrenfeld, 2004)[23]. Since 2002, the collaborating team at **Irvine** and **Davis** has used the literature from industrial ecology to introduce our students to the need for collaborative interdisciplinary work and to establish a solid foundation for understanding cross-cutting methodological issues across disciplines relevant to toxics research. Challenges have arisen, however, in our ability to fully incorporate experimental toxicology into our research, due to lack of expertise, methods and data sources. We now build upon this foundation by bringing in additional colleagues from **Irvine**, **Davis**, and **Riverside** with a wider range of expertise in toxicology and ecotoxicology to enrich the contribution of all participants in the **UC-REGM** lead campus program.

Provisions for Participating Faculty Interaction and Integrative Activities

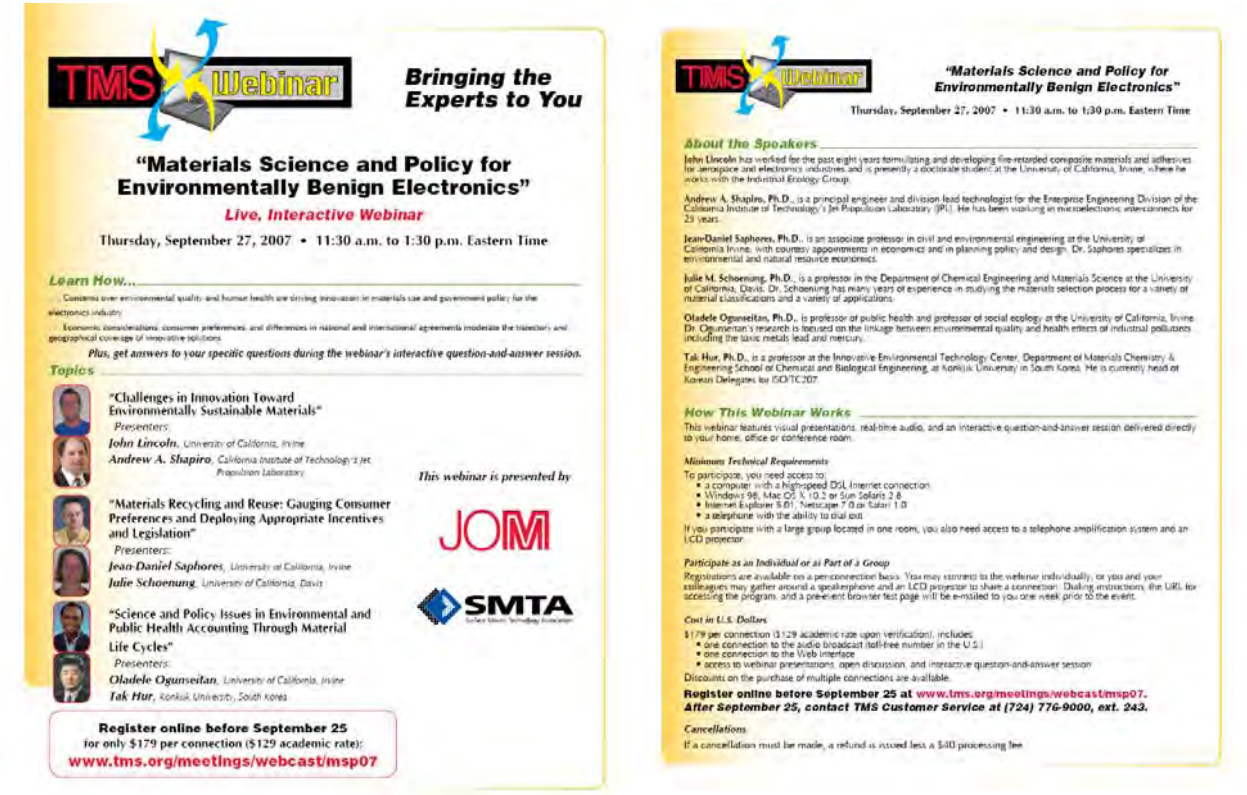
On September 27th, 2007 the industrial ecology research team, representing collaboration among UC faculty participants, implemented a "webinar" on "green" environmentally-benign electronics. The webinar was hosted and broadcast worldwide by ***The Minerals, Metals, and Materials Society*** (TMS) (Figure 4). In addition to the real-time webcast, participating faculty also responded online to comments and questions arising from the presentations over a week period, thereby providing opportunities for students, faculty, and manufacturers worldwide to participate and query the state-of-the-art research. This is one example of the type of activities planned for the proposed lead campus that will facilitate interactions among participating faculty. The strategy is effective in that it can produce a broad and long-lasting influence because trainees have access to interdisciplinary presentations across the three participating campuses, as well as opportunities to interact with invited researchers and practitioners in industry or government. Webinar programs can be integrated into classroom teaching, and be planned to coincide with broader conferences. We plan to develop webinars as a way to broaden faculty participation, and to integrate ongoing research within the **UC-REGM** lead campus framework. We have been fortunate so secure the appended letter of support for this proposal and our goals from the technical director of TMS. We will also develop an interactive website dedicated to **UC-REGM** to serve as a depository of activities, to disseminate news, funding opportunities, advertise courses and learning strategies, fellowship announcements, and a commentary and response (*wiki*-type) webpage.

