So Cal Research Initiative for Solar Energy
Solar Energy Research, Demonstration, and Training

May 15, 2009

Overview

Global interest in alternative energy is rising rapidly. The University of California, Riverside, the City of Riverside, and our partners propose to facilitate the development and application of solar energy by establishing the Southern California Research Initiative for Solar Energy (SC-RISE) to:

- **Train** electrical technicians, end users, college students, and the public about solar energy concepts, installations, maintenance, and operations.
- **Demonstrate** and assess new technologies, and help end users identify the best applications of solar energy to their needs.
- Conduct **research** in collaboration with government agencies and industry to advance the state of technology in photovoltaic electricity and other renewable energy concepts.

Because of its nature and scope, SC-RISE will be the first of its kind – and it will establish alliances with complementary institutions to enhance credibility and avoid redundancy. This initiative will fill a critically needed role as a trusted resource for information on the state of solar technology, the technical and economic feasibility of solar installations, and the benefits (Figure 1). We propose to base SC-RISE at the University of California, Riverside, Bourns College of Engineering-Center for Environmental Research and Technology (CE-CERT). CE-CERT has ample facilities and well established credentials in alternative energy and environmental protection. SC-RISE will continue CE-CERT's tradition of serving as the "honest broker" in the development and assessment of new technologies.

CE-CERT will provide facilities, and UCR will provide a base level of staff support. Public and private utilities, industry, trade organizations, unions, and other academic institutions will become members of SC-RISE. As members, they will guide the initiatives and benefit from its services. Our vision is that this collaborative effort will accelerate the adoption of solar technologies for appropriate uses in California and around the world.

In the following pages, we describe the need for SC-RISE, the vision, the agenda and goals, and our implementation plan.

Unions / Trade Assns.
- Installation training
- Maintenance and operations training
- Worker retraining

Alternative energy developers
- Collaboration on new technology with academia and government
- Reliable evaluations

Utilities
- Technology assessments
- Resource to assist customers in energy decisions
- Future employees
- Life-cycle analyses

Academic institutions
- Trade/scientific/ professional articulation
- International connections
- K-12 and public outreach

Figure 1. Prospective participants in SC-RISE and the benefits of their involvement.

1. The Need for *SC-RISE*

Today's global demand for energy is approximately 15 terawatts and is growing rapidly. For years we have depended on conventional energy sources such as oil and natural gas, but in recent years their prices have risen dramatically. Further, it is clear that global demand for energy is outstripping mankind's ability to locate and use new sources of fossil fuels. Even if these sources were readily available, the climate impacts of using them could be extremely harmful. As a result, global attention is turning with unprecedented enthusiasm to renewable energy resources – particularly solar energy.

The sun is the most abundant, sustainable sources of energy, providing over 150,000 terawatts of power to the Earth. The sun's energy is free, but harnessing it to produce electricity is not. For example, the typical payback period on today's photovoltaic installation is measured in decades, and government incentives and in the United States rebates play a substantial role in determining the feasibility of investments in solar power generation. In the near future, solar energy will be a rational choice for a wide array of business and household customers, not just for the "early adopters" of new technology and the most environmentally-conscious end-users.

Hence, one of the greatest scientific opportunities of our time is to learn to efficiently harvest, convert, store, and utilize solar energy. In addition, there is a need for a reliable resource that can help government agencies, utility companies, end-users, and the technology community make the right decisions about how to apply solar power economically and efficiently. In the long term, there will be a need for training in operations, maintenance, and eventually decommissioning and recycling of solar installations. SC-RISE will be that resource.

2. Vision, Agenda, and Goals

The vision of SC-RISE is to serve as the “honest broker” for information about all aspects of solar energy. This is a well-established role for CE-CERT, which has built a reputation as a trusted resource for analysis of controversial technologies for reducing air pollution and improving energy efficiency. SC-RISE will fulfill this vision by establishing three programs: training, applications/demonstrations, and research.

2.1. Training

SC-RISE will provide training and other education/outreach services to 1) graduate and undergraduate college students; 2) technicians and other industry practitioners; 3) K-12 students and teachers; and 4) the public. The expertise to provide this training will come from UCR faculty and staff, community colleges, unions, and job training programs.

