
2008 Solar Annual Review Meeting

Session: CSP Advanced Systems: Optical Materials

Organization: National Renewable Energy Laboratory



Cheryl Kennedy

NREL

303-384-6272

cheryl_kennedy@nrel.gov





Relationship to Solar Program Goals

“...to make CSP cost competitive in the intermediate power markets by 2015 (~7¢/kWh with 6 hours of storage) and in baseload power markets (~5¢/kWh with 16 hours of storage) by 2020.”

1. Optical Materials project overview

- a) Project description: Characterize advanced reflectors, perform accelerated and outdoor testing of commercial and experimental reflector materials, and provide industry support.
- b) Major FY08 Activities:
 - Mirror Characterization and Testing
 - CSP Advanced Concepts FOA Support
 - 3M – Hardcoats for Polymeric Mirrors
 - Abengoa – Advanced Front Surface Polymeric Reflector
 - Alcoa – Aluminum reflector
 - PPG – High Value Mirrors



Relationship to Solar Program Goals

“...to make CSP cost competitive in the intermediate power markets by 2015 (~7¢/kWh with 6 hours of storage) and in baseload power markets (~5¢/kWh with 16 hours of storage) by 2020.”

1. Project overview (continued)

Project description:

c) Planned Milestones

- Level 5:
 - Complete installation of new accelerated exposure chambers (3/08)
 - Determine new optical performance, lifetimes, and cost goals with input from technical community (3/08)
 - Report summarizing durability silvered thin-glass copper-free & lead-free mirrors after accelerated and outdoor exposure (6/08)

- Level 4:
 - Report summarizing durability of candidate solar mirror samples (9/08)
 - Report summarizing FOA support activities (9/08)

Relationship to Solar Program Goals



1. Project overview (continued)

Project description

d) Budget Table (FTEs, \$FTE, Subcontract Info)

Agreement	FTEs	\$(K)	Subcontract \$(K)
Mirror Characterization & Testing	0.93	310	
FOA Support	0.93	250	
FOA:			1900
3M – Hardcoats for Polymeric Mirrors			350
Abengoa – Advanced Front Surface Polymeric Reflector			448
Alcoa – Aluminum reflector			399
PPG – High Value Mirrors			323



Relationship to Solar Program Goals

1. Project overview (continued)

Project description:

e) Personnel contributing to the project:

NREL: Total <1 FTE

Cheryl Kennedy, Kent Terwilliger

Student interns: Marc Oddo, Andrea Warrick

2. Relevance to Program Plans & Goals

Solar Program Multi-Year Technical Plan targets cost reductions of up to 50% to the solar concentrator and recommends one of the ways the goals could be achieved is through technology advances that include lightweight front-surface reflectors that contain anti-soiling coatings.

FY08 Progress Report



1. What has been accomplished thus far?

a) Technical highlights:

- Continued durability testing of solar mirrors by accelerated and outdoor exposure in Colorado, Florida, and Arizona
- Responding to numerous (daily) industry requests for technical assistance & data
- Restoring capabilities
 - hiring staff
 - purchasing new accelerated weathering equipment
 - purchasing new optical measurement equipment
- Helped DOE organize “Specialty Glass Needs of the U.S. Solar Industry” workshop
- Organized 2 CSP Applications & Desalination sessions at SolarPACES
- Presented 2 invited papers at industry meetings

FY08 Progress Report



1. What has been accomplished thus far?

b) Issues that have come up; solutions proposed:

- Insufficient resources to meet urgent requests for technical information & data from established and emergent CSP (& CPV) industries; plus increased testing & evaluation for FOA awardees & industry.
 - Hiring replacement staff
 - Purchasing replacement equipment
 - Will not have sufficient resources to meet all requests
- Reduced number of outdoor test facilities
 - Discussing possible loan agreement w/ Excel (Pueblo, CO) & PPG (Pittsburg, PA)
- Working with industry to develop new goals & standards
 - Industry acceptance after Solar Glass Workshop
 - US/International: Glass, Silvering, Coating, Utilities, Developers

FY08 Progress Report



1. What has been accomplished thus far?

c) Costing (current level; projected end-year balance)

	FY06 Budget	FY07 Budget	FY08 Budget
Advanced Concepts	\$130k	\$135K	\$310k
Advanced Concepts FOA Support	\$0k	\$0k	\$250k
Capital Equipment	\$0k	\$113k	\$283k

Broad Industry Collaboration:

Glass Mirror

- Thick (>3-mm) Glass

- Flabeg
- NSG Pilkington
- Cristaleria Espanola S.A
(i.e., Saint-Gobain)
- Saint-Gobain
- PPG (CSP FOA)
- RioSolar
- CSR (formerly Pilkington
Australia → Veridian → CSR)
- Arch
- Cardinal
- Guardian

