CERC-BEE Cool Roofs and Urban Heat Islands:

infrastructure and anti-soiling coatings

2014 Building Technologies Office Peer Review

Ronnen Levinson, Staff Scientist, LBNL
RMLevinson@LBL.gov

Scott Hunter, Senior Research Scientist, ORNL
HunterSR@ORNL.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Summary (Cool Roof Infrastructure)

Timeline:

Start date: January 2011

Planned end date: December 2015

Key Milestones

1. Initiate natural exposure trials in many Chinese cities for roof product rating (6/2014)
2. Start black/white/garden roof experiments in Guangzhou and/or Chongqing (9/2014)
3. Complete modeling of urban, global cooling in Guangzhou (12/2014)

Budget:

Total DOE $ to date: $595K

Total future DOE $: $200K

Target Market/Audience:

Code officials, architects, developers, and building owners that influence roofing product selection in hot-summer Chinese climates.

Key Partners:

Guangdong Provincial Academy of Building Research (GPABR)	Research Institute of Standards and Norms (RISN)
Chongqing University (CU)	Chinese Academy of Sciences (CAS)

Project Goal:

Develop the infrastructure (including policies and rating systems) needed to promote the climate-appropriate use of energy- and carbon-saving cool surfaces (roofs, walls, and/or pavements) in China.

Demonstrate and quantify the benefits of cool-surface technology in China.

Purpose and Objectives (Cool Roof Infrastructure)

Problem Statement: Cool roof benefits (building energy savings, urban heat island mitigation, smog abatement, peak power demand reduction, global cooling) and infrastructure (code requirements and product ratings) need to be established in China to create market for energy-efficient cool roofs.

Target Market and Audience: Code officials, architects, developers, and building owners that influence roofing product selection in hot-summer Chinese climates. Choosing cool roofs for new construction and end-of-service-life replacement in these climates could save 120 TBTU/y source energy and 10 MT/y CO_2 by 2025. Market fraction would be about 50% of Chinese roofing sales.

Impact of Project: Promotes establishment of cool roof credits/requirements and cool roof markets in hot-summer Chinese climates through rigorous demonstration and quantification of cool roof benefits in China.

- Near-term: cool roof credits in some hot-summer climates.
- Intermediate-term: cool roof credits in all hot-summer climates.
- Long-term: cool roof *requirements* in some or all hot-summer climates.

Approach (Cool Roof Infrastructure)

Approach:

Collaborate with GPABR, CU, CAS, and RISN to provide the science needed to support development of cool roof / cool wall credits, requirements, and ratings in Chinese building energy-efficiency standards and incentive programs. Demonstrate cool roof technology in Guangzhou and/or Chongqing, and cool-wall technology in Wuhan.

Key Issues:

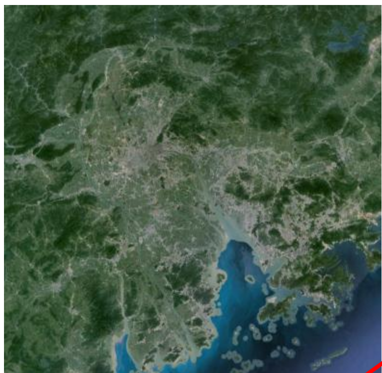
China requires systematic evaluation of cool roof benefits (climate-specific annual simulations and measurements), a roof product rating system, and rationalization of cool-roof credits/requirements in building energy standards.

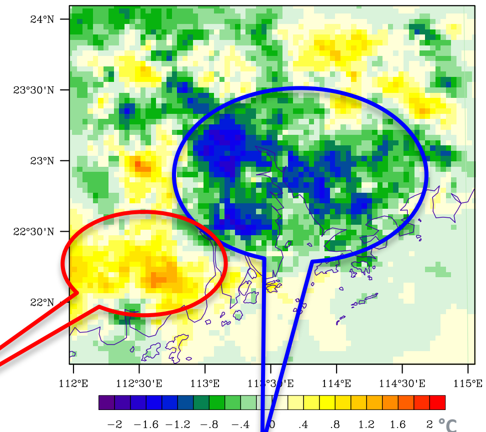
Distinctive Characteristics:

Strong collaboration with 4 Chinese academic/government partners validates that cool roofs work in China, not just in the U.S. All work joint.

