

Mesoscale Science of Damage Accumulation in Long-Lived Systems

Opportunity

Many societally valued Products/Devices have unclear lifespans

- Civil Infrastructure for Energy (Wind, Solar, Hydro)
- Medical Device Wear Out
- Other Durable Goods and Infrastructure Elements

Long timescale degradation prediction leading to lifetime performance prediction (prognostics)

For energy and medical devices, testing is typically focused on qualification, safety and initial performance

- Currently no scientific basis to predict lifetime performance

Meso Challenge

Investigate phenomena that span scales of time (fs-yrs), length(Å-cm), and energy scales

How to understand effects that initiate degradation, and the subsequent way that damage propagates and aggregates through time and length scales

- Defect and Damage Accumulation
- Chemical Reaction Progression

Further reaction rate modeling to include uncontrolled environments

Approach

Cross correlation of environmental exposure (use conditions)

- to lab exposures
- of multiple stresses (individual/combined)
- at multiple intensities (i.e. “accelerated”)

Computational (Big Data)

- Large sample population
- Multiple real-world exposure environments
- Non-destructive testing
- Accumulation of library of samples and data
- Cross-Correlation of Stresses and Responses

De-Convolution of Multi-Stress Synergistic Effects

Impact

Enables Device Design/Deployment:

- Novel processing/materials/components/systems
- Cost reduction opportunities
- Faster development of critical technologies

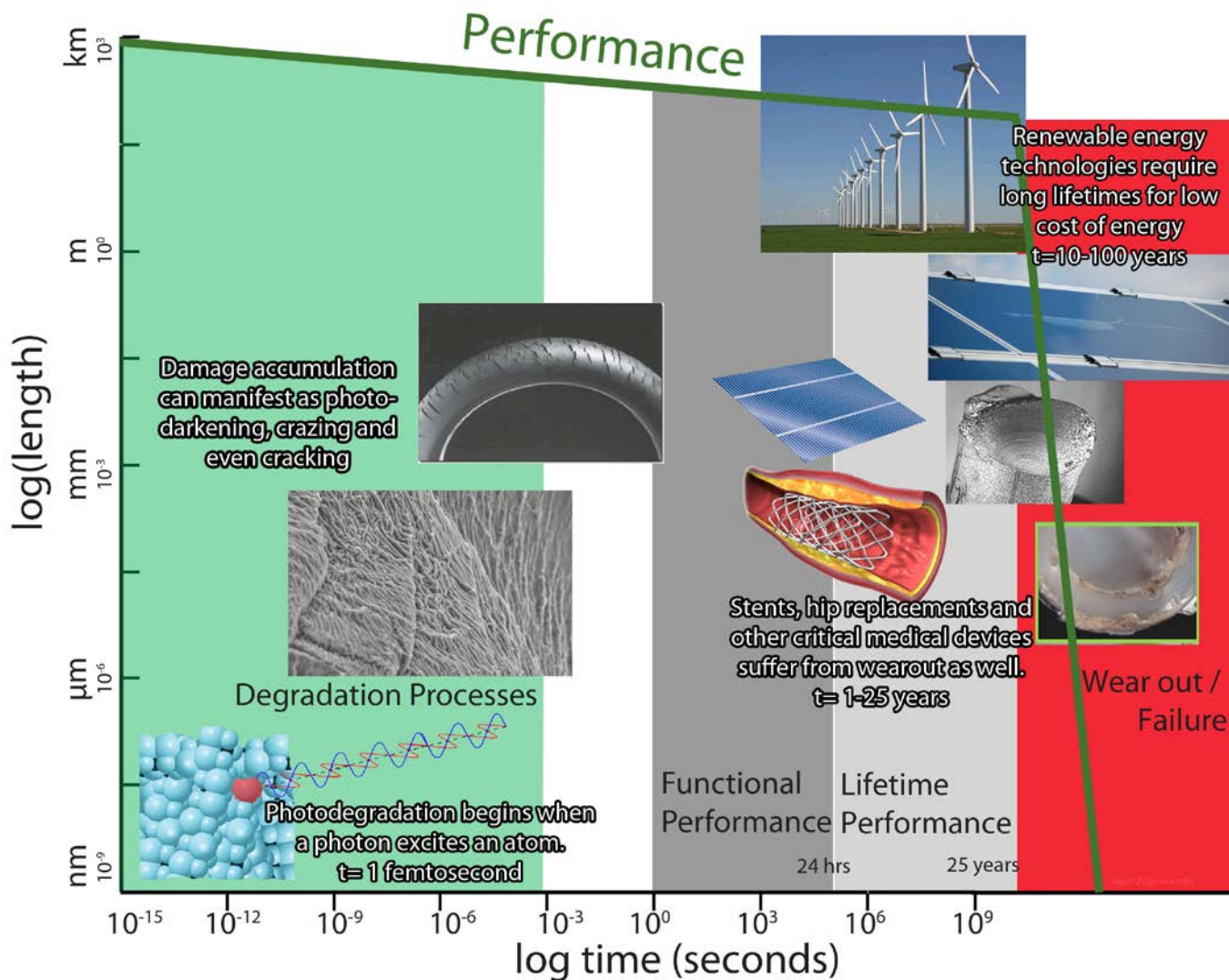
Understand complex systems independent of time and length scales