At the **collegiate** level, UCR already provides nationally and internationally recognized training to graduate and undergraduate students. Degree programs in Electrical Engineering, Environmental Engineering, and Materials Science and Engineering have classroom and research elements in solar energy. Faculty and researcher expertise stretches from the molecular/device level all the way to major studies of systems integration and macroscale impacts of solar energy. Every undergraduate engineering student at UCR is required to complete a capstone design project, and dozens over the past several years have worked on projects involving solar-device design, fabrication, or integration. These activities will only increase as UCR develops an interdisciplinary program in Energy and Power Engineering. UCR faculty and collaborators from other UC campuses, the Florida Solar Energy Center, and Tohoku University in Japan will lead this aspect of SC-RISE programs.

Technician training is already offered by several community colleges, unions, and job training programs in California. Indeed, the pipeline of trained installers already is growing so large that some industry insiders are fearful of a glut. However, the industry has not yet turned its attention to training technicians in how to service, maintain, and eventually decommission solar PV and/or solar thermal systems. This will be an early and unique thrust of SC-RISE. We will work with UCR Extension to establish a certificate program in solar energy, and with collaborators at the Riverside Community College District to provide a venue for technician training. Individual companies or industry consortia can work with SC-RISE to design training programs for installation and support of specific types of installations (e.g., residential, industrial).

At the **K-12** level, UCR is already in discussions with Project Lead the Way (PLTW) about establishing a training site for teachers. PLTW is a non-profit educational organization that provides pre-engineering curriculum to middle schools, high schools, and community colleges. PLTW recently created a 9^{th}-grade curriculum in Power and Energy, which will be offered nationally within the next year or two. SC-RISE will be the ideal setting for providing teachers with the training they need to deliver this curriculum. Additionally, the City of Riverside already has a teacher who visits local school districts to teach schoolchildren about energy. This teacher will be able to draw on SC-RISE resources and could become the summertime trainer for the PLTW curriculum. Another novel link is the **Middle College High School** operated by Riverside Community College. This program enables at-risk students in grades 11 and 12 to take classes at the college, earning high school and college credit simultaneously. This will serve as a pathway for transfers to UCR or other four-year institutions for some of the students, and to the technician track for others.

To serve the **public's** need for information about solar energy, SC-RISE will serve as an ongoing demonstration site (see below) with an organized "discovery center," provide workshops, host exhibits, and maintain a comprehensive web site. We will pursue support from the National Science Foundation (Division of Elementary, Secondary, and Informal Education) for one or more public workshops about the current state of solar energy and the technological and economic outlook.

2.2. Applications and Demonstrations

CE-CERT is uniquely equipped to serve as a facility for demonstrating and evaluating solar energy technologies. We will use our land, rooftop space, laboratories, and experimental equipment including load banks, data acquisition systems, and quality assurance procedures to assess technologies from the developmental stage through commercialization. CE-CERT also is ideally positioned to explore solar applications in the context of broader renewable energy concepts – for example, the use of solar energy to make hydrogen from water, or the integration of biomass conversion and solar-thermal technologies. We will study existing protocols for evaluation of solar and other renewable-energy technologies, propose our own, and collaborate with other academic institutions, industry associations, and government agencies around the world to assure that evaluations are reliable and meaningful.

We also envision SC-RISE as a resource for end-users to study how to incorporate solar energy into their businesses. Southern California Edison's Customer Technology Application Center and Southern California Gas Company's Energy Resource Center are examples of how utilities work with customers to identify the most efficient solutions for their needs. CE-CERT has a parallel track record, for example, having worked with fast-food companies to evaluate the energy consumption and emissions of different grills for their kitchens. SC-RISE will collaborate with member utility companies (investor-owned and municipal) to help their companies evaluate the best ways in which to invest in solar energy for maximum benefit.

CE-CERT already has a track record in solar energy research. CE-CERT was one of the first research labs in the world to create a sustainable solar hydrogen research facility in 1993 (see Figure 2). This system utilized a 3.5 kW photovoltaic array to generate electricity. The electricity in turn was used as part of an electrolysis process to create hydrogen, which was then stored at high pressure and subsequently used in a hydrogen vehicle refueling station. This system operated successfully for several years before it was decommissioned.

Figure 2. CE-CERT solar hydrogen research facility and hydrogen vehicle refueling station.