Cool roofs can mitigate urban heat islands in China

Modeled changes in 2 m air temperature over 4-day heat wave in Guangzhou (Aug 2004)





Rural temperatures increased by ~0.8°C

Urban temperatures reduced by ~1.5°C

Extend over space

Model changes in air temperature over all regions of China

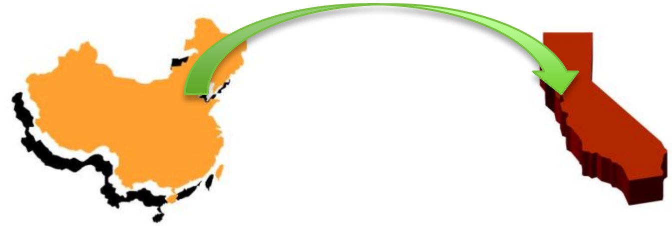
Investigate the causes of the differences between urban and rural temperature changes

Extend over time

Model changes in hourly air temperature by season

Collaborative Effort

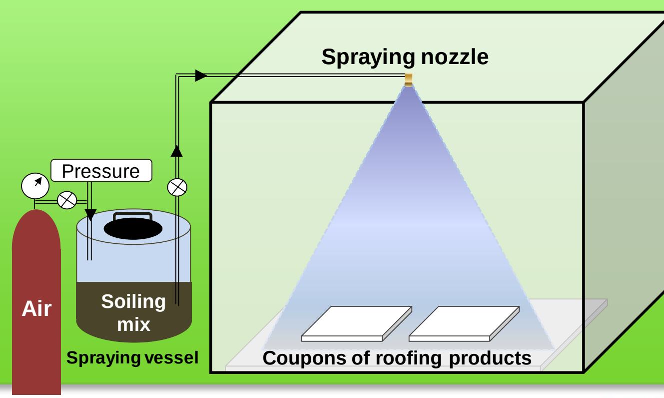
Scientist from the Chinese Academy of Sciences to visit LBNL this summer to model meteorological effects of cool roofs (using DOE's NERSC supercomputers)

