# A Basic Solar Energy Library for the Optical Specialist

The following is a partial list of the recommended references in the field of solar energy conversion and photovoltaics. These books and other sources can be explored for details on the topics introduced in this brief tutorial.


1. M. A. Green, *Silicon Solar Cells: Advanced Principles and Practice*, Bridge Printery, Sydney, 1995. This book (and any of Green's many articles found in the literature) is a must-read. It also contains useful constants and tables for silicon and a description of texturing the front of a solar cell.

2. American Society for Testing and Materials, *Standard for Terrestrial Solar Spectral Irradiance Tables at Air Mass 1.5 for a 37° Tilted Surface*, ASTM standard E 892, Vol. 12.02, West Conshohocken, Penn., 2002 Annual Book of ASTM Standards. This standard is equivalent to IEC 60904-3 and ISO 9845-1. ASTM standards E 948 and E 1021 are also useful for measurement of the I-V curve and Spectral Response curve, respectively.

3. H. J. Möller, *Semiconductors for Solar Cell*s, Artech House, Boston, 1993. Covers the materials science aspects of solar cells and gives specific examples of technology applications.

4. T. Markvart, *Solar Electricity*, 2nd Edition, John Wiley & Sons, New York, 2000. A more recent work exploring all aspects of solar cells.

5. A. L. Fahrenbrunch, R. H. Bube*, Fundamentals of Solar Cells*, Academic Press, 1983. One of the most comprehensive books on solar cell modeling equations.

6. A. Goetzberger, J. Knobloch, B. Voss, *Crystalline Silicon Solar Cells*, John Wiley & Sons, New York, 1998. This book covers solar cell device equations and characterization techniques. It is written by well-known authors from one of the leading solar laboratories in the world, the Fraunhofer Institute in Freiburg, Germany.

7. J. I. Pankove*, Optical Processes in Semiconductors*, Dover, New York, 1971. This is the classic book that describes the optical aspects of materials and it makes worthwhile reading for anyone in the optical field.

8. *Encyclopedia of Electrochemistry*, Volume 6, *Semiconductor Electrodes and Photoelectrochemistry*, John Wiley & Sons, New York, 2001. This work gives details on the dye-sensitized solar cell. The references therein may be useful for those who want details on photoelectrochemical solar cells.

9. C. Winter, R. Sizman and L. Vant Hull, *Solar Power Plants*, Springer-Verlag, New York, 1991. Details the thermodynamic and practical aspects of solar cells, concentrators, and systems.

10. J. Duffie and W. Beckman, *Solar Engineering of Thermal Processe*s 2nd Edition, John Wiley & Sons, Inc., New York, 1991, pp. 926–931. Covers material on solar energy (thermal and PV) and solar radiation detection.

11. G. Smestad, P. Hamill, "Concentration of solar radiation by white backed photovoltaic panels," *Applied Optics,* **23**, pp. 4394, 1984.

12. G. Smestad, H. Ries, R. Winston, E. Yablonovitch, "Thermodynamic limits of light concentrators," *Solar Energy Materials and Solar Cells,* **21**, p. 95, 1990.

13. G. Smestad, H. Ries, "Luminescence and current-voltage characteristics of solar cells and optoelectronic devices," *Solar Energy Materials and Solar Cells,* **25**, pp. 51, 1992.

14. G. Smestad et al., "Dye sensitized $TiO_2$ solar cells I & II," *Solar Energy Materials and Solar Cells,* **32**, pp. 259, 1994.

15. G. Smestad, "Absorptivity as a predictor of the photoluminescence spectra of silicon solar cells and photosynthesis," *Solar Energy Materials and Solar Cells,* **38**, pp. 57, 1995.

16. G. Smestad, "Demonstrating electron transfer and nanotechnology: a natural dye-sensitized nanocrystalline energy converter," *Journal of Chemical Education,* **75**, pp. 752, 1998. Papers 11–16 may prove helpful in building a more detailed understanding of the aspects of solar cells covered in this tutorial.

