Photovoltaic Manufacturing Laboratory (PML)

Major Research Programs

- Mechanical strength and integrity of silicon wafers
- Silicon wafering by diamond wire sawing
- Thin materials handling (Bernoulli)
- Residual stress measurement by near IR polariscopy
- Kelvin probe based PV metrology

Detailed Description of Programs

1. Mechanical strength and integrity of silicon wafers

This project focuses on the effect of wafering process (parameters) on the mechanical strength of various types (mc-Si, mono-like, mono, EFG, etc.) of silicon wafers. Parameters investigated include

- Diamond coated wire vs. slurry sawing
- Impact of slurry grit size distribution
- Impact of sawing wire speed
- Locations of wafers in an ingot
- Mechanical strength maps

Sponsors: SiSoC (NSF), REC, MEMC, AMAT
Publications:
Wu, H., Melkote, S. N and Danyluk, S,"Mechanical Strength of Silicon Wafers Cut by Loose Abrasive Slurry and Fixed Abrasive Diamond Wire Sawing", Advanced Engineering Materials. in press

2. Silicon wafering by diamond wire sawing

This project focuses on both theoretical (XFEM, eXtended FEM model) and experimental (diamond scribing) studies of diamond wire sawing for silicon wafering. Fundamental questions such as ductile to brittle transition are investigated through,

- Stress and deformation under grit contact,
- The effect of scriber tip shapes: conical, Berkovich and Vickers
- Crystallographic orientation dependence
- Surface morphology

Sponsors: SiSoC (NSF), MEMC, AMAT
Publications:
Wu, H and Melkote, S.N, "Study of Ductile-to-Brittle Transition in Single Grit Diamond Scribing of Silicon: Application to Wire Sawing of Silicon Wafers", Journal of Engineering Materials & Technology, ASME Transaction.
Wu, H and Melkote, S.N, "Effect of Crystallographic Orientation on Ductile Scribing of Crystalline Silicon Role of Phase Transformation and Slip", Material Science and Engineering: A.

3. Thin materials handling (Bernoulli)

Theoretical simulation (FEM) of stress distributions at different Bernoulli design parameters (pressure, geometry, etc) and their effect on deformation and breakage
Experimental verification of stress distribution under a Bernoulli gripper.
Sponsors: USiSoC (NSF), Schott Solar, RUV, Alta Devices
Publications:

Brun, X. and Melkote, S.N., Solar Energy Materials & Solar Cells, Vol. 93, pp. 1238-1247, 2009
Brun and Melkote, ASME Trans. Mfg. Sci. Eng., 2009

4. Full field residual stress by near IR polariscopy

Non-destructive measurement of full sized wafers and its impact to cell performances (carrier lifetime, mechanical strength)

- Residual stress distribution on PV wafers
- Correlation between R.S. and minority carrier lifetime
- Local stress near defects (G.B, inclusions, light elements)

Sponsors: SiSoC (NSF), Solar World, REC, Alta Devices

Publications:

Shijiang He, Steven Danyluk, I. Tarasov, Sergei Ostapenko, “Residual Stresses in Polycrystalline Silicon Sheet and Their Relation to Electron-hole Lifetime”, Applied Physics Letters, Vol 89, No. 11, p. 111,909 (2006).

Li, F., Garcia, V., Danyluk, S., Ostapenko, S., Kalejs, J., and Yates, D., “In-plane Residual Stress and Its Relationship to Dislocation Density in Polycrystalline (EFG) Silicon Sheet,” IEEE 4th World Conference on Photovoltaic Energy Conversion, (IEEE Cat. No. 06CH37747), 2006, p. 4.

5. Kelvin probe based PV metrology

Development of Kelvin probe-based metrology for PV wafer/cell inspections. Applications include

- Process-related (metallization, cleaning, implantation) defects
- Electrical fields near micro-cracks
- Quantum efficiency of solar cells
- Detection of sub-monolayer metallic contaminants

Sponsors: NSF, Qcept

Publications:

C. Yang, Y. Pyekh, S. Danyluk, Crack Induced Surface Potential Variation on Si PV Cells, 37th IEEE PVSC conference, Seattle, WA, June 19-24, 2011.

C. Yang, Y. Pyekh, S. Danyuk, Surface potential imaging of PV cells with a Kelvin probe, Solar Energy Materials & Solar Cells, in press