In addition to web-based interaction, we will encourage collaboration among participating faculty and students through joint submission of proposals for research funding and graduate student support. Within and between the three campuses, periodic research meetings will be scheduled to facilitate interaction among participating faculty and students who are supported with funds awarded to **UC-REGM**. Faculty participants in the industrial ecology research team have a long track-record of these types of interactions and integrative activities through face-to-face meetings and conference calls. We have also organized mini-conferences at national and international conferences to invite the contribution of experts and potential collaborators outside the UC System. For the past five years, participating faculty have collaborated to teach courses entitled "***Green Engineering***" at UC Davis and "***Environmentally-Sustainable Manufacturing***" at UC-Irvine. Once a year, we identify an instructor of record who coordinates the courses, but each participating faculty member delivers lectures, which necessitates traveling. We plan to continue these collaborative educational initiatives. But we will also develop additional courses germane to the **UC-REGM** framework, and we will broaden the scope to include an emphasis in toxicology and bring in participants from UC Riverside.

In addition to the required participation in the systemwide TSR&TP annual conference, participants in the **UC-REGM** lead campus will attend an annual retreat to review accomplishments and plan for future programs. These retreats will provide an opportunity for students to bridge their disciplinary boundaries and for participating faculty to enhance their network of potential research collaborators. During the retreat, administrative issues will also be addressed. For instance, we will use this opportunity to involve faculty from all three campuses in the review of graduate student fellowship proposals. Selected experts from outside the **UC-REGM** team will also be invited as keynote speakers. The retreats will be rotated among the

campuses annually so that in the six years of Lead Campus support, each of the three participating campuses will have had two opportunities to serve as host.

Figure 4. *The recent TMS-sponsored webinar program is an example of integrative activities conducted by participating faculty. This model will be adopted for interactions among the collaborating campuses, also open to participants across the UC System.*



Criteria for Selection of Students for Fellowship Support

We plan to support at least seven graduate students annually with at least one from each participating campus, and the others from any UC campus who submits a proposal to **UC-REGM**. The fellowships will be awarded on a competitive basis, after careful review of proposals by a committee of participating faculty members appointed by each collaborating campus Co-PI. Each application for a graduate fellowship will be reviewed initially by the group of participating faculty on each campus. Proposals that are judged to be scientifically rigorous and that incorporate the interdisciplinary mission of the **UC-REGM** lead campus program will be recommended to the Co-PIs for a final decision on funding. The criteria for selecting successful proposals will be based on those articulated by the TSR&TP, including creativity, innovation, relevance to UC TSR&TP's programmatic goals and to problems of the State of California, integration of interdisciplinary contexts, and qualifications of the investigators. Each graduate fellow will receive up to two years of support as a graduate student researcher (salary and fees). We will welcome applications for full support from all eligible graduate students who have research relevant to the **UC-REGM** framework in their dissertation research. We will also

consider funding at a full or reduced level for more advanced students who wish to add a new, relevant interdisciplinary dimension into their green materials research on the basis of recent findings, new government policies, or consumer preferences.

D. LEADERSHIP

The overarching administrative center of the proposed **UC-REGM** lead campus will be at Irvine, under the direction of Dr. Oladele Ogunseitan. Dr. Julie Schoenung, Co-PI, will oversee activities at UC Davis, and Dr. David Eastmond, Co-PI, will oversee the activities at UC-Riverside. The three Co-PIs have considerable academic leadership experience, as well as established connections with government and industry sectors. For the past seven years, Dr. Ogunseitan has been directing the activities of the Industrial Ecology Research Group at UC Irvine. For the past five years, he has played a leadership role in the development of the Program in Public Health at UC Irvine, coordinating the two undergraduate degree programs in public health, and serving as the designated coordinator for the Master of Public Health degree, and designated Chair of the proposed Department of Population Health and Disease Prevention[24]. He was recently (2008) appointed to the international committee on ***Materials and Society*** by the leadership of the Minerals, Metals and Materials Society (TMS). His expertise in mentoring was recently (2007) recognized by an ***Exceptional Mentoring Award*** by the Associated Graduate Students of UC Irvine. In the same year, he won a UC Irvine ***Excellence in Teaching*** award. Dr. Schoenung served for six years as the Department Chair in Chemical and Materials Engineering, while on the faculty at the California State Polytechnic University, Pomona. She also has many years of experience as a consultant to industry, including serving for three years as a Project Manager at IBIS Associates, which specializes in materials systems analysis. Dr. Eastmond is the Chair of the Graduate Program in Environmental Toxicology at UC Riverside and is currently serving a one-year appointment as the interim Director for the UC Washington Center and Sacramento Center internship programs for UC Riverside. He has had many years of experience as a consultant to government and industry. Dr. Eastmond has also served as an Associate Director for the UCLA/UCR/LANL lead campus program on Toxic Mechanisms that has been supported by the UC TSR&TP.

