Oak Ridge National Laboratory

October 24, 2007

Southeast Solar Summit

Session 1

Photovoltaic R&D

Managed by UT-Battelle
for the Department of Energy

OAK RIDGE
National Laboratory

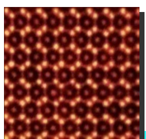
Material Science at Oak Ridge National Laboratory

- **DOE's largest multiprogram science laboratory**
- **Nation's largest energy R&D laboratory**
- **Nation's largest concentration of open source materials research**
- **Leading DOE National Lab in number of highly cited materials science authors**
- **1st DOE Nanoscience facility – Center for Nanophase Materials Science**
- **Second only to General Electric in number of R&D 100 Awards**
  - **Able to transfer technology to industry**

ORNL's View on Material Science to Energy

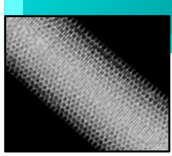
Integrate science and technology to accelerate the transition from discovery to application

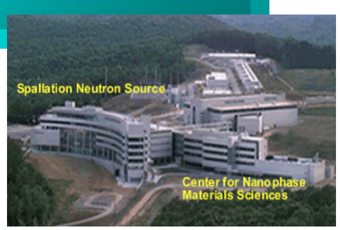
Bridging the Gap



Discovery – Driven <u>Research</u>

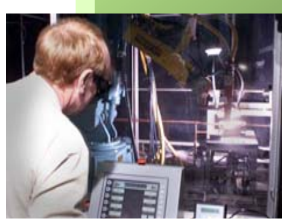
Synthesis
Fundamentals
Characterization
Modeling

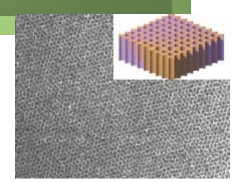




Applied Technology Development

Application R&D
Process Development
Scale-up
Real-time characterization tools
Prototypes

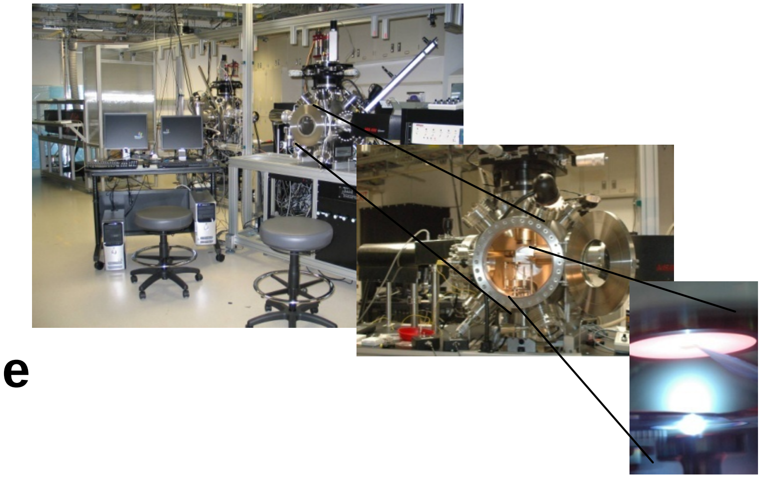




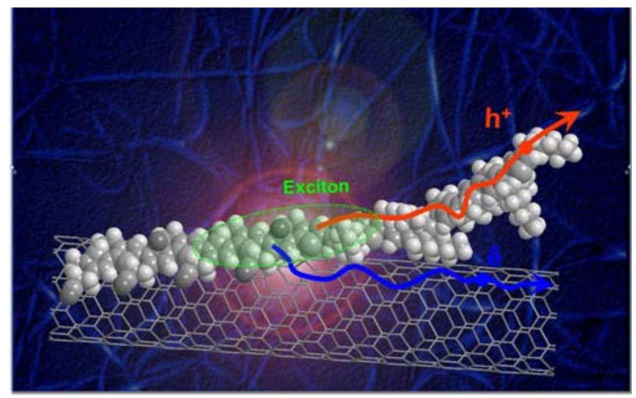
Product – Driven Industrial <u>Development</u>

Energy Storage
Solid State Lighting
Solar Power
Industrial Technologies
Transportation

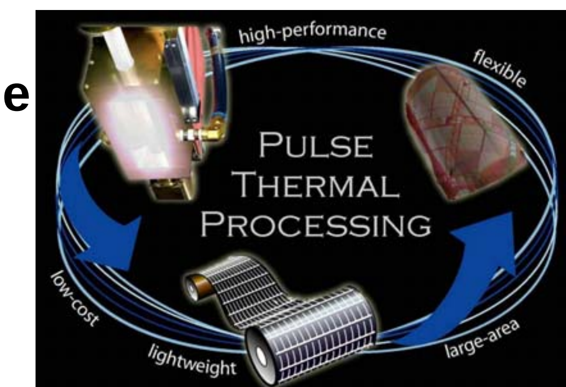
Sampling of Materials Fabrication Techniques