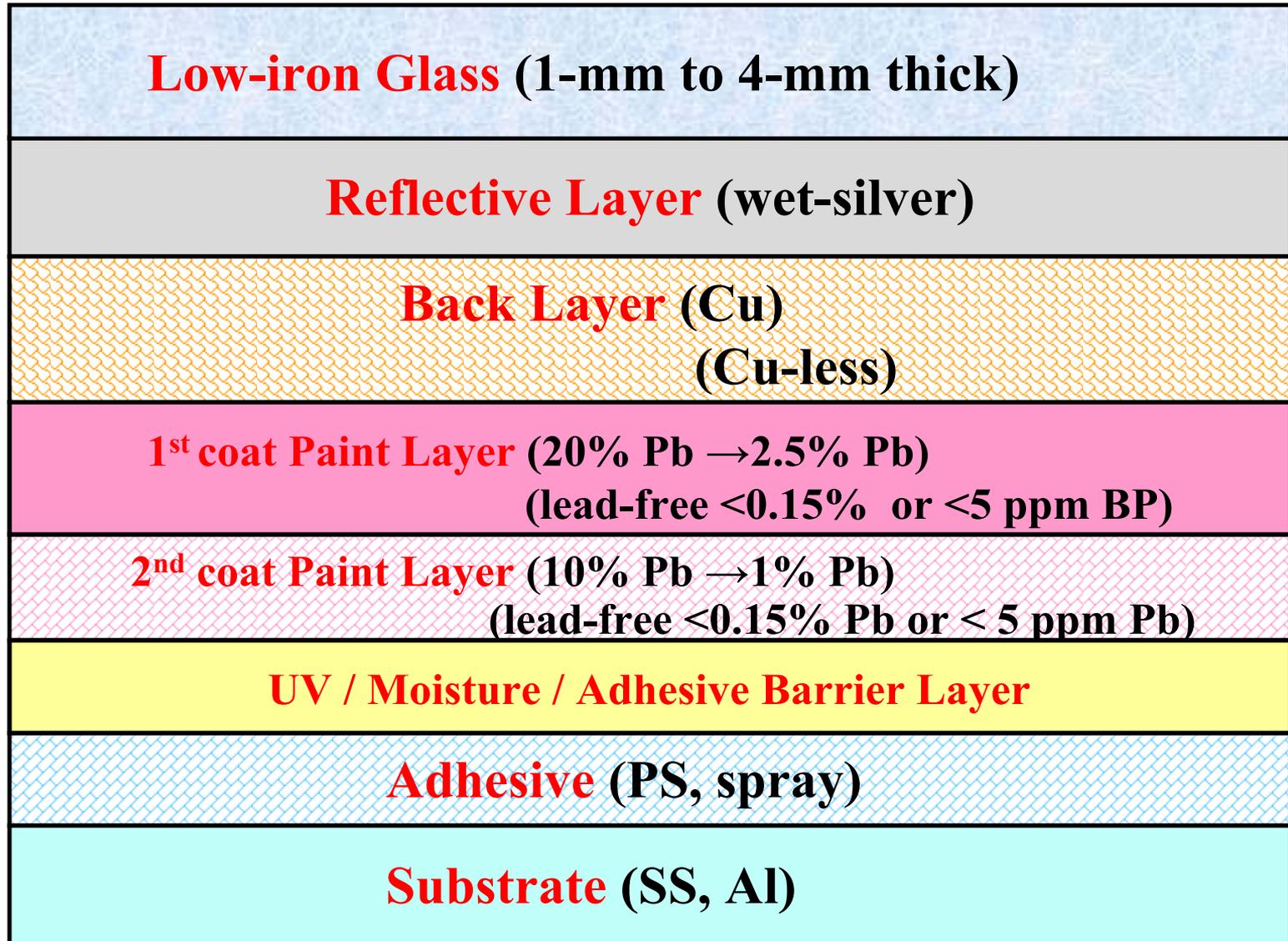
- Thin (~1-mm) Glass

- AGC Belgium
(i.e., Asahi Glass Company
formerly Glaverbel)
- AGC Thailand
- AGC Indonesia
- Naugatuck Glass Company

