

## Reports on Sponsored Research Projects

### A. Reports NREL<sup>1</sup>-NCSU<sup>2</sup> Project Number: AAT-2-31605-05:.

1. A. Karoui, **Optimization of Silicon Crystal Growth and Wafer Processing for High Efficiency and High Mechanical Yield, Three year report, NCSU, Dec. 15, 2004**
2. A. Karoui, J. Peters, Y.K. Park, G. Rozgonyi, M. Narayanan, **Correlation of Impurity Mapping by Microwave Photoconductance with Mechanical Properties of Solar Polycrystalline Silicon Wafers, QR. 11**, 9 pages, July 1 - Sep.30, 2004.
3. A. Karoui, M. Romero, G. A. Rozgonyi, and M. M. Al Jassim, **Detection of Nitrogen and Oxygen Radiative Centers in N-doped Silicon Using Cathadoluminescence, QR. 10**, 7 pages, Mar.31 - June 30, 2004.
4. A. Karoui, G. A. Rozgonyi, **Effect of Grown-in Light Element Impurities on the Mechanical Properties of Silicon , QR. 9**, 11 pages, NCSU, Jan.1 - Mar.31, 2004.
5. A. Karoui, **Investigation of N doped Silicon by High Resolution FTIR using Synchrotron Source, QR. 8**, 21 pages, NCSU, Oct. 1 - Dec. 31, 2003.
6. A. Karoui, G. A. Rozgonyi, **Mechanical Properties of Nitrogen Doped Silicon Using Nano-Indentation Testing: Effect of O and N Doping, QR. 7**, 19 pages, NCSU, July 1 – Sep. 30, 2003.
7. A. Karoui, **Modeling and Computer Simulation of Dislocation Impurity Atmosphere in Silicon and the Locking Effects, QR. 6**, 16 pages, NCSU, Apr. 1 – June 30, 2003.
8. G. A. Rozgonyi, Jिंगgang Lu, A. Karoui, L. Kordas, and T. Ciszek, **Optimization of Silicon Crystal/Film Growth and Wafer Processing via Structural, Chemical, and Electrical Diagnostics, QR. 5**, 43 pages, NCSU, Jan. 1 – March. 31, 2003.
9. A. Karoui, E. Van Dyk, G. A. Rozgonyi, **Setup of Novel Techniques For Stress and Carrier Lifetime Measurements in Semiconductors Based on Near-Field Scanning Optical Microscope, QR. 4**, 11 pages, NCSU, Oct. 1 – Dec. 31, 2002.
10. J. Lu, A. Karoui, G. A. Rozgonyi, **Investigation of Electrical Activities of Dislocations and Grain Boundaries in NREL FZ Polycrystalline Silicon, QR. 3**, 7 pages, NCSU, July 1, 2002 – Sep. 30, 2002.
11. A. Karoui, G. A. Rozgonyi, **Minority Carrier Lifetime in Nitrogen Doped FZ Si, QR. 2**, 5 pages, NCSU, Apr.1 – June 30, 2002.
12. A. Karoui, G. A. Rozgonyi, **Dislocation control in N-FZ and N-CZ Silicon, and Relation to Minority Carrier Lifetime, QR. 1**, 10 pages, NCSU, Jan. 1 – March 31, 2002.

### B. Annual Reports on Projects sponsored by SiWEDS:

13. F. Sahtout Karoui, A. Karoui, G. Rozgonyi, **Theoretical Investigation of the Elastic/Plastic Deformation in Si1-xGex based Heterostructures**, NCSU, Feb. 2004
14. F. Sahtout Karoui, A. Karoui, G. A. Rozgonyi, N. Inoue, **Identification of Dominant Nitrogen-Oxygen Defects in Silicon using First Principles Calculations**, NCSU, Feb. 2003.
15. A. Karoui, A. Kvit, G. Duscher, and G. A. Rozgonyi, **Nano-Scale Analysis of Precipitates and Stacking Faults in Nitrogen-Doped CZ Silicon Annealed Wafers**, NCSU, Feb. 2003.
16. F. Sahtout Karoui, A. Karoui, G. A. Rozgonyi, N. Inoue, **First Principles Calculations of Infrared Spectra of Nitrogen Dominant defects in N doped CZ/FZ Silicon**, NCSU, Feb. 2002.
17. A. Karoui, F. Sahtout Karoui, G. A. Rozgonyi, M. Hourai, K. Sueoka, N. Inoue, D. Yang, **Computer Modeling and Experiments of Oxygen Precipitation and Void Nucleation and Growth in Nitrogen Doped CZ Silicon Wafers**, NCSU, Feb. 2002.
18. A. Karoui, A. Kvit, G. A. Rozgonyi, and G. Duscher, **Nano-Scale Analysis of Defect Evolution in Nitrogen-Doped CZ Silicon**, NCSU, Feb. 2002.