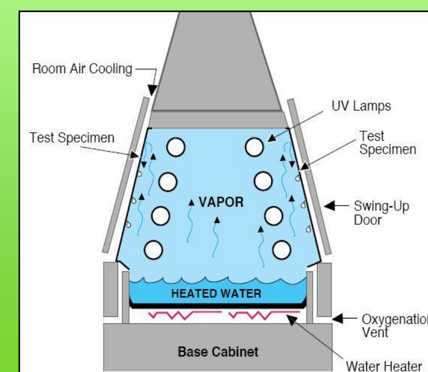


Natural exposure study will accelerate product rating in China

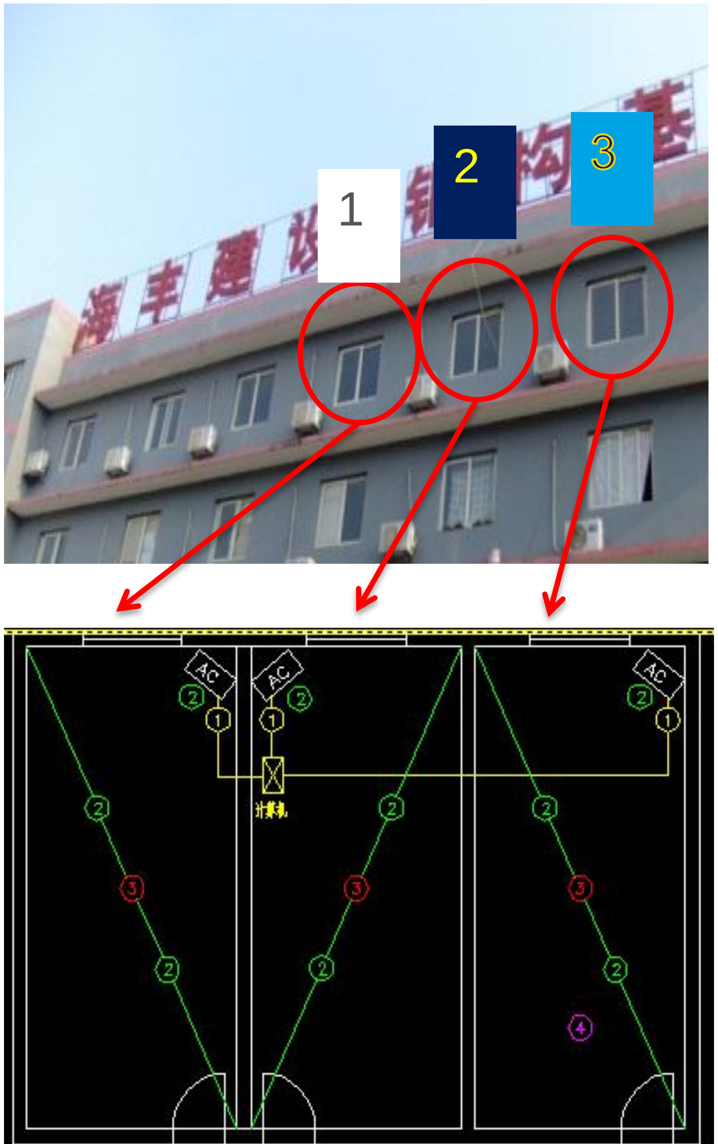
3-year natural exposure

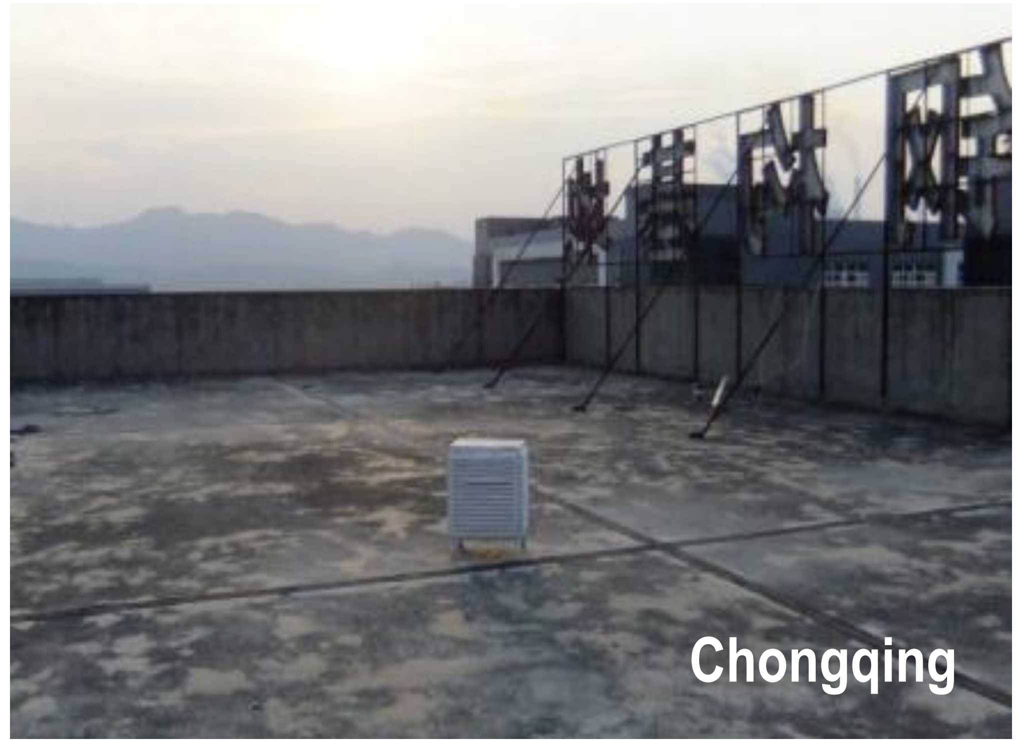
3-day laboratory exposure





Black/white/garden roof experiment to begin this summer





Progress and Accomplishments (Cool Roof Infrastructure)

Lessons Learned:

- Cool walls important in China (many tall buildings with wall area » roof area)
- Chinese also like garden roofs and rooftop PVs (helpful but expensive)

Accomplishments:

- Building simulations (CY12-13) show cool roofs save energy, money, emissions in all hot-summer Chinese climates
- Proof-of-concept experiments (CY12-13) demonstrated savings in Chongqing and Foshan (near Guangzhou)
- Climate simulations (CY13) indicate cool roofs can lower air temperatures in Guangzhou

Market Impact:

Newest national standard credits residential cool roofs in hot summer/warm winter climates; cool roof credits in other standards actively discussed in China.

