University Research in Thin Films

and the

Development of an Industry Cluster in Renewable Energy in the Toledo Metropolitan Area

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The development of unique capability at The University of Toledo, combined with forward-looking business development efforts, are providing the seed to build Toledo into one of the nation's leading areas in the newly emerging renewable energy industry. This summary explains what has been accomplished, and projects what may be possible through continued development and investment. This investment is in the area of thin films. One of the major areas of technology to grow from this work is in photovoltaics. These are solar cells that convert solar energy directly into electricity. Solar cells have been investigated since the 1970s, but improvements in technology and manufacturing are leading to their introduction into various markets. It is expected that this form of clean electricity will grow into a major industry in the coming decades. The University of Toledo, with its local industrial partners, is positioning itself to become a center for this new industry.

From left to right, Drs. Xunming Deng, Alvin Compaan and Randy Bohn

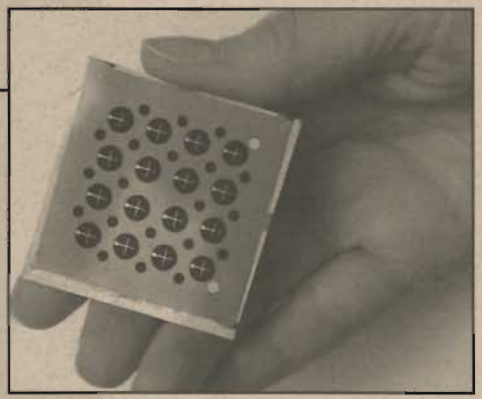
From left, Dr. Alvin Compaan and Dr. Xunming Deng with solar shingles from an industrial collaborator

Representative Marcy Kaptur has embraced this vision by placing her support behind a new initiative to bring this technology to applications of interest to the Department of Defense.

THE DEVELOPMENT OF THE CORE PHOTOVOLTAICS EFFORT AT UT AND NORTHWEST OHIO

The genesis of the program in renewable energy can be traced to the hiring of Professor Alvin Compaan by the Department of Physics and Astronomy in 1987. Within two years, UT won two Edison program awards. The first Edison award to UT in 1989 was an Edison Class I Development Agreement for $50,000 with 1:1 matching funds from Solar Cells Inc. for the period 6/19/89 to 6/19/90 for a project "Laser Processing for CdTe Solar Cells."

The second Edison award to UT was an Edison Class II Seed Development Agreement for $250,000 matched 1:1 by Glasstech Inc. for the period 6/27/89 to 9/30/91 for the project "Advanced Processing for Thin Film Solar Cells on Glass."

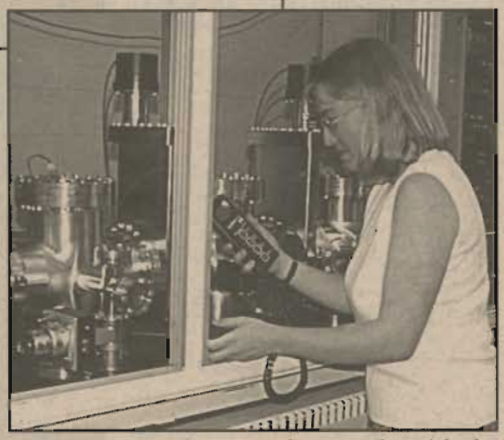


Shown above, an array of solar cells on flexible stainless steel

This relatively modest original investment by the State of Ohio through its Edison program has been very successfully leveraged by federal funds coming directly to The University of Toledo and also to Solar Cells Inc. of nearby Perrysburg, Ohio. In 1989 Compaan organized and authored a successful collaborative proposal with Solar Cells Inc. to the U.S. Department of Energy's Solar Energy Research Institute. This led to the first award in a line of continuous funding from the U.S. Department of Energy to UT and Solar Cells Inc. to support the development of novel approaches in the conversion of sunlight to electricity. Because of the magnitude of this multiyear award, and significance of the involvement of both parties, the funding for the award was split after the first year into separate awards to UT and SCI. Thus, the Ohio Department of Development funding assisted The University of Toledo to establish its photovoltaic program and helped Solar Cells Inc. win its first federal contract. Recently the state and federal funds have been leveraged by private investment capital in the transition of SCI into First Solar, LLC, and the construction of a solar module manufacturing plant that is likely to become the world's largest.

Building upon its growing program, in 1996 UT attracted a distinguished scientist, Dr. Xunming Deng, from ECD in Troy, MI, to join the Physics and Astronomy faculty. The availability of a major, state-of-the-art thin-film deposition system (the plasma-enhanced chemical vapor deposition system purchased with the Edison type II grant) was a major factor in Deng's decision to select Toledo. Professor Deng has played a key role in the growth and expansion into new areas of UT's PV program.

Together Profs. Deng and Compaan lead research on two of the three thin-film semiconductor materials classes (amorphous silicon and cadmium telluride) that are predicted to be economically successful in the solar electric power market. This gives UT a



A graduate student works with the plasma-enhanced chemical vapor deposition (PECVD) system.

leadership position in basic research on thin-film photovoltaics, and the availability of strong local industrial collaborations are helping to develop the technology for the marketplace. The federal funding awarded to UT through calendar year 2001 for solar cell (photovoltaics) research exceeds $4.7 million. Thus, by the end of these awards the State of Ohio contributions will have been leveraged with federal money by the ratio of 16:1.