<sup>1</sup> National Renewable Energy Laboratory

<sup>2</sup> North Carolina State University

19. A. Karoui, F. S Karoui, G. Rozgonyi, **Computer Modeling and Experiments of Oxygen Precipitation and Void Nucleation and Growth in Nitrogen Doped CZ Silicon Wafers**, NCSU, Nov. 2001.
  20. A. Karoui, F. Sahtout Karoui, G. A. Rozgonyi, T. Sasaki, D. Yang, P. Flesher, **Computer Modeling and Experiments of Oxygen Precipitation and Void Nucleation and Growth in Nitrogen Doped CZ Silicon Wafers**, NCSU, Feb. 2001.
  21. F. Sahtout Karoui, A. Karoui, T. Sasaki, and G. A. Rozgonyi, **Computer Simulation of Oxygen Precipitation in CZ Silicon Wafers**, NCSU, Feb. 2000.
  22. A. Karoui, G. A. Rozgonyi, **Stress Induced Lifetime Variations in Rapid Thermal Processed Silicon Wafers**, NCSU, Feb. 2000.
  23. F. Sahtout Karoui, A. Karoui, **SPECKLE: Stochastic Simulator of Point Defect Clustering By Fokker-Planck Equations**, NCSU, Feb. 2000.
  24. A. Romanowski, A. Karoui, G. A. Rozgonyi, **Contactless Defect and Impurity Mapping/Electrical Characterization**, NCSU, Feb. 1999.
- C. **Annual Reports on Projects sponsored by Sumitomo SiTix (Japan):**
25. A. Karoui, F. Sahtout Karoui, G. A. Rozgonyi,  **$VN_2$ ,  $N_2V_2$  and  $N_2$  Complexes in N- doped CZ Silicon: Complex Geometry and Diffusion**, NCSU, Dec.31, 2001.
  26. A. Karoui, F. Sahtout Karoui, G. A. Rozgonyi, **Defect generation during N-CZ Si Crystal Growth Molecular Dynamics Simulation of N-related Chemical Complexes**, NCSU, Dec.31, 2000.
- D. **Miscellaneous Reports at NCSU:**
27. Indradeep Sen, A. Karoui, **Stress Analysis in Epitaxially Grown Silicon Wafers for Bipolar Transistors Processed by Cypress Semiconductors**, NCSU, joint project NCSU-Cypress, Apr. 12, 2002.
  28. A. Karoui, **Nitrogen Defect Formation Factors in Astro-Power Polycrystalline N-rich Silicon Sheets in Comparison to High Purity N doped CZ Silicon**, NCSU, Apr. 24,2002.
  29. A. Romanowski, A. Karoui, E. Covalla, G. A. Rozgonyi, **Characterization and Ti Gettering of PV Substrates**, NCSU, NREL: Quarterly report Apr. '98. NREL XAF-8-17607-03.
  30. G. A. Rozgonyi, A. Romanowski, A. Karoui, **Frequency-Resolved Microwave Reflection Photo-Conductance Project: Detailed Non-Contact Electrical and Structural Characterization of Photovoltaic Silicon Substrates**, National Renewable Energy Laboratory Photovoltaic Program FY 1997 Annual Report NREL/BK-210-23607, 39 pages, June 1998.
  31. G. A. Rozgonyi, A. Romanowski, A. Karoui, **Measurement of Deep Recombination Levels Using Frequency Resolved Microwave Photo-Spectroscopy. Project: Detailed Non-Contact Electrical and Structural Characterization of Photovoltaic Silicon Substrates**, National Renewable Energy Laboratory Photovoltaic Program FY 1996 Annual Report NREL/BK-210-21966, NCSU, 35 pages, Aug. 1997.
- A. Romanowski, A. Karoui, G. A. Rozgonyi, **Detailed Non-Contact Electrical and Structural Characterization of Photovoltaic Silicon Substrates**, NCSU, National Renewable Energy Laboratory:
32. Annual Report: Dec. 1996,
  33. Quarterly report: July 1996,  
and Monthly reports Apr. 1996, June 1996, Oct. 1996, Nov. 1996.
- A. Karoui, F. Sahtout Karoui, **Monte Carlo Simulation of Electron Beam Induced Current**, Joint Project with Micron Technology, Boise (Idaho) and Microelectronic Materials Research Group, NCSU:
34. Carrier Generation by Monte Carlo Method and Mechanism of Carrier Recombination, Jan. 1996.
  35. Green Function of Charge Carrier Generation and Collection, Mar. 1996.
  36. Point Defects and Parallel Dislocations in Silicon Schottky diodes, May 1996.
37. A. Karoui, G. Marrakchi, **New approach to Decay Analysis for the Photo-Induced Current Spectroscopy**. Laboratoire de Physique des Matériaux, CNRS u. r. a. 358, INSA Lyon, May 1995.