CE-CERT has also participated in a long-term study on the effects of air pollution (i.e., smog) on photovoltaic efficiency. By simultaneously measuring pollutant and visibility levels along with the PV power output, it was found that even heavy atmospheric haze has only a small effect on PV efficiency (i.e., less than 5%). CE-CERT is equipped with one of the world's largest indoor atmospheric research chambers (Figure 3), where it is possible to precisely control conditions including insolation, temperature, and humidity for evaluations of solar panel performance.

Figure 3. CE-CERT's atmospheric chamber is one of the world's largest indoor facilities where illumination, temperature, and humidity can be controlled.

CE-CERT has recently developed a solar powered electric vehicle, as shown in Figure 4. This is a Neighborhood Electric Vehicle (NEV) and has been converted for solar operation. As a model system, this NEV solar testbed vehicle is being used for initial research and development for a larger research program in solar vehicles. With a 375 Watt PV array on top of the vehicle, this vehicle can charge while it is outside in the sun and then be operated for its approximate 25 mile range. It has an advanced solar controller for optimal charging efficiency.

Figure 4. CE-CERT solar testbed vehicle.

We intend to continue this track record of solar energy research, examining and demonstrating a variety of applications at the CE-CERT facilities. In addition, it is envisioned that several of the mature alternative energy systems could be located at different locations across the UCR campus.

2.3. Cutting-Edge Research

Solar energy research is under way at universities, national laboratories, and innovative companies around the world. UCR is engaged in solar energy research from the device scale (that is, the fundamental materials and configurations to move a single electron) to integration (for example, a solar-boosted electric vehicle as described earlier). In collaboration with partners around the world, we will continue our work to advance the state of fundamental technology in solar energy, specifically in greater efficiency and lower cost. We will work with our partners to accelerate promising technologies toward commercialization – the member-based framework of SC-RISE will be well-suited to this. And we will collaborate with colleagues around the country and around the world to share knowledge, educate students, and provide needed improvements in solar energy.

Our five-year goal for SC-RISE is to have a facility with at least one megawatt of installed solar panels, producing electricity and providing a testbed for training, demonstration, and research. In addition, we are currently in discussions with a start-up company, Terrafore, Inc., in the initial designs of an intermediate-scale solar thermal plant. With both of these systems, we will be able to integrate new technologies (e.g., new materials, sun-tracking technology, concentrators) and accurately measure the effects on electricity output. We also will be able to measure the effects of heat, dust, pollution, moisture, and time on PV panel and/or concentrator output.

A few examples of UCR's existing solar energy research are as follows:

High Performance Solar Cell Research—Professor Alex Balandin and his colleagues are developing high performance solar cells based on quantum dot superlattices (see, e.g., Bao et al., 2004). These new solar cells are targeted for space applications, where photovoltaic efficiency must be as high as possible. An example of the superlattice structure is shown in Figure 5.

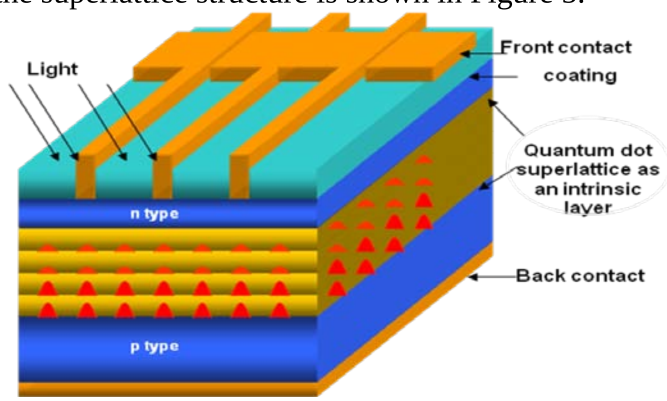

Figure 5. Superlattice structure for the high performance solar cell.

This research team continues to improve overall efficiency of this new solar cell, by: 1) tuning the effective band-gap in the structure and using tandem designs; 2) using a three-level concept to improve intermediate band assisted absorption; 3) improving the overall radiation hardness; and 4) extending the overall thermalization times.

Low Cost Organic Solar Cell Research—In addition to the high performance solar energy technology research based on silicon cells, Professor Mihri Ozkan's research team is exploring lower cost plastic organic cells (see, e.g., Chaudhary et al., 2007-2008). Figure 6 depicts the performance of their latest hybrid polymer-carbon nanotube solar device fabricated in their laboratory. Layer by layer deposited active layer materials and electrode materials of this solar device has a total thickness of about 2 μm and can be deposited on hard or flexible substrates. The current versus voltage plot of this solar device shows increase in the output current under AM 1.5 sun exposure (see Figure 6).