Awards/Recognition:

None

Project Integration and Collaboration (Cool Roof Infrastructure)

Project Integration:
LBNL collaborates with GPABR, CU, CAS and RISN with in-person meetings (7 in China, 3 in US) and teleconferences. Native Chinese speakers on LBNL team facilitate communication.

Partners, Subcontractors, and Collaborators:
Partners include GPABR & RISN (standards, ratings, and demonstration experiments); CU (demonstration experiments & simulations); and CAS (heat island mitigation and global cooling simulations). Dow Chemical has strongly supported CERC cool roofs.

Communications:
US-China Cool Roof Working Group (Shenzhen, 2011); China National Building Waterproof Association (Beijing, 2011; Berkeley, 2013); CU (Chongqing, 2012, 2013); CAS (Beijing, 2013); Chinese cool-roof standards workshop (Xiamen, 2013); CERC Steering Committee (D.C., 2013). Article submitted to *Energy Policy*.

Next Steps and Future Plans (Cool Roof Infrastructure)

Next Steps (CY2014):

- LBNL/GPABR/RISN initiate a China-specific method for rating the long-term ('aged') radiative properties of roofing materials
- LBNL/CAS quantify the urban- and global-cooling benefits of cool surfaces in Guangzhou
- LBNL/GPABR/CU initiate long-term black/white/garden roof demonstrations in Guangzhou and/or Chongqing

Future Plans (CY2015+):

- Complete at least 1 full year of black/white/garden roof demonstrations in Chongqing and/or Guangzhou
- Demonstrate Dow/ORNL/LBNL anti-soiling white roof coating
- Design large-scale cool surface demonstration for Chinese city
- Rationalize cool roof credits for all hot-summer Chinese climates
- Establish Chinese cool roof rating system

Project Summary (Anti-Soiling Cool Roof Coatings)

Timeline:

Start date: January 2013

Planned end date: December 2014

Key Milestones

1. Quantification cool roof coating self cleaning performance, optical reflectance/absorbance properties; June 30, 2014
2. Demonstrate 9 months stable anti-soiling cool roof coating on a demonstration building; Dec. 31, 2014

Budget:

Total DOE $ to date: $350K ORNL, $150K LBNL

Total future DOE $: $0

Industry cost-share to date: $500K Dow Chemical

Total future industry cost-share: $0

Target Market/Audience:

New building and upgraded cool roof coatings in hot summer US and Chinese climates

Key Partners – Three way CRADA:

Oak Ridge National Laboratory
Lawrence Berkeley National Laboratory
Dow Chemical Company

Project Goals:

Double energy savings of water-based spray-on cool roof coatings over service life by introducing a superhydrophobic additive making the coating waterproof and longer-lasting, and also resistant to soiling and microbial growth and hence solar reflectance (SR) aging.

Demonstrate these coatings in key buildings and facilities in the US and China.

Purpose and Objectives (Anti-Soiling Cool Roof Coatings)

Problem Statement: White cool roof coatings reduce heat load on building air conditioning systems during summer months, but roof soiling causes a loss of optical reflectivity. The project aims to demonstrate that superhydrophobic powders can be added as anti-soiling agents to environmentally friendly, acrylic based cool roof coatings.

Target Market and Audience: Widespread acceptance of cool roofs and cool walls in both residential and commercial construction in China and the USA:

- About 50% of the population in both countries live in hot-summer climates.
- Could upgrade 3B m^2 of roofs by 2025 at no cost (end-of-service-life replacement).

Impact of Project:

The wide scale adoption of this technology by 2025 will lead to saving 120 TBTU/y source energy and with a reduction of 10 Mt/y CO_2.

- Near Term: Demonstrated anti-soiling properties of Dow fabricated coatings.
- Intermediate term: Demonstrated reduced cooling costs for cool roof coated commercial and residential buildings.
- Long-term: Global market size for roof coatings is estimated to be $800M/y with an annual growth rate of 3-5% (Dow estimate).

