Fundamental R&D in c-Si: Enabling Progress in Solar Electric Technology

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With increasing acceptance of photovoltaic (solar electric) energy as a solution to many energy needs of the world, PV production has grown at about 20%/year in recent years. Worldwide shipments of PV modules reached about 400 megawatts (MW) in 2001. Because Si continues to be the dominant technology, solar cell manufacturing using c-Si (single or multicrystalline) has reached new pinnacles. Shipments of solar electric power products based on c-Si materials reached about 320 MW in 2001, representing more than 80% of total solar cell shipments. Because of the increasing demands of PV energy use, much of the current activity in the PV industry is heavily geared for increasing manufacturing capabilities. Nearly all major manufacturers are installing new production lines.

The industry expansion and attempts toward reducing production costs are guiding the production technologies in several directions:

— Development of automated processing-equipment such as infrared furnaces, and wafer/cell handling machines
— Fabrication of crystal-growth furnaces for larger ingots and higher chemical purity
— Sawing (cutting) thinner wafers (faster edge removal for ribbons)
— Encapsulation and module fabrication machines
— Testing and process monitoring instrumentation.

Many of these technologies implement the latest knowledge from fundamental research programs. These areas of science and technology that were topics of discussions in previous workshops include:

— Improved material quality through better thermal profiles and reduced impurity content
— Methods of mitigating deleterious effects of impurities and defects in Si through gettering and passivation
— Metallization techniques, screen printing with finer fingers, and fire-through SiN
— Minimizing the number of process steps.

These technologies are promising >17% solar cell efficiencies in commercial production.

With the tremendous push for manufacturing growth, there is a certain degree of danger in that installing these technologies may prevent the entry of newer scientific results into production. Such a stagnation of technologies can also diminish the interest in fundamental research and may promote a tendency to devote R&D resources to more applied research.

One may ask: have we run out of fundamental research? Clearly, the answer is NO.

The theme of this workshop reflects a need to establish directions for the future R&D—directions that can take Si PV beyond 17%-efficient commercial solar cells to 20% cells and further lower the processing costs.

Some of the important R&D areas are identified and are included in this workshop for further discussions. The various sessions are:

- Advances in rapid crystal growth and material issues
- Wire sawing and future wafering techniques
- Defects/light degradation
- Solar cell fabrication
- Characterization techniques
- Shunting in solar cells: mechanisms and diagnostics
- Hydrogen passivation and processing.

The discussions in this workshop will pave the way for R&D efforts that will enable future progress in the solar electric technology, particularly in Si PV. This workshop provides a forum for informal exchange of scientific and technical information among international researchers and industry representatives. Traditionally, this workshop has helped define the R&D objectives of the NREL/U.S. Department of Energy Silicon program. Attaining the objectives of this workshop is greatly helped by devoted efforts of all participants — many people who help in organizing, planning the program, making presentations, and participating in discussions. The workshop also recognizes the need to involve young scientists who will shape the future of the solar electric discipline. We are particularly thankful to PV companies who have contributed to the Graduate Student Awards; this year, seven students will share these awards.