- Accurately predict lifetime performance
- Realize cost and time savings
- Suppress degradation modes
- Reduce degradation rates

References: Sample, Tony (2011, February). *Failure modes and degradation rates from field-aged crystalline silicon modules* Presented at the NREL PV Module Reliability Workshop 2011, Golden, CO. ; Lee, Kevin, and Stuart B Goodman. “Current State and Future of Joint Replacements in the Hip and Knee.” *Expert Review of Medical Devices* 5, no. 3 (May 2008): 383–393.

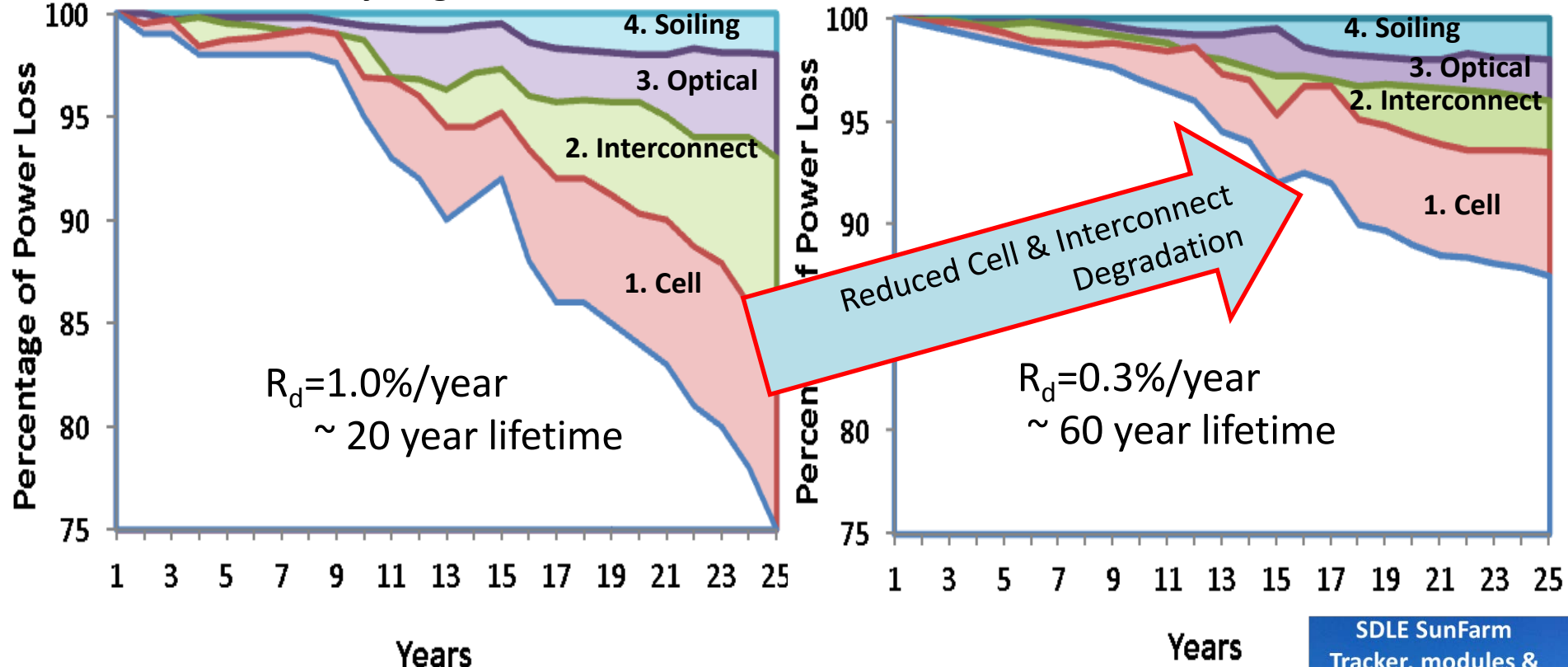


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Contributions of Key Degradation Modes To Lifetime Performance: From Simulated Results



$$R_d = \sum_{i=1}^n R_{d_i} = R_{d_1} + R_{d_2} + R_{d_3} + R_{d_4} + \dots$$

Degradation Modes (examples)
 R_{d_1} = Cell p/n Junction
 R_{d_2} = Interconnect
 R_{d_3} = Optical Obscuration
 R_{d_4} = Soiling