- **Thin film pulsed-laser deposition**
  - **Quickly explore numerous parameters**
  - **Grow specific interfaces at atomic-scale control**
  - **Allows defect analysis at the nanoscale**
- **Unique methods for nanoparticle fabrication and dispersion**
  - **Biosynthesized nanoparticles**



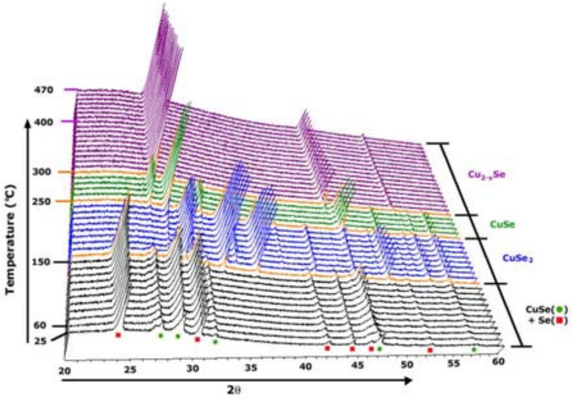
- **Organic photovoltaics**
  - **Dissociation of exciton on carbon nanotube/polymer interface**
- **Next generation rapid thermal annealing**
  - **Processing thin films and nanoparticle material systems on temperature sensitive substrates**



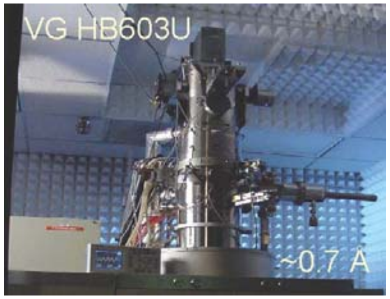
Sampling of Materials Characterization Techniques

- **18 user facilities**
- **Center for Nanophase Materials Science (CNMS)**
  - **DOE/BES**
  - **State-of-the-art $65M thin film user facility**
- **High Temperature Materials Laboratory (HTML)**
  - **DOE/EERE**
  - **6 user centers focused on materials characterization**
- *In-situ* time-resolved high-temperature X-ray diffraction
  - Allows detailed reaction pathways of $CuInSe_2$ absorber films which have very complex phase evolution and defect chemistry
- **Sub-Angstrom resolution microscopy**
  - **Unique capability to evaluate defects and interfaces at sub-angstrom resolution**

CNMS



Time/Temperature resolved XRD



Scanning tunneling electron microscope

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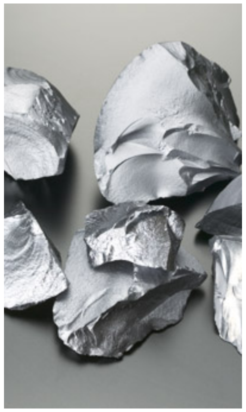
Defects and Photovoltaic Efficiency

- **Defects and the ability to control them during fabrication has a direct impact the efficiency of the cell**
  - **This will influence:**
    - **Material cost**
    - **Module cost**
    - **Installation cost**
    - **Manufacturing throughput**
- **Lower the levelized cost of energy (LCOE) for PV**



Developing Collaborations

- **Universities**
  - **Georgia Institute of Technology**
  - **University of Florida**
  - **North Carolina State**
- **Industries**
  - **United Solar**
  - **Ascent Solar**
  - **International Solar Electric Technologies (ISET)**
  - **NanoPV**
  - **ITN Energy Systems**
  - **Nanosys, Inc.**

ISET

International Solar Electric Technology, Inc.

IEEE ELECTRON DEVICE LETTERS, VOL. EDL-8, NO. 5, MAY 1987 249

Excimer Laser-Processed Oxide-Passivated Silicon Solar Cells of 19.5-Percent Efficiency

R. F. WOOD, SENIOR MEMBER, IEEE, R. D. WESTBROOK, MEMBER, IEEE, AND G. E. JELLISON, JR.

Abstract—Single-crystal p^--n-n^+ silicon solar cells with AM1.5 efficiencies exceeding 19.5 percent have been fabricated using glow-discharge implantation and pulsed excimer laser annealing, together with techniques for reducing the recombination current. These techniques include extrinsic passivation by thermal oxide growth and fine-line photolithography for metallization in order to reduce the area of metal–silicon contact. These are the highest efficiency ion-implanted nonconcentrator cells reported to date and to our knowledge they are the highest efficiency *p*-on-*n* cells made by any technique.

knowledge no such technique has yet been developed, but in view of its importance for much of the semiconductor technology we may be optimistic that methods of low-temperature passivation will be found. In the meantime, as demonstrated here, passivation by oxide growth at ~850°C can be combined with pulsed laser processing to achieve very high efficiencies. These temperatures are far less than those (≳925°C) required for the thermal formation of boron-doped

- **ORNL collaboration with the Solar Energy Research Institute (SERI)**
  - **Setting near record efficiencies with single crystal silicon**
- **Expertise existed then and has only grown through the years to establish a better understanding of materials processing and analysis**

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Georgia Institute of Technology University Center of Excellence for Photovoltaics

Dr. Vijay Yelundur