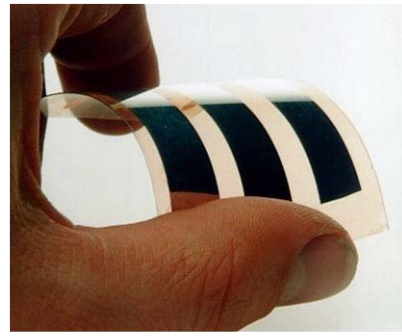

Figure 6. Performance of hybrid polymer-carbon nanotube solar device fabricated in UCR. Device parameters such as open-circuit voltage, short-circuit current, fillfactor and device efficiency are listed for different devices with varying carbon nanotube content. Picture shows that these devices can be fabricated on flexible substrates as well.

Nanowires for Multi-Junction Solar Cells—Professor Cengiz Ozkan and colleagues are working on large-area solar cells based on nanowire arrays embedded in hole-conducting polymers (Figure 7). The nanowires will enable solar devices to absorb a greater range of the solar spectrum. Nanowires provide a much more efficient way for solar energy conversion via its small lateral dimension (10-200 nm) and large surface area, which enables a highly efficient collection of electrons at the nanowire-polymer interface, whereas their greater length (several microns) will enable maximized absorption of photons. We expect that within the next several years, we can achieve a conversion efficiency of 20%. By December 2008, we will initiate the fabrication of wafer-scale nanowire based devices on conventional silicon and glass platforms using a new metal-organic chemical vapor deposition (MOCVD) system at UCR, which will be crucial for low-cost and large-scale fabrication of solar devices.

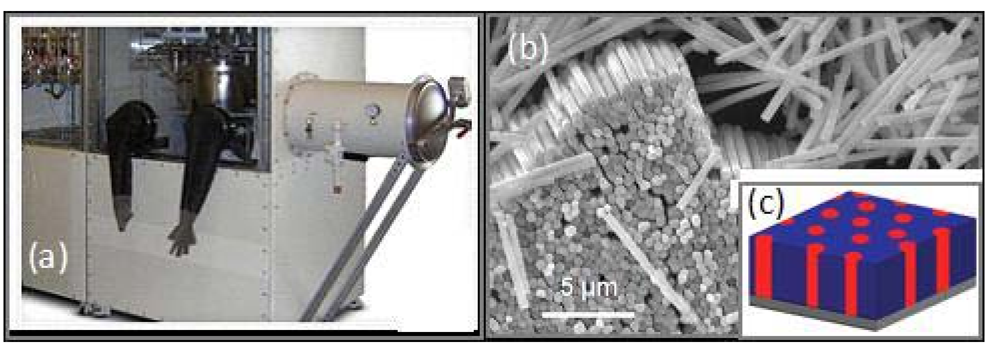

Figure 7. (a) Metal-organic chemical vapor deposition (MOCVD) system purchased from ATOMET Corporation will be used in fabricating the large area nanowire solar device platforms. (b) Free-form produced III-V group nanowires at UCR. (c) illustration of a vertical nanowire array embedded in a polymer matrix such as P3HT.

Additionally, SC-RISE will have comprehensive and easily accessible databases and library resources available through a web site in English and possibly other languages. SC-RISE will be recognized as a trusted resource for training, evaluation, assessment, and new ideas in solar energy.

3. Management and Organization

The management structure of SC-RISE will reflect the needs and priorities of its various members. Figure 8 presents a preliminary organizational structure for SC-RISE. Key elements of the organizational structure include the following:

Director: The Director will hold an academic or research appointment at the University of California, Riverside. The Director will report to the Director of CE-CERT and to the Dean. The Director will have overall responsibility for the management and operations of SC-RISE. The Director will oversee staff dedicated to administering SC-RISE resources, including experimental infrastructure, demonstration facilities, and on-line references. The Director and staff will coordinate research projects involving international collaborators, U.S. collaborators, postdoctoral researchers, visiting industry researchers, students, and trainees.