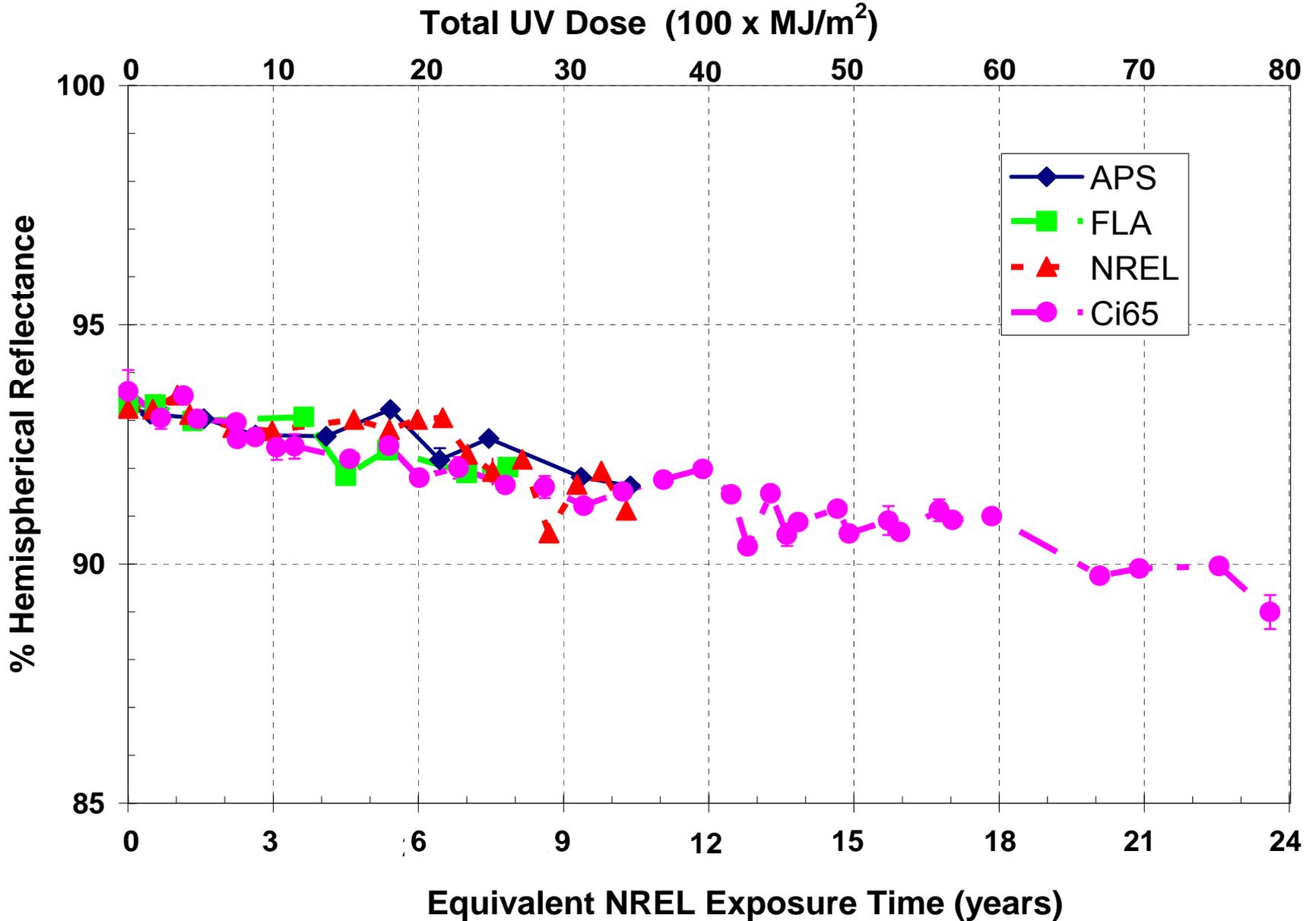
- Mirror Coating

- Valspar
- Spraylat

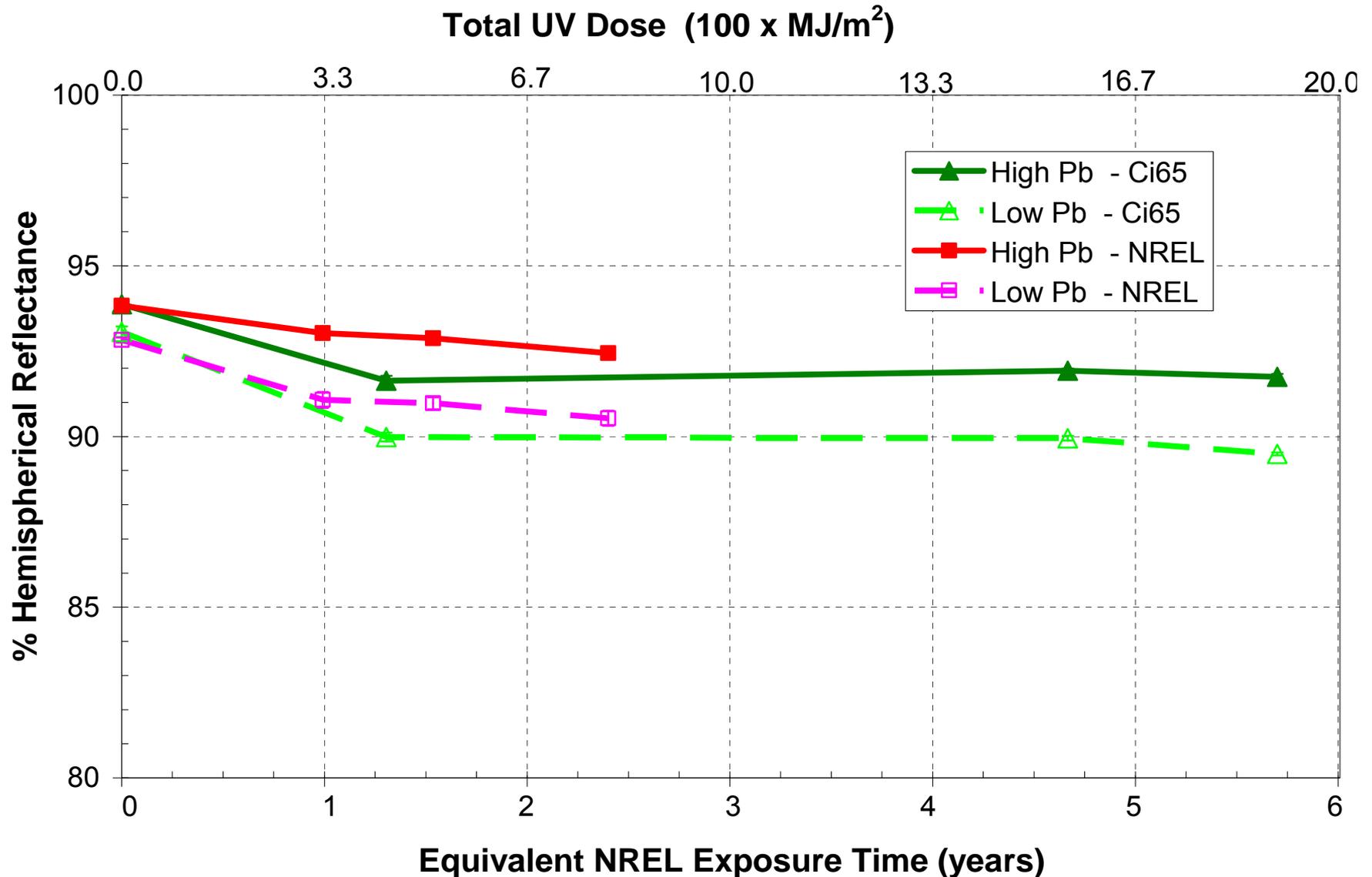
Architecture of Glass Mirror



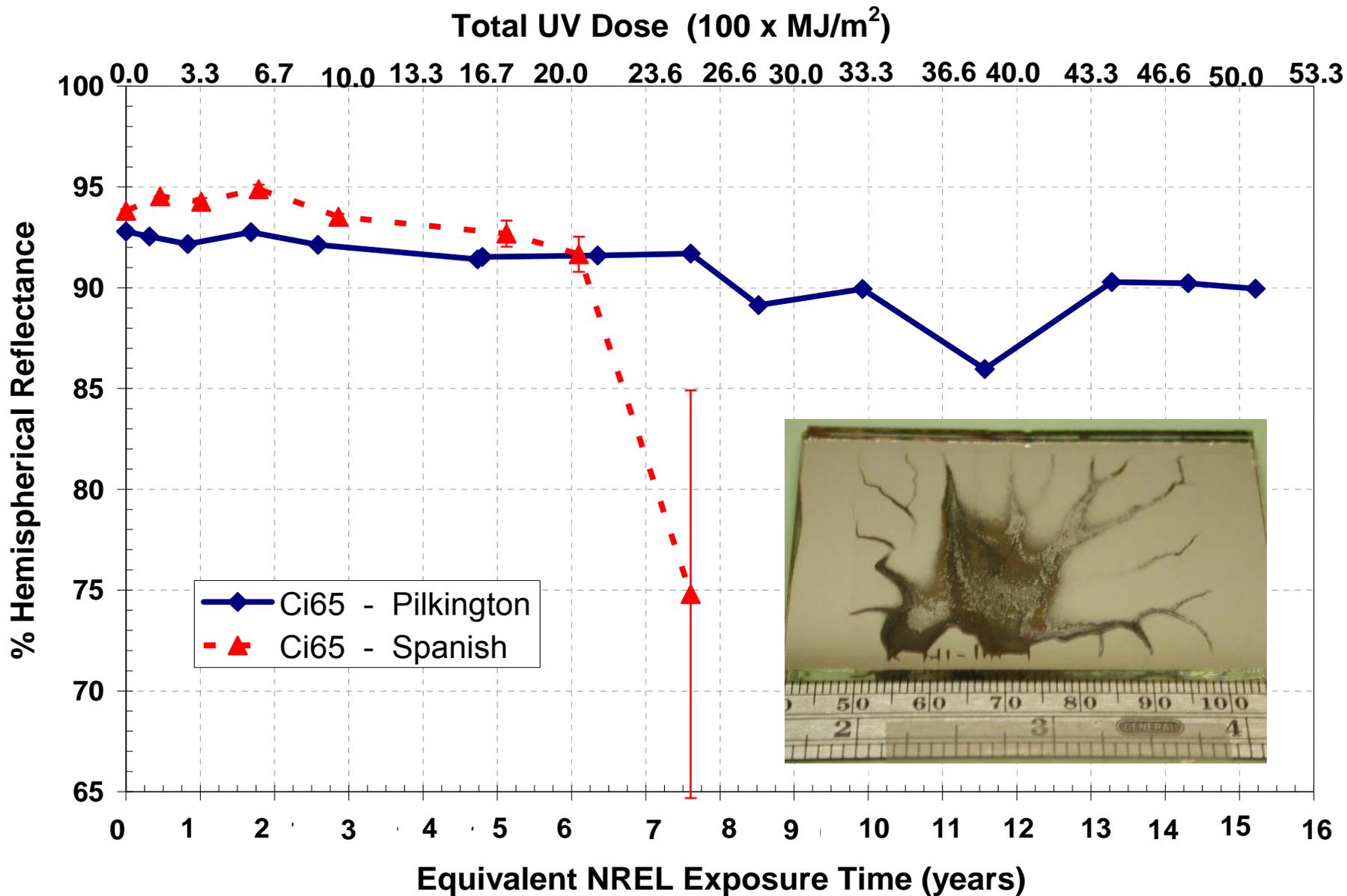
Original High-Pb Flabeg is durable