In addition to receiving venture capital funding based upon the promise of its technology, First Solar has received at least $12 million in federal R&D funds (not counting SBIR awards) for the development of this technology. Thus, the State of Ohio DOD (Edison) monies played some role in attracting additional federal funds to local industry with an additional leveraging factor of 40:1 through FY00. In addition to the attraction of federal funds into the private sector in Northwest Ohio, First Solar maintains a payroll of 142 employees. These employees include two UT physics Ph.D. students and one physics M.S. student. In addition, three graduate and undergraduate student interns are also currently employed by First Solar on a part-time basis.

Rep. Marcy Kaptur held a press conference at UT to announce an appropriation from the Department of Defense to the UT photovoltaics program.

Thus the ODOD money has helped to establish a start-up company in a new high-tech field that has been growing at 30% per year for the last three years. The First Solar manufacturing plant is expected soon to have the largest volume of photovoltaics production of any plant in the world. Its close ties to faculty, laboratories, and students at The University of Toledo will help First Solar stay at the forefront in the development of this new research-based industry.

EXPANDING THE UT PV RESEARCH IN NEW DIRECTIONS

Up to now, the UT photovoltaic research has focused on terrestrial applications of solar cells with its funding primarily provided by the federal National Renewable Energy Laboratory. On November 27, 2001, Rep. Marcy Kaptur held a press conference at UT to announce an appropriation from the Department of Defense to the UT photovoltaics program. The UT PV research will receive $1.0M from DOD's DARPA program in the current budget. This announcement signals a major expansion of the UT research effort into a variety of applications for light-weight solar cells of much interest for aerospace and expeditionary operations. The combination of low mass and flexible cells opens up major opportunities in new applications for solar power and also can lead to major advantages in large-scale manufacturing. Solar power is on the verge of playing a significant role in helping the U.S. reduce greenhouse gas emissions while reducing its dependence on imported oil.

SOLAR HYDROGEN FROM PV AND THE TRANSPORTATION CONNECTION

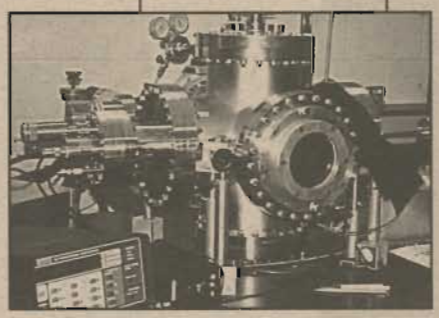
About two years ago, researchers at the University of Hawaii and at the National Renewable Energy Laboratory recognized that the triple-junction, tandem solar cells fabricated by Dr. Deng were almost ideal for efficient generation of hydrogen from water. Since 1999, the U.S. Department of Energy through the University of Hawaii has supported Deng's research with a total of $96,000. This year the General Motors Warren Research Laboratory has provided funds to Deng's group to explore photo-electrochemical generation of hydrogen. GM scientists are excited by this new technology which they say holds great promise for the development of non-polluting sources of hydrogen for combustion engines and especially for fuel-cell electric vehicles. Using solar cells for hydrogen generation would allow for fully zero-emission transportation.

THIN FILMS FOR FLAT PANEL PLASMA DISPLAYS

As UT has built the instrumentation and personnel infrastructure for thin-film photovoltaics, opportunities have opened in a variety of related fields. One of these is in flat panel displays. Specifically, UT has been collaborating with the Toledo-area company, Electro Plasma Inc. in the advanced development of *color plasma display panels* (PDPs). Thin-film coatings are critically important in helping to lower the power consumption and increase the brightness of PDPs. EPI and its corporate partner LG Electronics are working to improve on their prototype, large-area (~60 inch diagonal) plasma display and the UT group is an active participant. EPI has funded the UT effort with more than $220,000 in the past three years. In addition to the PV infra-structure, this collaboration was facilitated by an Ohio Board of Regents Research Challenge award of $30,000 in 1994. This technology has the potential to become a major consumer product in the area of HDTV and the UT-EPI collaboration has the potential to develop into a major research cluster. By agreement, the manufacturing of consumer PDPs will be controlled by the Korean firm but a wide variety of specialty markets are available to be developed by Toledo-based EPI.