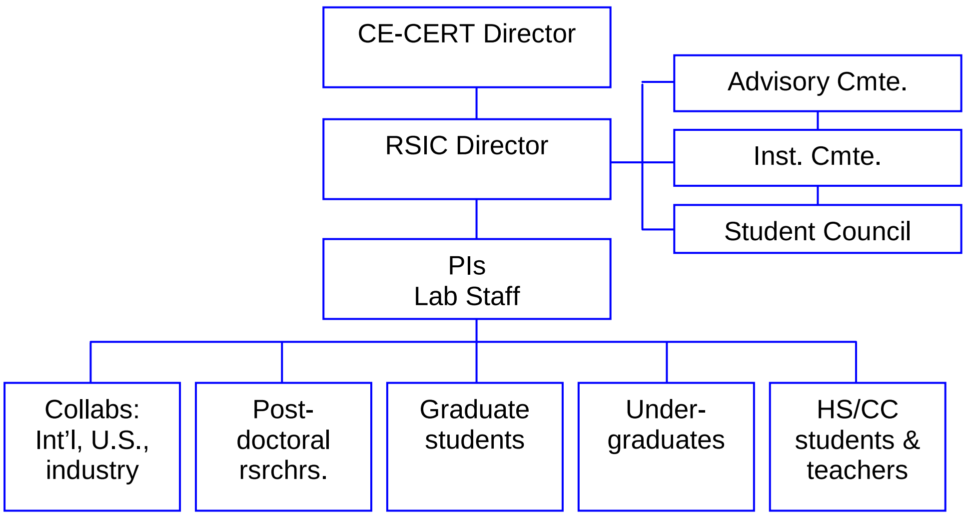

Figure 8. Preliminary organizational structure for SC-RISE.

Advisory Committee: Every member of SC-RISE will have a seat on the Advisory Committee. Additionally, seats on the Committee are reserved for the Riverside Mayor's Office, Riverside Public Utilities, Tohoku University, Sendai City, and a student representative. Initially, the committee will meet formally at least once a quarter and via web-conference or conference call informally approximately once per month. The committee will review the strengths, weaknesses, opportunities, and threats. It will advise the Director on the strategic direction for SC-RISE. Committee members also will have an important role in SC-RISE outreach to potential stakeholders and prospective new members.

Institutional Oversight Committee: Members will include the Dean of the Bourns College of Engineering, the Chancellor of UC Riverside, and the Vice Chancellor for Administration, who oversees the campus sustainability and energy management programs. This committee will review the academic, research, and financial status of SC-RISE once or twice per year. The committee will identify ways of assuring that SC-RISE has the resources it needs to remain at the forefront of solar energy research, and it will seek links with other research initiatives on campus, elsewhere in the UC system, and elsewhere in the academic world.

Student Council: Graduate and undergraduate students associated with SC-RISE will have a Student Council to represent student needs and priorities within SC-RISE. This council will collaborate with stakeholders, professional societies, and workforce development organizations. One representative from the Student Council will be appointed to the Advisory Committee.

Individual Investigators and Research Groups: Individual investigators and teams will lead specific projects under the umbrella of SC-RISE. We envision that most of the researchers will be full-time professors at UCR, although some full-time researchers with PI status will be involved.

4. Implementation Plan

The vision for the SC-RISE calls for us to be an internationally recognized resource within five years. Figure 9 summarizes the resources that we will bring to bear, and the following discussion describes the planned timeline and expected financial requirements.

	Training	Demon-stration	Protocols	Research/ Devt.	Personnel	Commer-cialization
UCR	✸	✸	✸	✸	✸	✸
Florida Solar Energy Center (proposed)		✸	✸	✸	✸	✸
Tohoku University, Japan (in progress)				✸	✸	✸
Labor unions and agencies	✸		✸		✸	
DOE, DOD, National Laboratories	✸	✸	✸	✸		
PV manufacturers		✸	✸			✸
PV retailers/installers	✸					✸
Other renewable energy companies		✸	✸	✸		✸

Figure 9. Resource integration plan for SC-RISE.

- **Year 1: Startup.** In 2009, SC-RISE will formalize collaborative relationships with the Florida Solar Energy Center[*] and Tohoku University[†] in Japan. We will inventory the databases, training programs at all levels, research resources, and other resources to provide an integrated picture of the resources of SC-RISE and its collaborators. With this, we will consult with our members to identify needed investments to support the mission of SC-RISE, and we will secure those resources. We will convene an initial stakeholders meeting and formalize the operating plan. We will identify and engage full-time, permanent staff. We will establish the web site and on-line database repository. We will accredit our processes, enabling us to certify photovoltaic, concentrated PV, and solar thermal technologies. In addition, we will continue our collaboration with Terrafore, Inc., on 1) solar thermal storage techniques; and 2) the design and implementation of an intermediate-scale solar thermal electricity plant, to be demonstrated on CE-CERT's property.
- **Year 2: Operation.** SC-RISE will provide resources for current solar energy research at UCR. We will provide resources to researchers from UCR and our partner to seek additional projects supported by Government agencies and industry. We will begin developing curriculum for a UC engineering sequence in power and energy.