Low-Pb Flabeg Mirror may be less durable than high-Pb



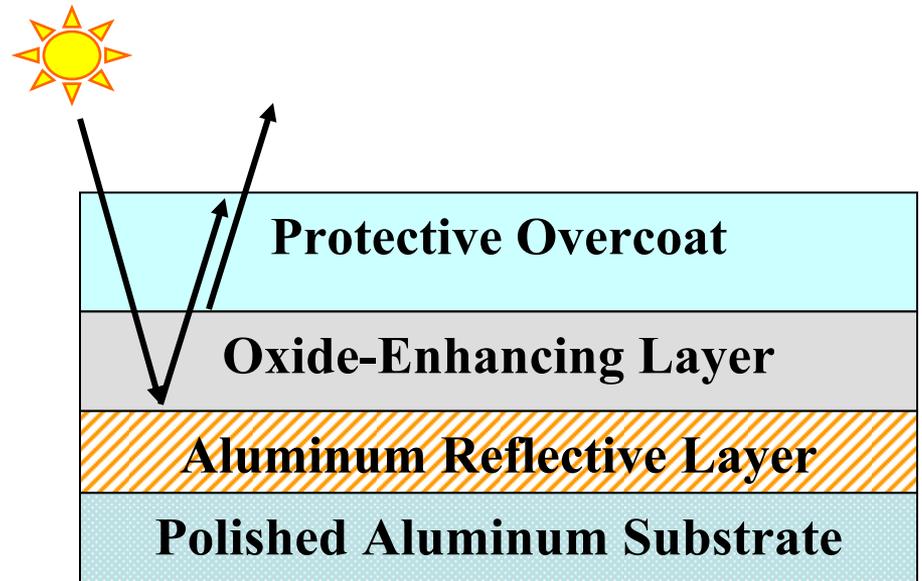
Alternate Thick Glass Mirror



Industry Collaboration:

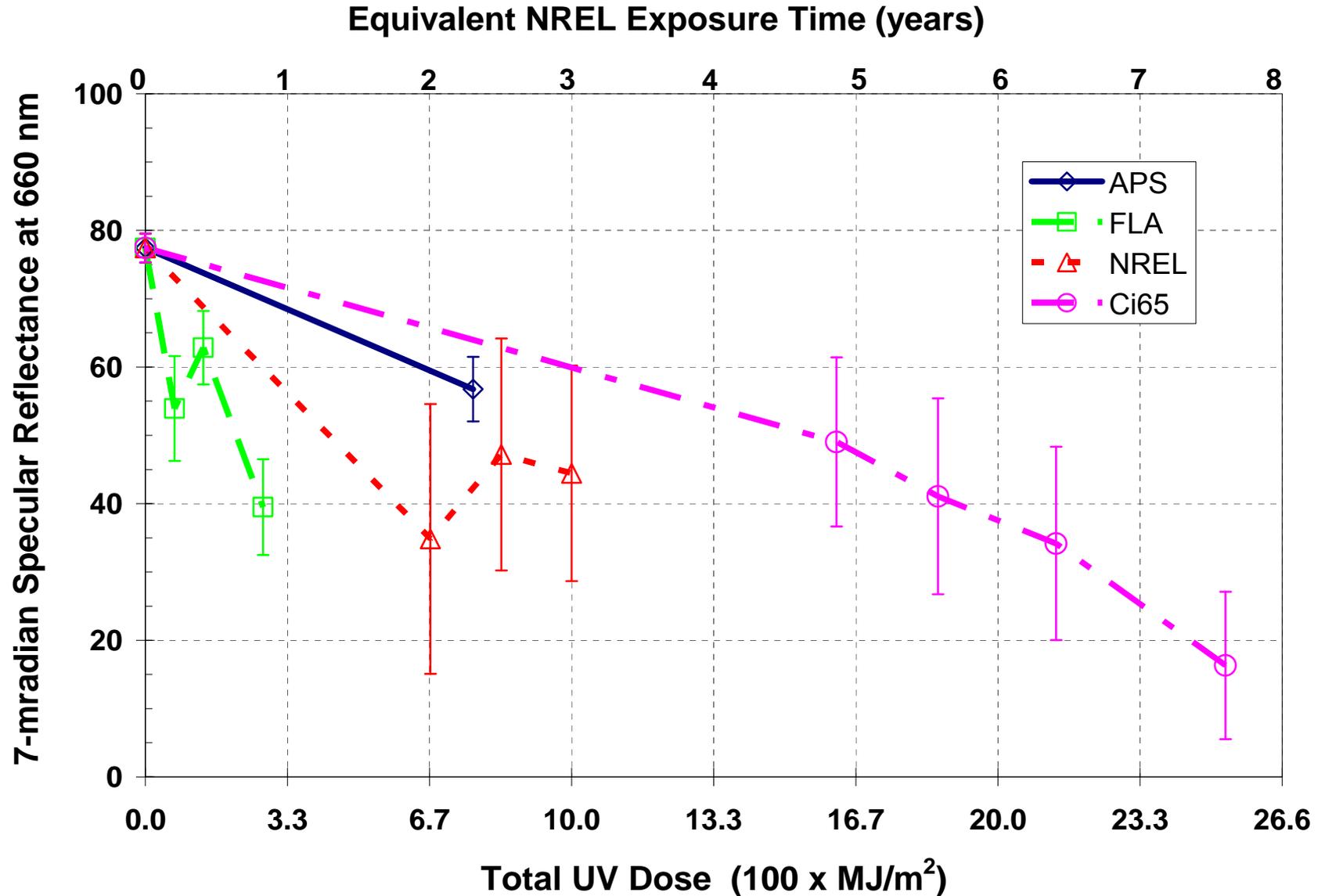
Aluminized Mirror

- Alanod
- Alcoa (CSP FOA)
- Alcan
- Aluminum Coil Anodizing (ACA)