Development of Leaders/Leadership

We interpret this facet of the program in two ways: building strong leadership within the lead campus, and training strong leaders who will go on to implement the research outcomes of **UC-REGM** in the public and private sectors.

The quest for "greener" materials and how to implement their adoption into commercial products will always provide opportunities for interdisciplinary research in the foreseeable future. Therefore, we fully intend to make **UC-REGM** a permanent fixture of the UC System. We expect that the strong inaugural leadership will do everything possible to establish the lead campus on a strong foundation, but we also have to make provision for cultivating new leaders and for regular evaluation of leadership performance. We are beginning with a strong pool of participating faculty members who are committed to the goals of TSR&TP in general and those of **UC-REGM** in particular. Every faculty participant can potentially assume a position of leadership in the lead-campus, and having collaboration across three campuses provides us with

an uncommon robustness of leadership to ensure that the mission of **UC-REGM** is sustainable even if there are transitions or changes in faculty positions. Through our dedicated website, announcements for fellowships, and targeted presentations, we plan to be very visible on each of the participating campuses, and across the UC system, such that newly recruited faculty members who work on related topics will be welcome to join as participating faculty members. Through research collaborations, joint student advising, and regular retreats, we will ensure that each campus maintains a strong sense of collaboration among participating faculty members, which is essential for developing future **UC-REGM** leaders.

Our educational program will emphasize building strong networks among trainees and between trainees and the audience of their research products. We believe that to truly transform our society into one that minimizes the use of toxic substances across the board of commerce, we need to put people in leadership positions that understand the interdisciplinary nature of the endeavor and have strong skills in translational science. We will emphasize these traits in our training program through the invited participation of influential leaders in industry and government agencies that have implemented strategies designed to make a "green" transformation. Many large multinational manufacturing corporations now have a "green" branch. They are not equally strong, but we do not anticipate difficulty in identifying those leaders from which our students will benefit.

Establishment of an Appropriate Mechanism for Program Governance

There is already an office dedicated to the activities of the group of participating faculty members under the auspices of the industrial ecology research team on the UC-Irvine campus (room 248, Social Ecology I building). This office will also provide administrative support for the **UC-REGM**. It is separate from Dr. Ogunseitan's administrative offices in the Program in Public Health, College of Health Sciences (room 254, 101 Theory Drive), and his office in the School of Social Ecology (room 1365, Social Ecology II) where he also maintains a research laboratory. The office has phone conferencing equipment, computer, laser printer, and essential office equipment. We are requesting through this proposal, to recruit a part time (50% FTE) administrative staff assistant who will combine the skills of a Student Affairs Officer and managerial services to support participating faculty and students in **UC-REGM**. The three Co-PIs will schedule a monthly telephone conferencing to conduct the business of the lead campus and to ensure that effective communication pathways are open for disseminating information. They will be responsible for organizing related activities of participating faculty and students on their respective campuses, including, as appropriate, weekly seminar series, journal clubs, and networking events. In the event that a Co-PI's role must change, participating faculty members on each campus will solicit applications to appoint a new campus representative who will organize the activities on that campus. If the situation of the director at Irvine changes, the other Co-PIs will consult with participating faculty members to recommend someone else to the role.

In addition to the central governing body represented by the three Co-PIs, we will establish a three-member advisory board consisting of at least one faculty member from the TSR&TP Executive Committee. The second member of the advisory board will be appointed from a government regulatory agency associated with toxic substances. For example, one of our previous mentees (Dr. Hai-Yong Kang) is now employed by the California Department of Toxic

Substances (DTSC) in Sacramento. Moreover, Dr. Schoenung is currently collaborating with DTSC staff to identify pollution prevention opportunities in the printed circuit board manufacturing industry; she is also serving on a DTSC Workgroup focused on the implementation of California RoHS. Furthermore, the Co-PIs have established contacts with individuals at DTSC that are involved with the State's green chemistry initiative and with e-waste recycling. Thus, a representative from DTSC, which should be easy to identify, will facilitate the exchange of ideas between **UC-REGM** academic research and the government agency perspective. The third member of the advisory board will be appointed from the private sector, representing California manufacturing companies, recycling companies, or those otherwise needing to make trade-offs among materials selected for toxicity, cost, performance, environmental burden, and consumer preferences. Through our work in electronic products and other previous industrial collaboration, we have built a network of colleagues from which an appropriate individual with sufficient breadth of perspective can be easily identified. Each member of the advisory board will be appointed for a renewable period of two years. The board members will meet with the Co-PIs and participating faculty members and students at the annual retreat of **UC-REGM** lead campus. The board will provide feedback on program activities and identify new and emerging issues for consideration.