Approach (Anti-Soiling Cool Roof Coatings)

Approach:

Dow is incorporating ORNL identified, fabricated and tested candidate superhydrophobic (SH) powders in water based acrylic cool roof coatings. ORNL, Dow and LBNL are testing the optical, soiling and microbial resistance of SH coatings and the cool roof coatings incorporating the SH powders.

Key Issues:

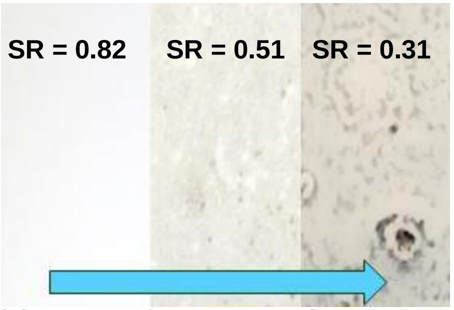
Dispersing water repellent SH powders in water based coatings is a significant challenge. Addition of SH anti-soiling agents must not negatively impact key coating parameters – optical reflectance, abrasion and UV resistance, water permeability.

Distinctive Characteristics:

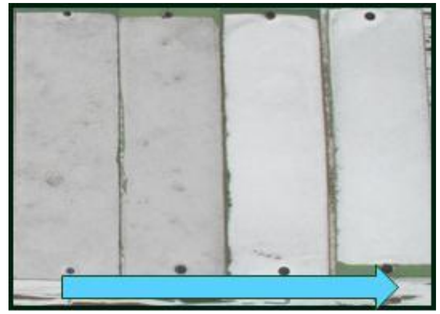
Presently used biocides to control growth of biological organisms (bacteria, fungi, algae, etc.) in paints are toxic and can leach from the coatings. SH anti-soiling powders used in cool roof coatings are biologically inert, extremely cheap and environmentally friendly when incorporated in acrylic (water based) paints.

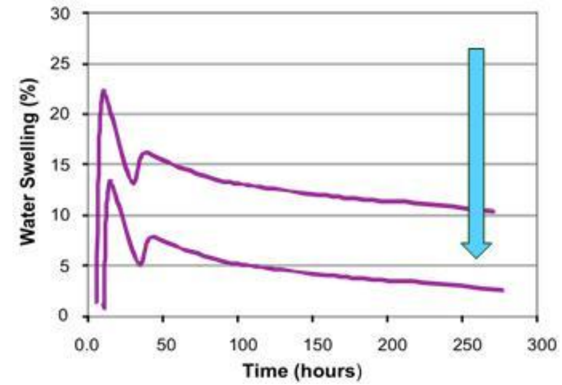
Importance of Hydrophobicity to Roof Coatings

Problem:

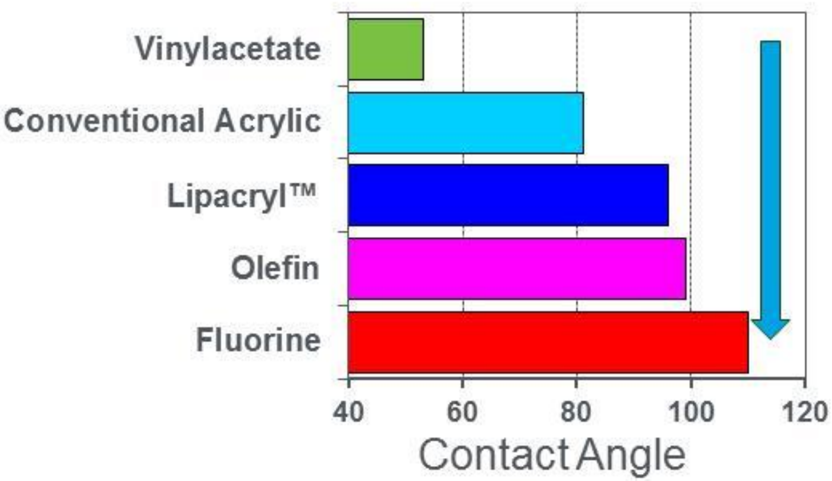


Soiling resistance decreases over time due to soiling and microbial growth





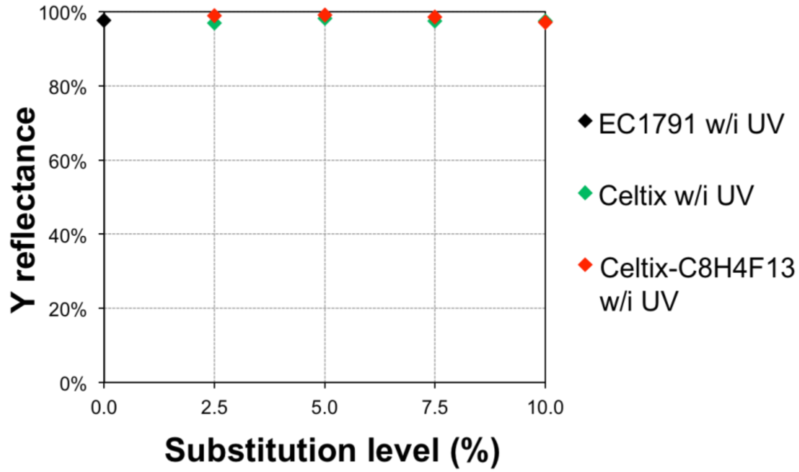
Increasing hydrophobicity can improve dirt resistance and reduce water swelling improving roof coating life



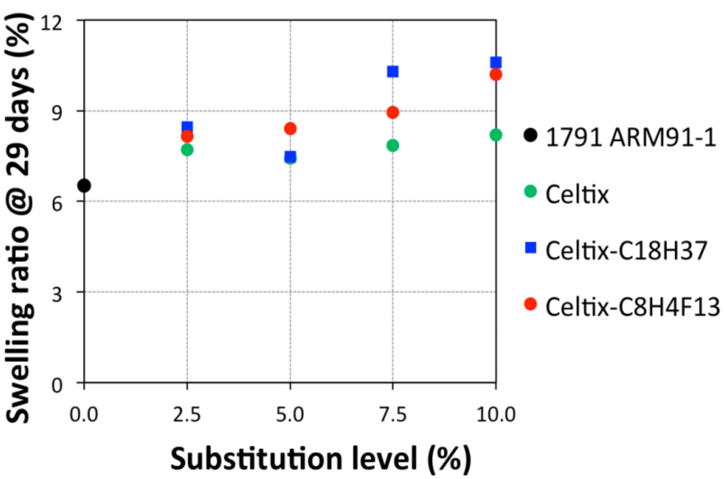
Acrylic chemistry can increase hydrophobicity but not completely solve soiling and water permeation problems

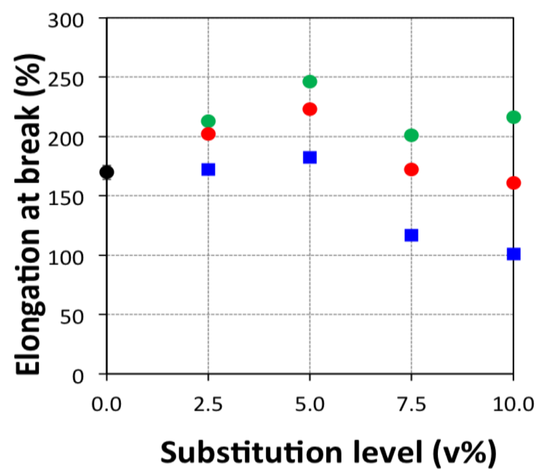
Solution: Superhydrophobic additives increase resistance to water, soiling and microbial growth

Superhydrophobic Powder/Acrylic Coating Studies



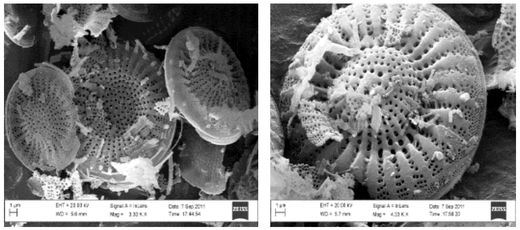
Dirt resistance of EC1791 reference acrylic coating is unaffected by the presence of the SH particles