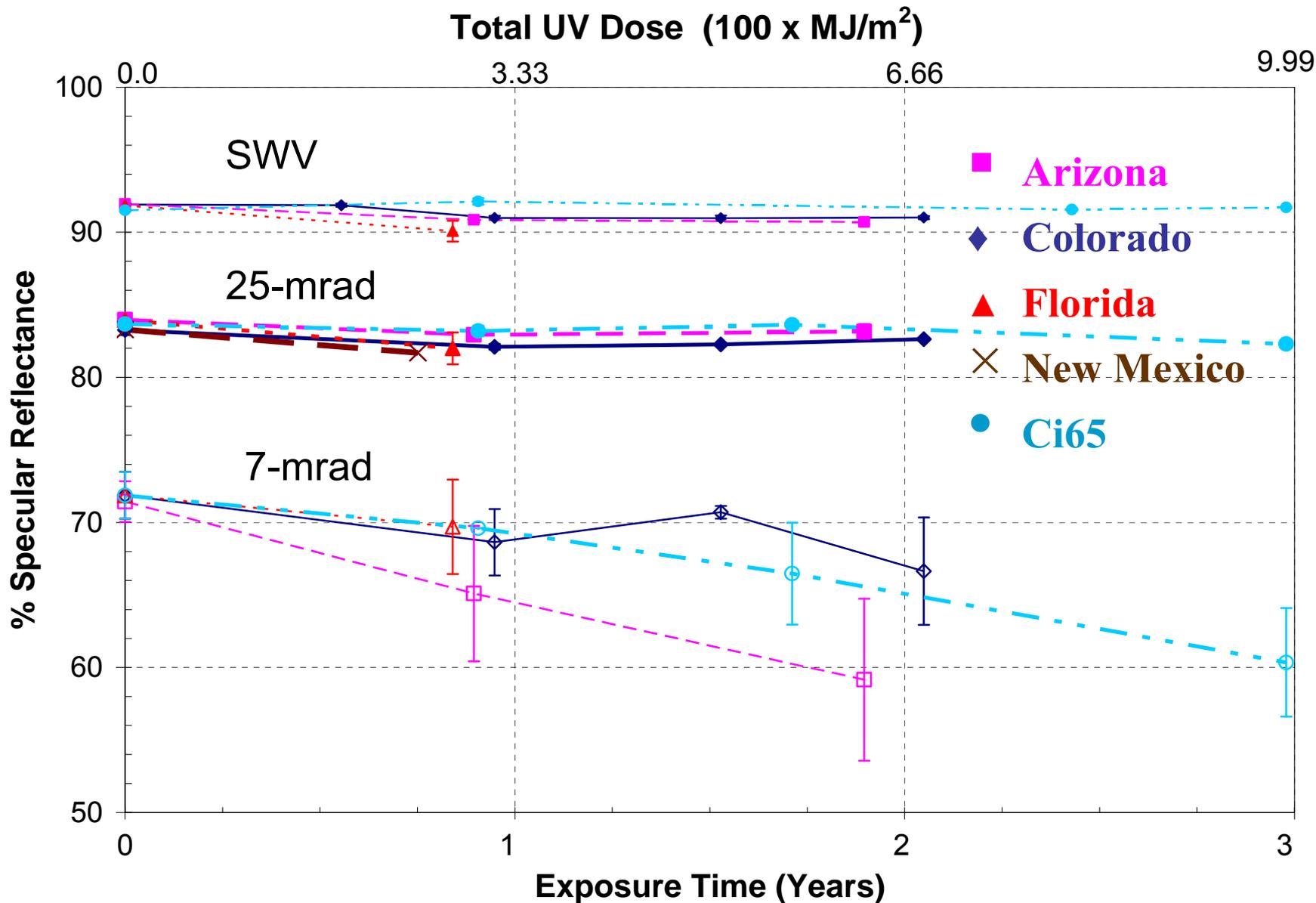


Architecture of aluminized mirrors

Loss of Specularity of Alanod Aluminized Reflector w/ Fluoropolymer Overcoat

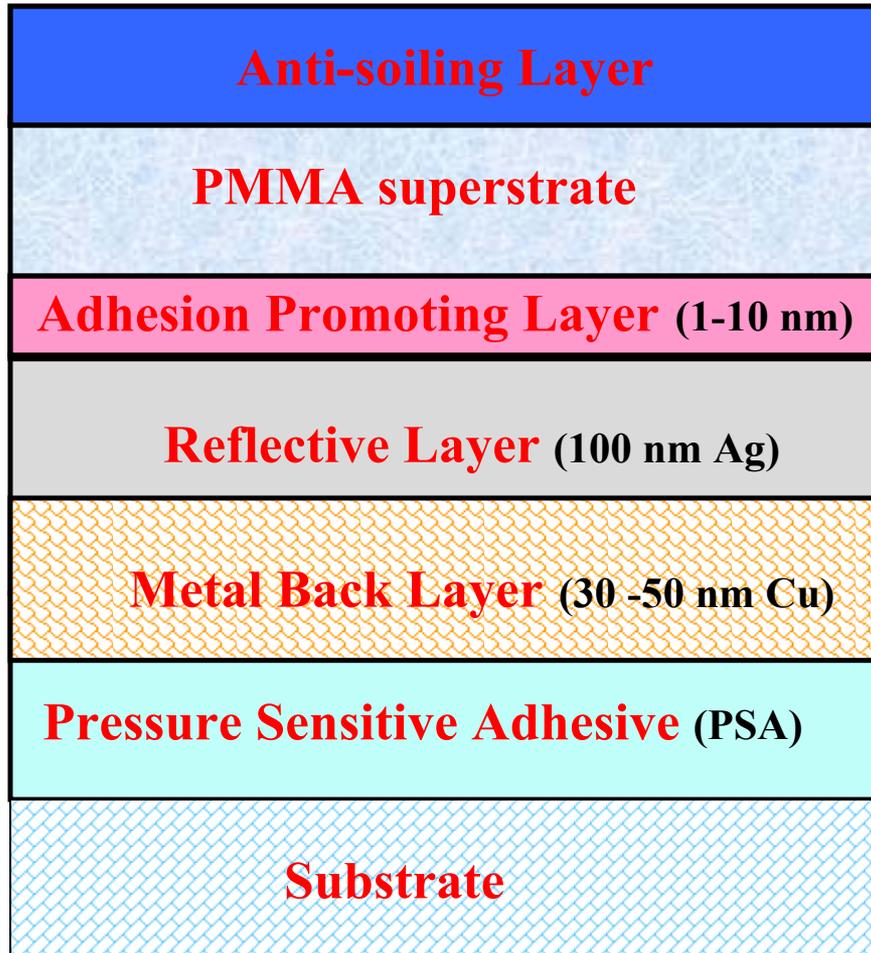


Alanod Aluminized Reflector with Nanocomposite oxide layer



Development of Improved 3M Polymer Mirror

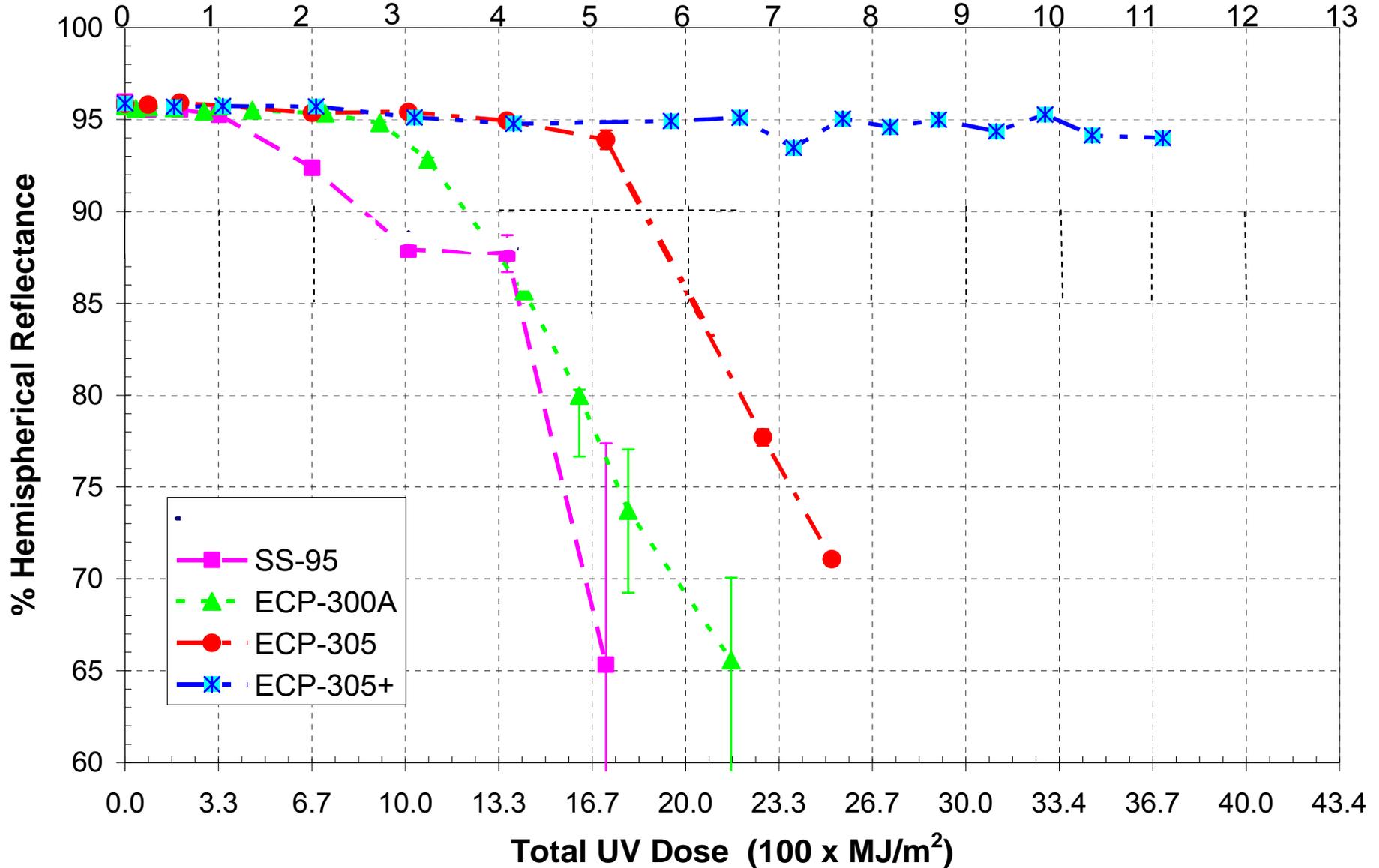