E. THE SYNERGY OF THE UNITS INVOLVED IN THE UC-REGM PROGRAM

The **UC-REGM** lead campus will benefit from almost a decade of collaboration by participating faculty from Irvine and Davis. Furthermore, the collaboration was supported in part by one of the initial two "team" grants awarded by the UC TSR&TP (Dr. Ogunseitan was the Principal Investigator). Indeed, the work of the team was featured in the summer 2002 TSR&TP newsletter [25]. Furthermore, Dr. Ogunseitan gave a presentation on the collaboration at the 2003 TSR&TP research symposium, which was also covered in that year's newsletter [26]. The team has worked very well together, securing a $1.5 million grant under the "Biocomplexity in the Environment" program of the National Science Foundation, and building a strong network of current and alumni students, postdocs, and national and international collaborators on the theme of "green" materials. In 2007, one of the publications from this team won the "best publication" award from TSR&TP, covered in the summer of 2007 newsletter [27]. So, there is already strong synergy between the Irvine and Davis campuses. The collaboration with Riverside will be newer, but there is a strong level of shared interests in the goals of **UC-REGM**. We believe that the inclusion of faculty and students with expertise in toxicology will bring a valuable new dimension to our on-going research, and allow us to expand our focus and address a broader range of issues related to the manufacture, use and disposal of green materials.

F. TRANSITION PLAN FROM TSR&TP FUNDING

Our long term vision is to establish a **UC Center of Excellence in Green Materials and Pollution Prevention**. We expect to accomplish designation as a Center of Excellence within the six-year period of support from TSR&TP. As noted, the demand for greener, less toxic consumer products has intensified in recent years due in part to more stringent government regulation responding to scientific findings on risks associated with toxic exposures and pressure from consumers and advocacy groups. We expect that extramural funding for interdisciplinary research in the topic of "green" materials will continue to be strong. Our track record over the

past decade supports this view. Thus, our short-term goal is to continue to work to leverage TSR&TP funds awarded to the **UC-REGM** lead campus for gaining extramural funding. The National Science Foundation, National Institute of Environmental Health Sciences, National Institute of Occupational Safety and Health, U.S. Environmental Protection Agency, and The Global Environment Facility are all potential sources of extramural funding to support collaborative research by participating faculty members.

As the collaborations develop and mature during the initial three-years of funding, we will direct our efforts to secure training grants (e.g., NSF IGERT) to continue to support our graduate students and postdocs such that there will be a seamless transition to the independence of **UC-REGM** at the end of the six years of direct support from TSR&TP. The administrative office of **UC-REGM** will be responsible for timely distribution of notices for funding opportunities to participating faculty and trainees, and for providing administrative support to coordinate collaborative grant applications. We are confident that **UC-REGM** will be able to independently sustain and even expand the funding base provided by TSR&TP after the six-year period of support. Table 2 presents the timeline for our short-term and long-term goals.

Table 2. *Timeline and milestones for implementation of the **UC-REGM** program*

Activities	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Short-term goals	Solicit applications and award graduate fellowships	Implement web-enhanced inter-disciplinary course. Research workshop	Solicit applications and award graduate fellowships Lead campus mid-term review	Webinar hosting Research workshop	Solicit applications and award graduate fellowships	Research Workshop
Long-term goals	UC-Discovery Program grant application	NSF IGERT Proposal Application	Implement NSF IGERT Program in Green Materials	Application for major Center grant – federal and private funds	Application for status as UC designated Center of Excellence	Establish UC Center of Excellence in Green Materials and Pollution Prevention

E. LITERATURE CITED

[1] ROHS. http://www.rohs.eu/english/index.html Accessed on 14 February 2008.
[2] Ogunseitan, O.A. 2007. Public Health and Environmental Benefits of Adopting Lead-Free Solders. *JOM: Journal of Minerals, Metals and Materials.* 59(7): 12 – 17.
[3] Lincoln, J.D., O.A. Ogunseitan, J.-D. Saphores, and A.A. Shapiro. 2007. Leaching Assessments of Hazardous Materials in Cellular Telephones. *Environmental Science & Technology*, 41 (7), 2572 – 2578.
[4] Lincoln, J.D., A.A. Shapiro, J.C. Earthman, J.-D. Saphores, and O.A. Ogunseitan. 2008. Design and Evaluation of

Bioepoxy-flax Composites for Printed Circuit Boards. *IEEE Transactions on Electronics Packaging Manufacturing*. Accepted for Publication.

[5] Schoenung, J.M., O.A. Ogunseitan, J.-M. Saphores, and A.A. Shapiro. 2005. Adopting lead-free electronics: Knowledge gaps and policy differences. *Journal of Industrial Ecology* 8 (4):59 – 85.

[6] Saphores, J-D. M., H. Nixon, O.A. Ogunseitan, and A.A. Shapiro. 2007. California Households' Willingness to Pay for "Green" Electronics. *Journal of Environmental Planning and Management*. 50:113 – 133.