FOCUSING INVESTMENT AT THE UNIVERSITY OF TOLEDO

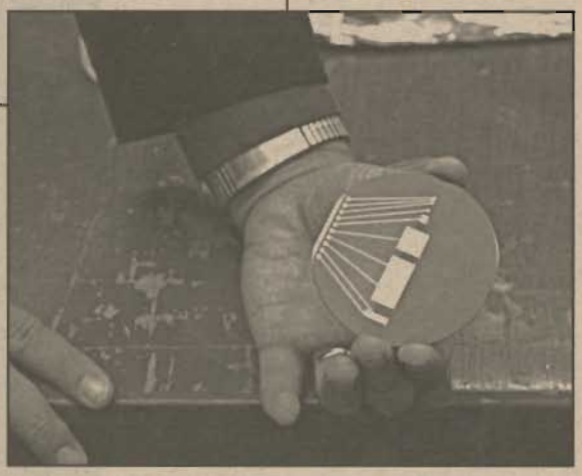
In early 2001, The University of Toledo completed an assessment of areas of research strength at the University as a basis for investment into programs that will emerge as nationally recognized centers of excellence. The Advanced Films and Coatings program received this recognition. As a result of this, the University sought congressional funds in support of its programs and is developing a new research position (using Research Challenge funds) in the area. The congressional initiative has already resulted in the awarding of the $1M announced by Rep. Kaptur.



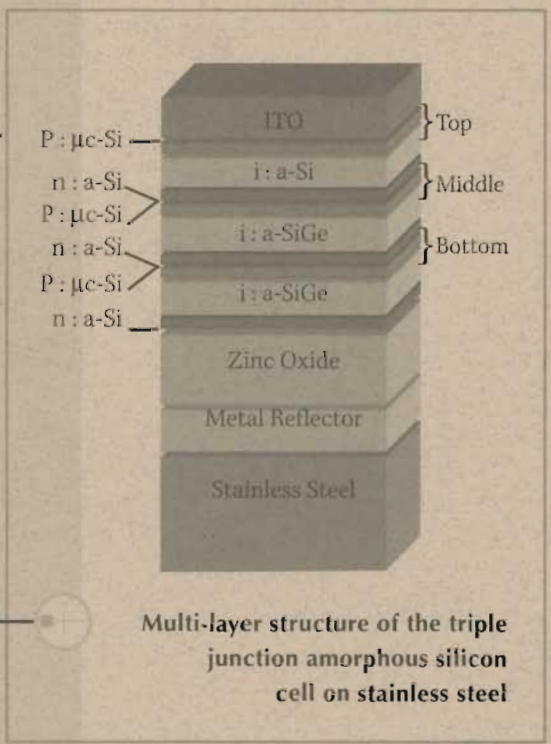
Above, the magnetron sputter deposition system

Above, the DC sputter metallization system

A graduate student operates the solar simulator used for solar cell testing.



Amorphous silicon charged particle detector test structure



Multi-layer structure of the triple junction amorphous silicon cell on stainless steel

OTHER SPIN-OFF RESEARCH AND COLLABORATIONS

Recognizing the need to move the nation away from a reliance on petroleum from Southwestern Asia and other politically unstable areas, the nation is searching for domestic alternatives for heating, electricity generation, industrial use, and most importantly vehicle use. Proposals under consideration include the opening of environmentally sensitive areas for energy exploration and production, the increased use of coal, and the development of new technologies to use coal in a cleaner, more environmentally benign manner. Even though the U.S. has received criticism from other nations because of its position with respect to greenhouse emissions, the nation is continuing its search for ways to satisfy domestic energy demand from the most reliable and cleanest domestic sources.

Prof. Compaan has participated in a proposal with a private company to assist in the development of a *micropower source* that uses radioisotopes (alpha or beta emitters) as the energy source rather than solar photons, but retains the cadmium telluride photovoltaic element to convert this energy to electricity. Such a stand-alone, integrated electrical power source can replace conventional batteries for powering microelectronics for military and medical applications.

THE FUTURE

Federal leadership in both the White House and Congress is strongly supportive of the use of fossil fuels. President Bush favors the opening of new areas for gas and oil production, as well as the continued expansion of the use of coal. Senator Byrd, Chairman of the Senate Appropriations Committee, also favors coal and other fossil fuels.

The United States is lonely in the industrialized world in its push for continued fossil fuel production as other advanced nations see great dangers in greenhouse emissions and other externalities from fossil fuel production.

Even the most ardent supporters of fossil fuels recognize that they are "bridge fuels" to the day that supply alternatives are developed. The two major alternatives include nuclear power (fusion, not fission) and solar energy. Toledo is taking the steps today so that the renewable industry will be a major part of its economy, and so that industries and researchers interested in this industry will seek out experts and companies in the Toledo area. In addition, Toledo will forge strong linkages to the automotive industry in the development of solar power and solar hydrogen for vehicles. These vehicles will rely on energy capture and storage systems that will make them independent of gas or oil. This new economy will be large and will continue to expand into new areas of research that uncover new ways to design materials and to manufacture systems to power the nation from the sun's energy.

The University of Toledo is a state-assisted Carnegie Foundation Doctoral/Research University-Extensive located in Toledo, Ohio. The University offers more than 140 programs of study in eight colleges: Arts and Sciences; Business; Education; Engineering; Health and Human Services; Law; Pharmacy; and University College. The University supports 18 Ph.D. programs. With over 800 faculty members and over 20,000 students, the University's annual external sponsored awards is approximately $20 million annually. The University holds title to over 135 domestic and foreign patents and has 40 license agreements for University technology.

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The First Solar manufacturing plant is expected soon to have the largest volume of photovoltaics production of any plant in the world.