- based on prior NREL collaborations



- Antisoiling/hardcoat (FOA)
- Adhesion promoting layer
- Possibly provide laminated to substrate and heat treated
- Built on:
 - Joint NREL/3M subcontract
 - NREL patent
 - 2 NREL DDRDs

3M Metallized Polymer Films

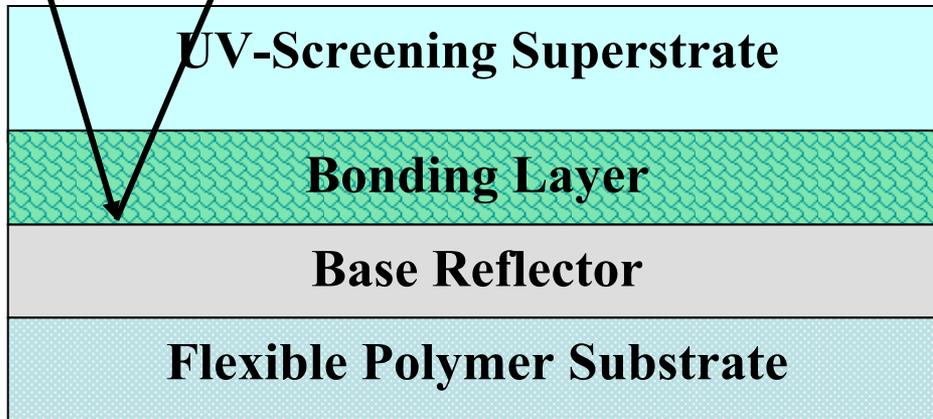
NREL Exposure Time (years)