[7] Shapiro, A.A., J.K. Bonner, O.A. Ogunseitan, J.-D. Saphores, and J.M. Schoenung. 2006. Implications of Pb-free microelectronics assembly in aerospace applications. *IEEE Transactions Components and Packaging Technologies* 29 (1):60 – 70.

[8] Pesticide Action Network. 2008. Petition to ban Endosulfan. http://action.panna.org/t/5185/petition.jsp?petition_KEY=906 . Accessed on 8 February 2008.

[9] Solomon, G., O.A. Ogunseitan, and J. Kirsch. 2000. Pesticides and Human Health: A Resource for Healthcare Professionals. Physicians for Social Responsibility. http://www.psrla.org/documents/pesticides_and_human_health.pdf .

[10] California Department of Pesticide Regulation. 1995. http://www.cdpr.ca.gov/docs/emon/methbrom/mb4chg.htm. Accessed on 8 February 2008.

[11] Thacker, P.D. 2004. "No Silver Bullet to Replace Methyl Bromide" *Environmental Science & Technology*. Technology News. http://pubs.acs.org/subscribe/journals/esthag-w/2004/dec/tech/pt_silverbullet.html.

[12] Bhuie, A.K, O.A. Ogunseitan, M. Sain, and D.N Roy. 2005. Modeling the environmental fate of manganese from methylcyclopentadienyl manganese tricarbonyl in urban landscapes. *Science of the Total Environment* 339:167-178.

[13] Bhuie, A.K, O.A. Ogunseitan, and D.N Roy. 2004. Manganese content of *Tradescancia* species exposed to automotive combustion of methylcyclopentadienyl manganese tricarbonyl in urban and rural landscapes. *Journal of Air and Waste Management* 54:181-190.

[14] Sathyanarayana, S., C.J. Karr, P. Lozano, E. Brown, A.M. Calafat, F. Liu, and S.H. Swan. 2008. Baby Care Products: Possible Sources of Infant Phthalate Exposure. *Pediatrics*. 121 (2): pp. e260-e268.

[15] Vagn C. Johansen and Garth J. Hawkins. 2003. Mercury Emission and Speciation from Portland Cement Kilns. Portland Cement Association, PCA R&D Serial No. 2567a. Accessed online on 20 February 2008. http://www.cement.org/pdf_files/SN2567a.pdf

[16] Ogunseitan, O.A. 1998. Protein method for investigating mercuric reductase gene expression in aquatic environments. *Applied and Environmental Microbiology*. 64:695-702.

[17] Ogunseitan O.A., and B.H. Olson. 1991. Potential for Genetic Enhancement of Bacterial Detoxification of Mercury Waste. In: Smith, R., and T. Mishra (Editors) Mineral Bioprocessing. Engineering Foundation. New York.

[18] Frosch, R.A. and N.E. Gallopoulos. 1989. Strategies for Manufacturing. *Scientific American* 189(3):152.

[19] Industrial Ecology: http://www.pnas.org/content/vol89/issue3/.

[20] Allenby, B.R., and D.J. Richards (Editors) 1994. The Greening of Industrial Ecosystems. National Academy of Engineering. 259 pages. National Academy Press, Washington, DC.

[21] Erkman, S. 1997. Industrial Ecology: An Historical View. *J. Cleaner Prod*. 5(1-2):1

[22] Geiser, K. 2001. Materials Matter: Toward a Sustainable Materials Policy. 479 pp. MIT Press, Cambridge, MA.

[23] Ehrenfeld, J.R. 1994. Industrial ecology and Design for Environment: The Role of Universities. Pages 228-240 In: Allenby, B.R., and D.J. Richards (Editors) The Greening of Industrial Ecosystems. National Academy of Engineering. National Academy Press, Washington, DC.

[24] Department of Population Health and Disease Prevention. http://www.evc.uci.edu/EVC/mpclark/DPHDP.pdf

[25] Tolson, Mika Pringle. Summer, 2002. **Removing Lead Solders from the Waste Stream: Does Your Cell Phone Pose an Environmental Risk?** http://tsrtp.ucdavis.edu/public/our_program/newsletters/summer_2002/LeadSolders.php. Accessed on 15 Feb. 2008.

[26] Tolson, Mika Pringle. Summer, 2003. **2003 Research Symposium Focuses on Collaboration.** http://tsrtp.ucdavis.edu/public/our_program/newsletters/spring_2003/Symp03.php. Accessed on 15 February 2008.

[27] UC Toxics News. Summer 2007. **2007 TSR&TP Best Publication Award Winners.** http://tsrtp.ucdavis.edu/public/our_program/newsletters/summer_2007/BestPubs.php

UPDATED EDUCATIONAL PLAN

Two of the four specific objectives of the TSR&TP Lead Campus program entitled Research and Education in Green Materials (REGM) address educational initiatives:

1. Implement a team-taught course that introduces students to multidisciplinary perspectives on the selection of materials used in product manufacturing.
2. Expand existing seminar and other courses to include speakers and topics addressing issues related to material science, life cycle assessment, toxicology, risk assessment, environmental health and international policy.