- E. **Silicon Polycrystalline Solar Cell Fabrication: projet ERESMAT<sup>3</sup> sponsorisé par SERST<sup>4</sup>**
38. A. Karoui, M. Bouaicha, A. Sallami, M. A. Zaibi, Annual Reports Juillet '94, Juillet '95, Juillet '96.
  39. A. Karoui, M. Bouaicha, S. Bouzaine, A. Sallami, M. A. Zaibi, R. Bennaceur, **Development of a New Cell Fabrication Process for the INRST Photovoltaic Pilot Plant**, INRST, Juin 1995.
  40. A. Karoui, **Materials Optimization of Tab and Electrical Interconnect Welding on Thin Silicon Solar Cells using a YAG Laser Automated Station**, INRST, Mars 1994.
  41. A. Karoui, **Robust screen printing processes in Solar Cell Technology:**
    - **Experiment Design and Optimization of 'Integral Screen Printing' Process for Silicon Solar Cell Fabrication**, INRST, Tunis, Oct. 1994.
    - **Identification of Materials Parameters for Screen Printing of Solid State Doping Source, Electrical Contacts, and Antireflective Coating Films**, INRST, Tunis, Mars 1994.
    - **Correlation of Fabrication Parameters with the Optical and Electrical Properties of Screen Printed Layers**, INRST, Tunis, Oct. 1993.
  42. A. Karoui, F. Sahtout Karoui, R. Bennaceur, N. Meskini, **Analysis and Development of Parallel Numerical Methods for Electronic Structure Calculation at Surfaces, Interfaces and Defects in Silicon** - Rapport Final du projet ERESMAT (Code P5/89/FST) - FST Dec. 1990.
  43. A. Karoui, R. Bennaceur, **Cell Sorting and Interconnection – Contribution au Rapport Final ERESMAT: Encapsulation De Modules Photovoltaïques et Installation d'une Pump Solaire**. Project Code P3/86/INRST-FST-ENSET,<sup>5</sup> Dec. 1988.
- F. **Other Reports**
44. A. Karoui, **Evaluation of the project "Pilot Plant Unit for Thin Film Solar Cell Fabrication - submitted to the Tunisian Energy Counsel, March 1989"**, INRST - May 1989.
  45. A. Karoui, **Draft of the Tunisian Quinquennial Plan for Renewable Energy Sources** – Secretariat d'Etat à la Recherche Scientifique et de la Technologie and the Agence de Maîtrise de l'Energie, Tunisia, Oct 1992.
  46. A. Karoui, **The State of the Art of Supercomputers and the Scientific Computing Benchmarks**, INRST, Tunis, Juillet 1995.
  47. A. Karoui, **Computer Viruses, their Evolution, and the Immunization of Informatic Resources**, Report for the Director of the INRST, Tunis, Jan. 1995.
  48. A. Karoui, **(3) Rapports Annuels d'Activité du Département de Physique et Energie de l'Institut National de Recherche Scientifique et Technologique**, for the Secretariat d'Etat à la Recherche Scientifique et la Technologie, INRST, Juin 1991, Mai 1992, et Juillet 1993.
  49. A. Karoui, **(12) Rapports Annuels d'Activité de Recherche**, INRST, SERST, period 1983-1995.

<sup>3</sup> ERESMAT: Encouragement pour la Recherche sur l'Energie et les Sciences des MATériaux

<sup>4</sup> SERST : Secretariat à la Recherche Scientifique et à la Technologie

<sup>5</sup> ENSET : Ecole Normale Supérieure de l'Enseignement Technique, University des Sciences de Tunis