Development of Improved Polymer Mirror

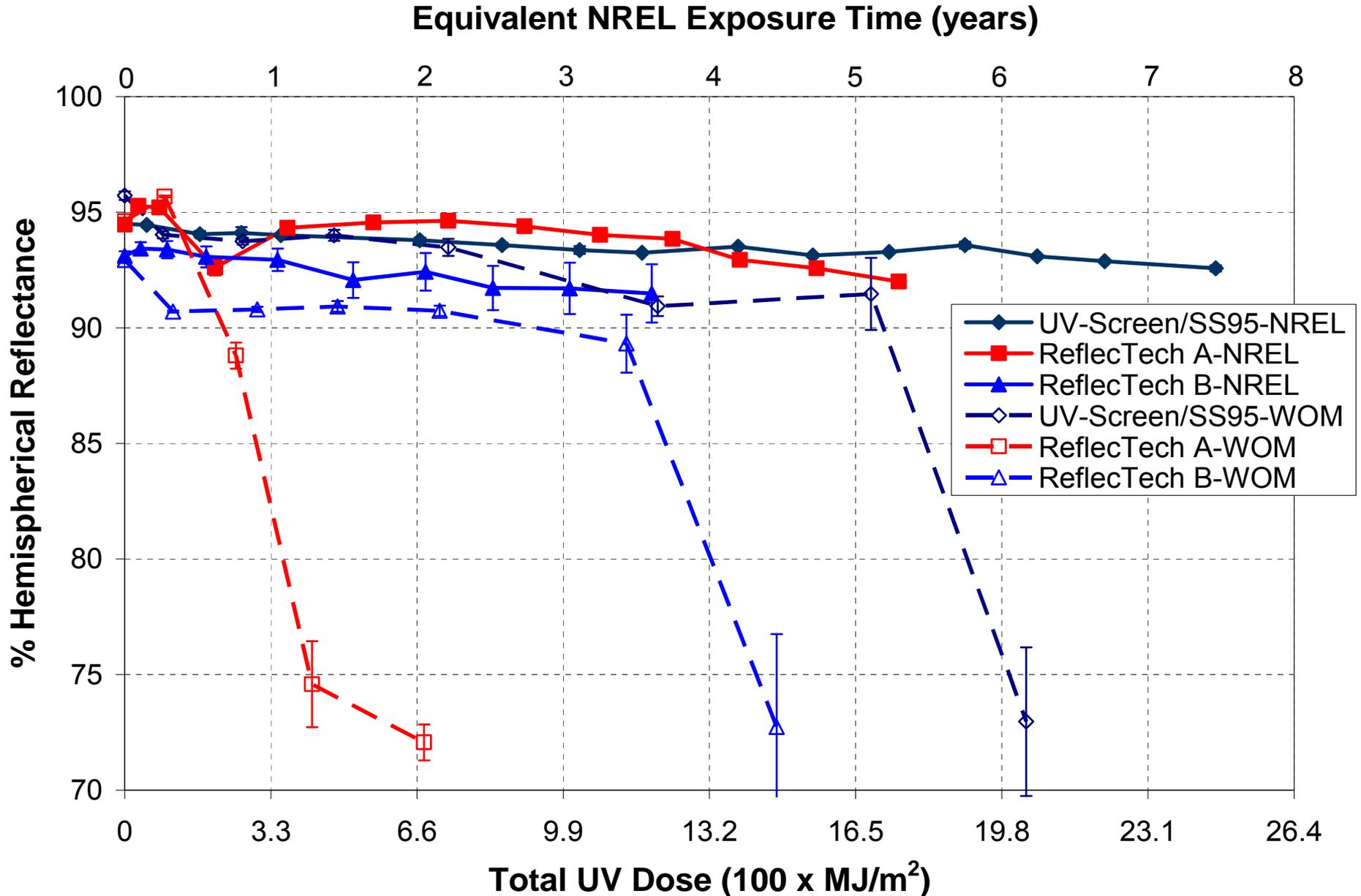
- based on prior NREL collaborations

- ReflecTech CRADA
 - Hardcoats
- Built on:
 - Joint NREL/ReflecTech patent
 - NREL/ReflecTech subcontract