In the following paragraphs, we describe specific steps that we will initiate over the next three years to meet the goals of the educational program. We address the issues in four sections as requested in the award letter.

1. Title and content of team-taught course

Some of our participating faculty members already contribute to related team-taught courses, including a course in "*Environmentally Sustainable Manufacturing*" (EECS-272) at Irvine, and a course entitled "*Green Engineering: Theory and Practice*" (ECM-281) at Davis. Our immediate goal is to update the content of the "*Green Engineering: Theory and Practice*" course and make it available to students in all the participating campuses through real-time video streaming. Beginning Winter 2009, we plan to offer the ECM 281 course in a digitally enhanced classroom with remote participants in similarly enhanced locations at their respective campuses. Depending upon the success of this course, we may try the same approach with the "*Environmentally Sustainable Manufacturing*" course at UC Irvine. Our long term goal is to develop a fully web-enhanced capstone course that builds upon the existing courses to serve as a permanent archive of essential methodologies and case-studies, entitled "*Green Materials: Science, Technology and Society*". An envisioned sample syllabus is appended to this document. The first half of the course is dedicated to the interdisciplinary perspectives essential for understanding the complexity of the challenges associated with toxic material uses and for inspiring sustainable solutions based on solid science and technological innovation. The second half of the course is focused on contemporary case studies to illustrate for students how the various disciplines converge on particular products. We expect that the identity of case studies will be sufficiently flexible to make the course responsive to pressing issues in green materials research on each campus. The interdisciplinary nature of the course warrants the participation of faculty from different academic units and industry experts. We have carefully reviewed participating faculty on each campus to have a potential role in the delivery of the course. We also plan for inter-campus faculty visits to participate as guest lecturers on specific topics. Our previous experience with such intercampus team teaching has been successful, and we will build on that success in this case.

2. Plan for expansion of existing seminars and other courses

Seminars and workshops provide unparalleled opportunities to enhance educational opportunities available through regular courses and informal discussions. The REGM program will host seminar series with distinguished speakers invited from the ranks of academic and industrial institutions working on various aspects of green materials. We expect to sponsor 4 – 6 seminars per year initially, rotating across the campuses. These seminars will initially be embedded in ongoing seminar series on each campus. In the next phase, we expect that each campus will host at least one seminar per quarter, with

the option of developing independent regular seminar series focused on green materials. We will videotape each presentation, and make the content available on our website to be accessed by all faculty and student participants. All participants on each of the campuses will be eligible to nominate and host speakers. Dr. Ogunseitan was recently appointed to a six member national *ad hoc* committee on "Materials and Society" by the President of The Minerals Metals and Materials Society. One of the goals of the committee is to develop a web-enhanced "Materials Sustainability Digital Resource Center" (see www.materialstechnology.org for examples of Digital Resource Centers). We will work with the resource center to broaden the scope of seminar topics and archives available to our students and faculty.

To encourage student participation in the REGM program (especially for students who are not yet funded, but who wish to find out more about green materials), we will support registration in 2-unit seminar courses under the "directed studies" or "independent studies" courses. For example, at UC Irvine, these courses are numbered "298" and "299" within academic units, and faculty members are assigned specific codes. Participating faculty members can enroll students who attend the seminars physically and online and write a summary of the presentations with an assessment of the influence on their own research direction. Further, we will use our planned annual interactive retreats as an opportunity to implement workshops on special interdisciplinary topics essential for the research mission of the Lead Campus program, including, for example, "*Toxicology for Non-Specialists.*"

3. Course requirements for REGM fellows

Every funded REGM graduate fellow will be required to enroll in one of the existing courses described above, and when it becomes operational, in the web-enhanced course entitled "*Green Materials: Science, Technology and Society.*" Each funded student will also be required to attend the sponsored seminars when physically possible, and to review web-based presentations of seminars given at distant participating campuses. We will maintain a record of attendance through sign-in or log-on templates.

4. Availability of educational resources to all students in the program

We are committed to the implementation of the REGM lead campus as a genuinely inter-campus program. To be truly transformative, the educational plan must accommodate slight variations in campus educational environments and the curricula of various degree programs within which we will draw student participants. To facilitate equal access and participation, we have planned to invest heavily in our presence on the worldwide web, and to provide each participating campus with resources to ensure quick and reliable access to lead campus documents and programs. We will of course establish a comprehensive electronic mailing list as soon as we start in July 2008, and we will have an interactive website linked through the UC Irvine "EEE" portal. We are also fortunate to have the California Institute for Telecommunications and Information Technology (Cal-iT^2) facilities at Irvine, and we will consult with them about teleconferencing and the emerging opportunities of web-3 (http://www.calit2.net/). An example of a successful free online on a related topic is the web-based course in Life Cycle Assessments (LCA) developed at Harvard School of Public Health (http://www.sciencenetwork.com/lca/index.cfm). We will work closely with the Teaching Learning and Technology Center (TLTC) at UC Irvine to produce videos (http://www.tltc.uci.edu/video_01.html) and for video teleconferencing (http://www.tltc.uci.edu/vtc_01.html). The facilities that are immediately available for our use include the video teleconferencing room (Anteater Instruction and Research Building, room 3030), and desktop video teleconferencing using MSN Messenger and iChat ($30 per hour). We believe that these resources will ensure that all funded REGM fellows are knowledgeable about the overarching issues on green materials as they pursue their focused research projects.