17. B. Andresen, R. S. Berry, M. Ondrechen and P. Salamon, *Accounts of Chemical Res.,* **17**, pp. 266, 1984.

18 B. Andresen, P. Salamon and R. S. Berry, *Physics Today,* September, 1984. These articles discuss the general thermodynamics of energy conversion.

19. A. De Vos, *Endoreversible Thermodynamics of Solar Energy Conversion*, Oxford Univ. Press, Oxford, 1992. A mathematical treatment of the fundamental (thermodynamic) aspects of all solar converters. It covers thermal and photo-conversion, photosynthesis, and tandem systems; and it provides useful insights for those who wish to determine the limitations of a given approach.

20. A. Luque, G. L. Araujo*, Physical Limitations to Photovoltaic Energy Conversion*, Adam Hilger, New York, 1990. Researchers at the leading lab in Spain cover thermodynamic aspects of solar conversion. The book has a good section on light concentrators.

21. M. Andreev, V. A. Grilikhes, V. D. Rumyantsev, *Photovoltaic Conversion of Concentrated Sunlight*, John Wiley & Sons, New York, 1997. This book offers a look at materials science aspects of solar cells as used in concentrators. These Russian authors bring together a wealth of information on solar cells from the long history of research in the former Soviet Union.

22. P. Würfel, S. Finkbeiner, E. Daub, "Generalized Planck's radiation law for luminescence via indirect transistions," *Appl. Phys. A,* **60**, pp. 67, 1995.

23. W. T. Welford, R. Winston, *High Collection Non-Imaging Optics*, Academic Press, New York, 1989. This is a good source for optical concentrators from the researchers who invented the CPC.

24. D. Pimentel, G. Rodriguez, "Renewable energy: economic and environmental issues," *Bio. Sci.,* **44**, pp. 536, 1994.

25. J. Turner, "A realizable renewable energy future," *Science,* **285**, p. 687. References 24–25 are good sources for the potential for solar and other renewable energy.

26. E. Martinot, "Renewable energy investment by the World Bank," *Energy Policy,* **29,** p. 689, 2001.

27. N. Myers and J. Kent, *Perverse Subsidies: Tax Dollars Undercutting Our Economies and Environments Alike*, International Institute for Sustainable Development, and Island Press, Covelo, CA, 1998. Covers both energy and transportation, as well as other subsidies.

28. M. Oliver, T. Jackson, "The evolution of economic and environmental cost for crystalline silicon photovoltaics," *Energy Policy,* **28,** pp. 1011, 2000.

29. Useful websites:
National Renewable Energy Laboratory, http://www.nrel.gov/
Renewable Energy Policy Project, http://www.repp.org/

# Index

**Greg P. Smestad** received his Ph.D. in Physical Chemistry from the Swiss Federal Institute of Technology in Lausanne under the guidance of Drs. Michael Grätzel and Harald Ries. He received his M.S. in Materials Science in 1985 from Stanford University and his B.S. in Biology in 1983 from the University of Santa Clara, California. He currently works in the optoelectronics industry.

From 1985 to 1990, Dr. Smestad was employed by the Hewlett-Packard Company, first as a materials engineer, and later as an optics design engineer. From 1990 to 1992, he created and managed the optics lab at the Hahn-Meitner Institute Solar Energy group in Berlin, Germany, and conducted research on iron pyrite photoelectrochemical solar cells. In 1992, he became part of the Solar Chemistry group of the Energy and Process Technology department at the Paul Scherrer Institute in Villigen, Switzerland. In 1994, he was employed by Lawrence Berkeley National Laboratory as an electrochemist and researcher on the topic of electrochromic windows. From 1995 to 2002, he was a professor, first as a chemist at the California State University, Monterey Bay, and then as an energy science-policy specialist at the Monterey Institute of International Studies. From 1996 to 1999, he served as a consultant for Prof. Grätzel at the Swiss Federal Institute of Technology, and from 1990 onward he has served as Assistant Editor for the Elsevier journal *Solar Energy Materials and Solar Cells*.

Dr. Smestad has also served as a conference chair at international conferences, authored more than 15 scientific papers in technology and materials science, and holds three U.S. patents. He enjoys combining his interests to solve practical problems in chemistry, solar and renewable energy, and energy policy.