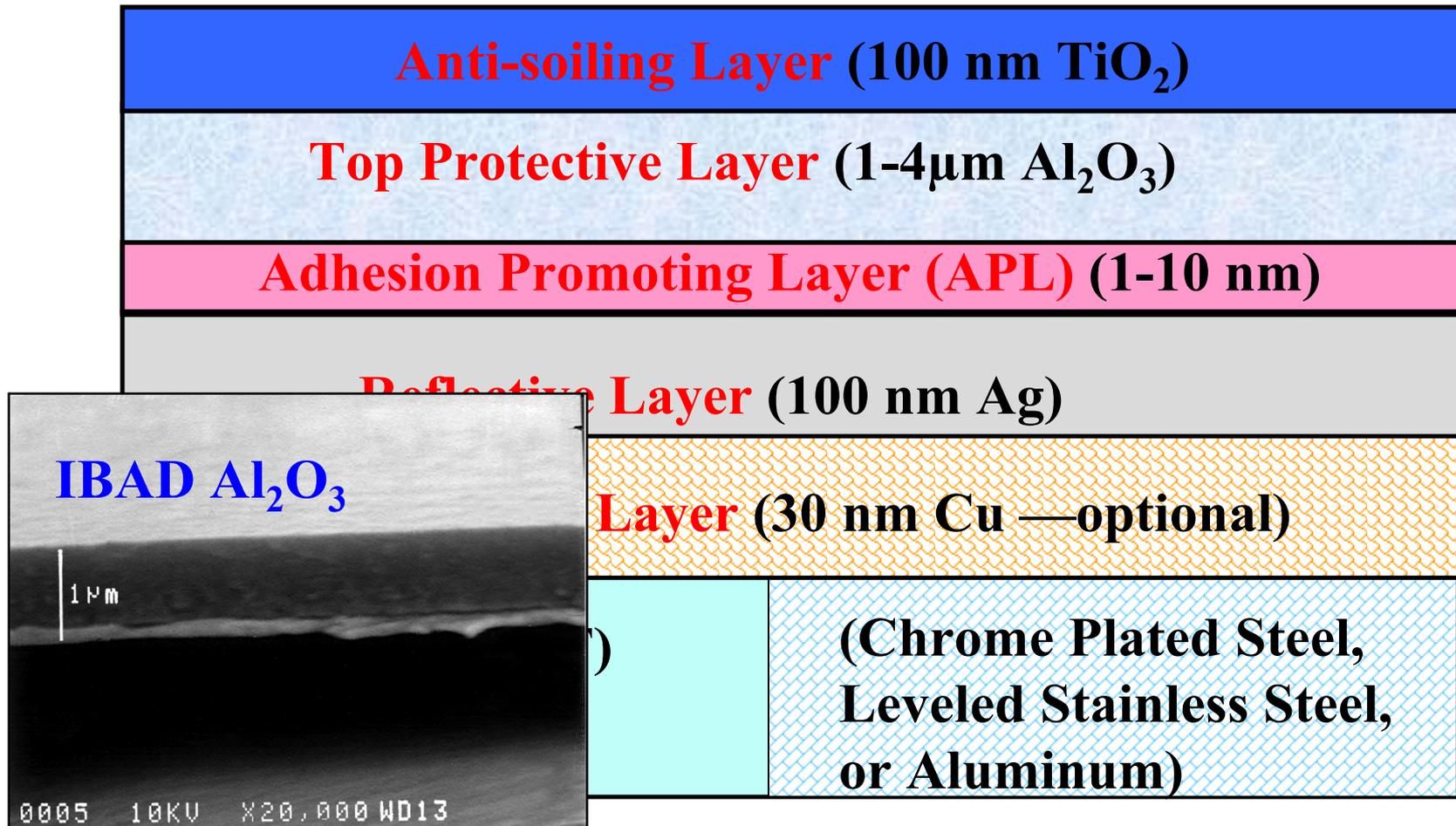
ReflecTech

ReflecTech Prototypes

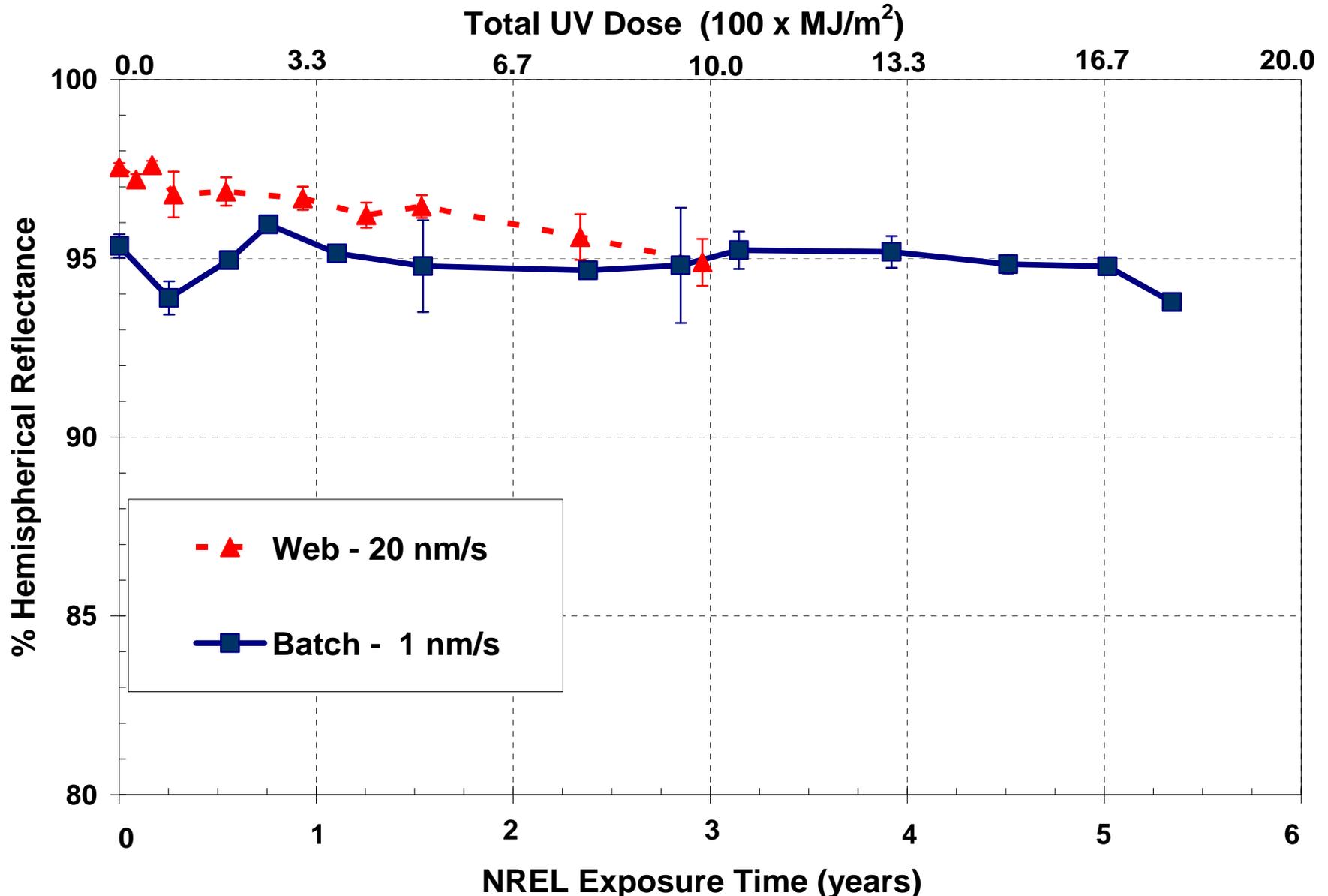


Front Surface Solar Reflector Architecture

- Abengoa Solar (CSP FOA)
 - commercialize NREL / SAIC IBAD Al_2O_3 ASRM subcontract



Outdoor exposure at NREL of Roll-Coated IBAD Al_2O_3 Samples



FY08 Progress Report



2. What will be accomplished in the 3rd and 4th Quarters?

Status of milestones:

a) Level 5:

- Complete installation of new accelerated exposure chambers
- Determine new optical performance, lifetime, and cost goals with industry
- Report summarizing durability silvered thin-glass copper-free & lead-free mirrors after accelerated & outdoor exposure testing

b) Level 4:

- Report summarizing durability of candidate solar mirror samples
- Report summarizing FOA support activities

Future Activities



1. FY09 Planned Activities

a) Follow-on efforts:

- Continue current R&D activities
- Continue to support of CSP FOA awards & industry
- Additional support of Phase II FOA awards
- Upgrade database to web accessible

b) New directions:

- Determine acceleration factor for damp-heat
- Reproduce service lifetime prediction (SLP) methodology for new 3M ECP-305+
- Develop standards and qualification tests with industry for solar mirrors
- Determine soiling rates for different materials at sites

Future Activities



1. FY09 Planned Activities

c) Budget Table - assuming level budget

	FTEs	\$FTE	Purchase	Subcontract
Advanced Concepts	0.83	\$248K	\$100k	\$60k
Advanced Concepts FOA Support	0.63	\$188K	\$100k	\$1900k
Capital Equipment				\$290k

d) Projected Milestones

- Report on solar mirrors and FOA projects
- Upgrade database to web accessible
- Report on soiling rates
- Durability of solar mirror review article

Future Activities



2. FY10 (FY09?) and Beyond Ideas

a) Future Projects:

- Continue to test advanced solar mirrors
- Continue to provide FOA & industry support
- Expand service lifetime prediction (SLP) methodology to other FOA (PPG, Alcoa, Abengoa) materials
- Correlate barrier properties (water & oxygen) with durability for advanced front surface reflectors
- Develop advanced front surface reflector concepts
- Develop advanced antisoiling coatings & cleaning techniques
- Develop CSP/CPV reflector standards

Future Activities

2. FY10 and Beyond Ideas



b) Outside the Box Ideas:

- Overloaded with current task plans and urgent industry request and to need bring new staff up to speed before can brainstorm “Outside the Box” ideas

c) Your vision of the solar future:

- Deployment of parabolic troughs, dishes, and heliostats that use 30 to 50 M m² of highly specular, durable, low-cost, light-weight, advanced solar reflectors with coatings that prevent soiling thus reducing O&M and water usage