Green Engineering: Theory and Practice

Multi-campus Course Video-cast

Winter Quarter 2009

Course Registration Code: ECM289

Instructor of Record:

Professor Julie M. Schoenung
Department of Chemical Engineering and Materials Science
2017 Kemper Hall
University of California, Davis
Phone: 2-5840
E-mail: jmschoenung@ucdavis.edu
Office hours: by appointment

UC-Riverside Coordinator: Professor David Eastmond (Eastmond@ucr.edu)
Environmental Toxicology Program, UC Riverside.

UC-Irvine Coordinator: Professor Oladele Ogunseitan (Oladele.Ogunseitan@uci.edu)
Program in Public Health, and School of Social Ecology,
UC Irvine.

Objectives: Study of the methods and impacts of selecting alternative technologies, processes, materials, chemicals, and/or products so as to reduce the pollution, waste and the use of toxic substances, thereby creating "green," environmentally responsible, and sustainable solutions. Topics include environmental regulations, recycling, life-cycle assessment, economic analysis, design-for-the-environment, green chemistry and toxicology.

Course Details:

Class meeting time: W 1:10-2:00 PM, F 1:10-3:00 PM

Locations: Olson 230 (at UC Davis)

UC Irvine – Real-time Interactive Video

3003 Anteater Instruction and Research Building

UC Riverside – Real-time Interactive Video

Texts: Select journal papers and other readings will be required.

Prerequisites: Graduate level standing in engineering, science or related field; or permission of instructor. Computer skills including word processing, spreadsheets, and PowerPoint.

Grading:

Attendance and Participation	20%
Midterm Exam	30%
Term paper and presentation	50%

Topics:

Week-1	Introduction
	What Does 'Green' Mean?
	The Design Process; Products, Processes, Substance (Materials, Chemicals)
Week-2	Industrial Ecology
	Pollution Prevention, Design for the Environment, Design for X
Week-3	Green Chemistry and Green Engineering
	Toxicology, Exposure, Risk (Health Risk Assessment)
Week-4	Environmental Law
	P2 Economics, Time Value of Money, Environmental Accounting
Week 5	Life Cycle Assessment
	Streamlined LCA
	Normalization and Weighting
Week 6	Cost-Benefit Analysis
Week 7	Measures of Toxicity
Week 8	Human Toxicity Mechanisms
Week 9	Ecotoxicology
Week 10	Assessment Methods and Tools (Integrated throughout the courses)
	Input-Output Analysis
	Materials Flow Analysis
	CES Eco-Selector
	EPA Tools
	Ecoindicator
	Toxicity Potential Indicator

Participating Faculty Speakers:

Dr. Andrew Shapiro (Jet Propulsion Laboratory and UC Irvine)
Prof. Alissa Kendall (UC Davis)
Prof. Debbie Bennett (UC Davis)
Prof. Jean-Daniel Saphores (UC Irvine)
Prof. Kent Pinkerton (UC Davis)
Prof. Dele Ogunseitan (UC Irvine)
Prof. Dave Eastmond (UC Riverside)

Course Policies:

1. Attendance is required and contributes to the course grade.
2. The UC Davis Code of Academic Conduct will be strictly enforced (see http://sja.ucdavis.edu/sja/cac.htm).
3. It is expected that students will abide by the UC Davis Principles of Community (see http://www.ucdavis.edu/principles.html).

Video-casting made possible by the Lead Campus in Green Materials, UC Toxic Substances Research and Teaching Program.

http://www.industrial-ecology.uci.edu/Green-Materials.html

TMS

February 26, 2008

Oladele A. Ogunseitan, Ph.D., M.P.H.
Professor
Program in Public Health
College of Health Sciences
and
Professor of Social Ecology
University of California
Irvine, CA 92697-7070
USA

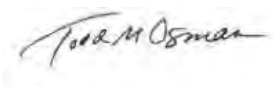
Dear Dele:

The Minerals, Metals, and Minerals Society (TMS) would like to endorse your proposal to establish a Center of Excellence in Green Materials and Pollution Prevention. TMS is a professional society with the mission to promote the global science and engineering professions concerned with minerals, metals, and materials. It comprises over 11,000 members representing industry, academia, and government. In fulfilling its mission, TMS holds meetings, publishes journals, provides continuing education, maintains a vital web presence, and liaisons with other technical societies and organization around the world.