[*] The Florida Solar Energy Center is a 30-year-old operation of the University of Central Florida. Established by the Florida Legislature, this large center (~150 employees) has a mission similar in scope to SC-RISE, but with a greater emphasis on applications and less on materials and devices.

[†] Tohoku University is one of the world's leading research universities for photovoltaic devices. The university is in Sendai, Japan – Riverside's sister city. UCR and Tohoku have established some collaborations and have identified solar energy as a field for further collaboration.

- **Years 3-5: Ongoing Operations and Expansion.** Years 3-5 will involve building and refining the programs in training, demonstration, and research of SC-RISE. We anticipate steady growth in membership and increasing impact as we leverage resources from the different thrust areas and the multiple members.
- **Finances.** Pending the inventory of resources, we estimate that start-up costs will be approximately $1 million (cash and in-kind), and ongoing operating costs will be approximately $600,000 per year. This includes funding for one managing director (staff), two dedicated postdoctoral researchers, one support staff position (library, database, web site, events), and a discretionary research budget. Travel for exchanges with Tohoku University and the Florida Solar Energy Center will be needed. Beginning in year 2, a presence at international solar energy conferences will be necessary, and in time perhaps SC-RISE will sponsor its own annual conference.

5. Key Research Personnel and Contacts

Professor Matthew Barth, Director of CE-CERT, will lead the establishment of SC-RISE. Other key UCR faculty members who are involved in solar energy research, and who will be involved in SC-RISE, include the following

Name	Department	Other Affiliations		
		Ctr. For Nanoscale Science and Engineering	Materials Science & Engr. Program	CE-CERT
Barth, Matthew	Electrical Engineering			✷
Balandin, Alexander	Electrical Engineering	✷	✷	✷
Bufalino, Charles	CE-CERT			✷
Dames, Chris	Mechanical Engineering	✷	✷	
Farrell, Jay	Electrical Engineering			✷
Haddon, Robert C.	Chemica/Envir. Engr.	✷	✷	
Kisailus, David	Chemical/Envir. Engr.	✷	✷	
Lake, Roger	Electrical Engineering	✷		
Liang, Ping	Electrical Engineering			
Ozkan, Cengiz S.	Mechanical Engineering	✷	✷	
Ozkan, Mihri	Electrical Engineering	✷	✷	
Tan, Sheldon	Electrical Engineering			
Vafai, Kambiz	Mechanical Engineering			
Vullev, Valentine	Bioengineering		✷	
Xu, Daniel	Electrical Engineering			
Zaera, Francisco	Chemistry	✷		

Other affiliates:

- Terrafore, Inc.
- City of Riverside

References

Y. Bao, A.A. Balandin, J.L. Liu and Y.H. Xie, “Experimental investigation of Hall mobility in Ge/Si quantum dot superlattices,” *Applied Physics Letters*, 84: 3355 (2004).

Chaudhary S, Müller AM, Huang W, Al-Kaysi R, Bardeen CJ, Ozkan CS and Ozkan M, “Effects of Solvent and Annealing on Photophysical Properties of Polythiophene Photovoltaic Cells”, *Advanced Science Letters* (in press) (2008)

Chaudhary S, Lu H, Müller AM, Bardeen CJ and Ozkan M, “Carbon nanotubes in polymer:fullerene solar cells: Hierarchical Assembly Realized and Functionalities Revealed”, *NANOLetters* (2007)

H.Lu, S.Chaudhary, A.Muller, C.Bardeen, M.Ozkan, “Effects of mild plasma exposure on the active-layer in polythiophene:fullerene bulk-heterojunction solar cells,” *J. Nanoelectron. Optoelectron*. 2, 282–286, (2007)

S.Chaudhary, M.Ozkan, '”Self-organization dependent emission of luminescent polymers in nanoporous alumina templates,” *J. Nanoelectron. Optoelectron*. 2, 278–281 (2007)