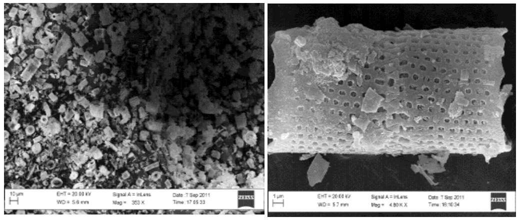


Silica powders provided by ORNL to Dow

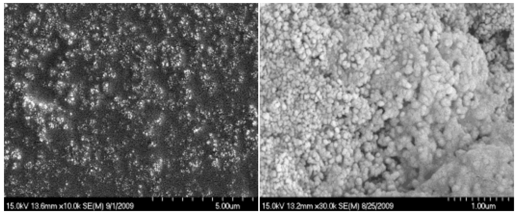
Celtix DE



Diafil DE



Fumed Nanosilica



- ➢ All coatings exceeded elongation at break values >100% of the ASTM standard
- ➢ Water adsorption of coatings greater than for the reference acrylic coating

Accomplishments (Anti-Soiling Cool Roof Coatings)

Accomplishments:

- Dow has found that the dispersability of ORNL SH Extenders into aqueous acrylic roof coatings can be achieved using dispersants and high shear mixing
    - **This was one of the main challenges of the project – dispersing water repellent powders in water based acrylic coatings**
- Dow has observed significant improvement in dirt resistance, a surface property, using fluorinated silane functionalization for the superhydrophobic particles embedded in the acrylic coatings
- ORNL has initiated anti biofouling studies using surface modified SH coatings that are expected to have enhanced anti biofouling properties
- 2 invention disclosures submitted: J. Simpson and G. Polyzos, “Superhydrophobic Coatings using Double Silane treated Silica Particles.” S. Allman, M. Cheng, A. Desjarlais and D. Graham, “Art and Method on Accelerating Microbial Test of Materials.”

Market Impact:

Too early in the cool roof coating development cycle to have any measureable market impact to date.

Awards/Recognition:

None

Project Integration and Collaboration

Project Integration:

Researchers at ORNL and LBNL regularly hold teleconferences with technical staff at Dow, and exchange materials and test results to rapidly identify and resolve coating development issues.

Partners, Subcontractors, and Collaborators:

Three way CRADA established between partners:

ORNL—fabrication, testing and supply of SH powders & microbial growth testing

LBNL—accelerated soiling and weathering tests & optical reflectance characterization

Dow Chemical—develop and test anti-soiling acrylic cool roof coatings

Communications:

Broad Homes (China) and China National Building Waterproof Association seminars (ORNL, Feb. 2013)

U.S. China CERC-BEE Joint Workshop (Wuhan, China, Oct. 2013)

CERC Steering Committee (D.C., 2013), CERC-BEE IAB Meeting (Berkeley, 2014)

Next Steps and Future Plans (Anti-Soiling Cool Roof Coatings)

Next Steps (CY2014):

- ORNL provides various fluorosilane functionalized silica based SH powders for Dow's acrylic based cool roof paint development effort
- ORNL will use an accelerated microbial testing protocol and test facility to test proposed new modified SH materials and coatings
- LBNL will implement its accelerated aging methodology (standard and extended approach) to evaluate the retention of solar reflectance in aged SH coatings, and will determine changes in hydrophobicity with contact angle measurements
- ORNL, Dow and LBNL will characterize coupons coated with these acrylic resins for water repellency and optical properties in comparison with standard solvent based coatings

Future Plans (CY2015+):

- Measure optical properties of anti-soiling coatings after one year of accelerated microbial growth (ORNL) and roof soiling (LBNL) conditions
- Demonstrate Dow/ORNL/LBNL anti-soiling white roof coatings in U.S., China
- Dow will launch a commercial cool roof coating to a select number of customers that includes SH materials with improved life and maintenance of cool roof properties

REFERENCE SLIDES

Project Budget (Cool Roof Infrastructure)

Project Budget: $595K (LBNL, CY11-CY14)
Variances: none
Cost to Date: $400K (LBNL)
Additional Funding:
GPABR & RISN funded by Energy Foundation Beijing Office. CAS self-funded.