As part of its Materials and Society Initiative, TMS seeks to promote the engagement of the scientific and engineering communities in solving the real problems facing mankind. Materials and society are intertwined. Materials are enablers, allowing humankind to shape the globe. Civilizations have been built upon materials, from the "Stone Age" through the "Iron Age" through the current "Silicon Age". In the past, the focus has been on the consumption of materials. Our future, however, must focus on the conservation and wise use of materials.

The UC Irvine-Davis-Riverside consortium is well-positioned to promote awareness, increase scholarship and advance technical solutions for the green materials production and environmental stewardship. I applaud your efforts and look forward to working with you as we address these critical issues facing our profession and society as a whole.

Sincerely,



TODD OSMAN, PH.D.
TMS TECHNICAL DIRECTOR

February 25, 2009

Oladele A. Ogunseitan, Ph.D., M.P.H.
Professor
Program in Public Health
College of Health Sciences
and
Professor of Social Ecology
University of California
Irvine, CA 92697-7070
USA

Dear Dele:
On behalf of Henkel Corporation, I would like to extend my endorsement and support for your proposal to bring together the collaborative efforts of the University of California campuses' research and education programs in green and sustainable materials, with the goal of establishing a Center of Excellence in Green Materials and Pollution Prevention. Henkel Corporation is a multinational supplier of materials for consumer and industrial applications. We have over 55,000 employees globally, with a clear vision to bring value to our customers through innovative materials design. As a core value, Henkel has placed sustainability at the forefront of its development activities. We have been recognized as a sector leader in the Dow Jones Sustainability Index (DJSI) for 2007-08, we are 1 of 50 companies worldwide to participate in the Global Challenges Index, and we were recognized by the ECPI Ethical Index EURO & GLOBAL for 2007.

As part of its sustainability initiative, Henkel has committed itself to providing products with improved sustainability, with corporate social responsibility in mind. We have set metrics to not only improve the sustainability of our operations, but to provide products to our customers that support their sustainability initiatives. As part of Henkel's new product development process, each new material and process is subject to a sustainability risk assessment, which is the basis for sustainability improvement. In order to deliver on this initiative, it is imperative that intuitive measures for comparative toxicity of alternative materials are developed, and that assessment metrics to measure the trade-offs among material toxicity indices, product performance and reliability, economic costs, component recyclability, and potential ecological impacts are developed. Without these tools, the measure of sustainability for new materials development is left to subjective differentiation.

The UC Irvine-Davis-Riverside consortium is well-positioned to help develop these much needed tools to assess materials sustainability, as well as promote awareness of sustainability and pollution prevention through education and industrial interaction. I applaud your efforts and look forward to working with you as we address these critical issues together.

Michael Todd
Vice President, Product Development and Engineering
Henkel Corporation
Electronic Materials

Michael Todd
V.P. Product Development
Henkel Electronics

Henkel of America, Inc.
15350 Barranca Parkway
Irvine, CA 92618
USA

Phone: 949-789-2500
Fax: 949-789-2595

Michael.todd@us.henkel.com
www.henkel.us

SANYO Commercial Solutions
Toshiaki Inoue, President
Tel: 800-858-8442 / Fax: 630-238-0074
www.sanyocommercialsolutions.com / E-mail: tinoue@sss.sanyo.com

February 24, 2009

Dear Dele,

SANYO Commercial Solutions is honored and pleased to be invited to support the University of California's Green Materials research and advisory program and we formally accept the invitation to serve as a board member. We believe this to be an exceptional opportunity to provide mutually beneficial research and development, leadership and insights on sustainable initiatives for future generations.

'Think GAIA' is SANYO's pioneering Brand Vision which aims to create solutions for a sustainable Earth by synergizing SANYO's core technologies. SANYO views the world as a single living organism and this conviction guides its constant innovation of new products which promote environmental sustainability and societal values. 'Think Gaia' a threefold approach for product development, consisting of action on the Environmental, Energy and Lifestyle fronts. In each of these fields, SANYO redefines conventional ideas and takes a radically new perspective, taking advantage of its unique technological resources and know-how to propose global solutions for life and the Earth. Focused green product development areas include rechargeable batteries and devices, electric bicycles, solar panels and rechargeable infrastructure, energy saving HVAC systems, and energy efficient biomedical laboratory equipment, all which ultimately will reduce lifecycle costs and lessen our global carbon footprint.

'Gaia' is a world rapidly taking hold in the 21st century, which describes the world as a single living organism, where all life and nature co-exist interdependently. Guided by the keywords 'symbiotic evolution' and 'sustainability' and equipped with world-leading technologies, SANYO's ultimate goal is to restore a beautiful Earth to future generations, which is in line with the goals and propositions of the UC Irvine Center for Excellence in Green Materials and Pollution Prevention. We look forward to many successful collaboration together and applaud your forward thinking initiative in this very important area.

Kind regards,

Toshiaki Inoue, President
SANYO Commercial Solutions