DOE Si workshop summary

29 July 2015

Overall Themes

- Incremental/Evolutionary will reach 3 cents/kWh in 15 years
- O, defect reduction, mapping and tracking
- Faster cycles of learning
- Kerfless, direct wafers
- Reliability
- Process integration, higher throughput
- Standardization
- Smaller, focused, industrially guided projects

Overall Metrics

- LCOE
- Efficiency
- Cost
  - Cost modeling, cost benefit analysis
- Reliability

Metrology

- P-type mono: BO complexes
- N-type mono: O precipitates

  - Detecting and resolving O precipitates
  - Fe detection

- p-type multi: kerfless, epi, direct wafer. Need to solve reuse, crystal defects (stacking faults) and metal impurities
- n-type multi: O detection methods that are faster and down to 10^{10} cm^{-3} limit.

Metrology

- O detection and tracking
  - Tracking gettering and hydrogen passivation effects
- Defect tracking
  - In-line, feedback, faster learning cycles, binning, impact on reliability, at ingot level
- Develop process equipment with built in metrology
- Proactive: predict failure upstream
- Tools: PL, PC, FTIR, RUV
- Standardization: to be able to compare measurements

Metrology

- Types of projects
  - More projects at smaller $/project
  - Focused, less partners
  - Guided by industry
- Metrics:
  - LCOE
  - EL barcoding to track wafers
  - Collaboration with industry

Si Material

- Incremental will reach 3 cents/kWh in 15 years
  - Reduce consumables
  - Larger ingots, wafers
  - Defect control
  - Crucible coatings, reuse, elimination
  - Thorough analysis of crystal growth techniques
  - Recycling kerf

Si Material

- Innovations
  - Kerfless, direct wafering
- Projects
  - Need to incorporate cost benefit analysis
  - Small projects suitable for universities and labs

Cell Processing and Metallization

- Incremental will get to 3 cents/kWh in 15 years
- Major areas:
  - Wafer: cheap/high quality, thinner (20 um), purity, mc-Si vs Cz, pre-processing and gettering as a challenge (always an extra step)
  - Diffusions: costs (abatement, cleaning, throughput, two-sided), streamlining, future of BSF, implantation
  - PECVD: atmospheric, higher throughput, spray-on, reduced abatement costs, reduced cleaning costs, multipurpose layers
  - Metallization: Ag (reduce or alternative), optimized grid design and interconnection

Cell Processing and Metallization

- Other
  - Light trapping, integration
- Metrics
  - Cell performance, cost analysis, publications, industrial impact, scalability

Heterostructures

- Need cheap and simple processing
- Thin wafers – how to handle?
- IBC and CSC:
  - How to reduce patterning and processing cost
  - Need wider materials search (beyond SiO_2, SiNx, Al_2O_3, a-Si:H)
  - Light management
  - Standards for bifacial
  - Could investigate tandems but need 20% cheap top cell
- Reliability

Heterostructures

- Metrics
  - Efficiency
    - Transparency, lifetime, contact resistance for CSC
    - Increased energy harvest due to CSC such as lower TC, higher LLE, higher off-axis light capture
    - Understand loss mechanisms and efficiency limits
  - Cost: wafer thickness, # of steps, Ag usage, wafer quality, uniformity, degradation rate

Modules and Reliability

- Modules
  - materials (cost and durability), assembly, installation, communication, power interconnection, temperature management, hybrid, plug and play
  - smart electronics: sunsvoc, performance, field yield
  - data mining
  - faster feedback time
  - research areas: assembly (methodology, edge connection, jbox, durability testing, durability connectivity, glass evaluation, encapsulent, materials isolation)
- Reliability
  - Soiling (new products)

Modules and Reliability

- Lowering costs
  - understand physics of failure
  - lifetime prediction
  - geographical implications
  - standards: develop common method, innovative design, physics based testing, module integrated electronics