Budget History					
CY11 – CY13 (past)		CY14 (current)		CY15 (planned)	
DOE	**Cost-share**	**DOE**	**Cost-share**	**DOE**	**Cost-share**
$395K	None (US)	$200K	None (US)	$200K	None (US)

Project Plan and Schedule (Cool Roof Infrastructure)

Project Schedule		
Project Start:1/2011		Completed Work
Projected End:12/2015		Active Task (in progress work)
Project evaluated annually		Milestone/Deliverable (Originally Planned) use for missed
		Milestone/Deliverable (Actual) use when met on time

	CY2013				CY2014				CY2015			
Task	Q1 (Jan-Mar)	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar)	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar)	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)
Past Work												
Q1: Survey availability of climate simulation inputs												
Q2: Measure heating penalty in Chongqing												
Q3: Initiate Chinese climate simulations												
Q4: Revise roof rating measurement techniques												
Q1: Review cool roofs credits/requirements in China												
Current/Future Work												
Q2: Initiate natural exposure trials in China												
Q3: Begin black/white/garden roof experiment(s)												
Q4: Draft cool roofs credits for Guangdong province												

Project Budget (Anti-Soiling Cool Roof Coatings)

Project Budget: $350K (ORNL, CY13-CY14) + $150K (LBNL, CY13-CY14)

Variances:

Cost to Date: CY13 and CY14 cost to date = $175K (ORNL) + $25K (LBNL)

Additional Funding: Dow anti-soiling coating development work self funded

Budget History					
CY2013 (past)		CY2014 (current)		CY2015 (planned)	
DOE	Dow cost-share	DOE	Dow cost-share	DOE	Cost-share
$225K (ORNL) $25K (LBNL)	$250K	$125K (ORNL) $125K (LBNL)	$250K	0	0

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Plan and Schedule (Anti-Soiling Cool Roof Coatings)

Project Schedule	
Project Start:Jan. 2013	Completed Work
Projected End: Dec. 2014	Active Task (in progress work)
	Milestone/Deliverable (Originally Planned) use for missed
	Milestone/Deliverable (Actual) use when met on time

	CY2013				CY2014				CY2015			
Task	Q1 (Jan-Mar	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)
Past Work												
Q1: Complete three way CRADA												
Q2: Provide SH silica samples to Dow												
Q3: Dispersion silica powders in water based acrylic												
Q4: Complete first evaluation acrylic formulation												
Q1: Complete anti-soiling coating development												
Current/Future Work												
Q2: Complete pigmented formulation development												
Q3: Accelerated microbial growth and soiling experiments												
Q4: Accelerated environmental coating tests complete												

A Project of CERC-BEE (US-China Clean Energy Research Center Building Energy Efficiency Consortium)

Pioneering U.S. – China Innovation for Widespread Adoption of Very Low Energy Buildings Through Partnerships and Real World Impact

BERKELEY LAB · OAK RIDGE National Laboratory · MIT · ICF International · NRDC · UC DAVIS University of California

U.S. Research Leads

DOW · Energy Foundation · SAINT-GOBAIN · Bentley · ClimateMaster · C3 Energy · 3M · LUTRON

U.S. Industrial Partners *(Funding +40% Annual Average Growth Rate)*

Research Strategy → Huge Impact:
- U.S./China construction market ~ 2B m2
- CO_2 savings ~ 100Mt/year by 2025

Technologies, Software → **New Patent Applications**

Demonstration Buildings, Commercial Impact, Tools and Guidebooks → **Market**

Wide Adoption Very Low Energy Buildings → **Policy**

ABOUT: CERC-BEE is a five year, $50M program created by the U.S. Department of Energy and Chinese Ministry of Science and Technology.

R&D TEAMS: U.S. national laboratories, and U.S. and Chinese universities, and research institutes team up with industry partners to accelerate innovation and deployment.

SELECTED RESEARCH OUTCOMES:
- Launched eight new products and developed two software tools (e.g. Cloud tool for microgrids, 40 new users from China)
- Won R&D Top 100 Award for GSHP by Climate Master
- Exceeded IP goals: ~ 25 patents filed, 4 approved; inventions disclosed and more in process (e.g. sprayable liquid flashing, cool roof materials)
- Developed 20 standards (e.g. LBNL involved in new Chinese commercial building code revision)
- Published 135 Chinese and 54+ US academic research papers

Website: cercbee.lbl.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy