PEG LLC

Providing ground-breaking technologies for energy applications

Erosion Resistant and Ice-Release Coatings for Wind Turbines

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NSF SBIR Awards # 1248831 & 1353626

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Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

VCU
VIRGINIA COMMONWEALTH UNIVERSITY
School of Engineering | Chemical and Life Science Engineering

Icing

> Compromised power

> Safety Issues

> Disrupted

- transportation
- communications
- production

Release by Gravity

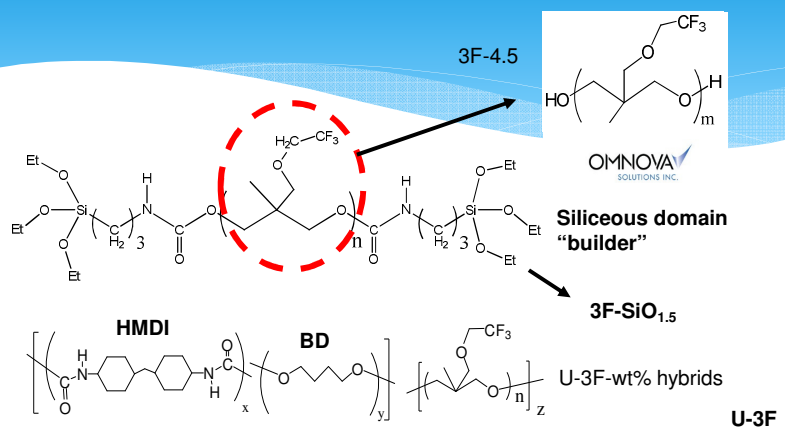
Testing after the frozen rain and snow on February 18, 2015

Release by Gravity

Testing after the frozen rain and snow on February 18, 2015

Richmond, VA, USA

Hybrid Coating

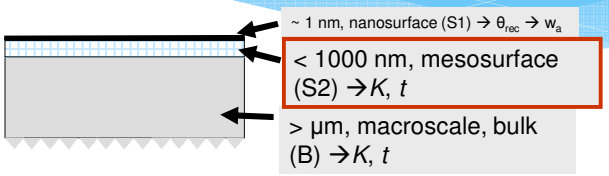


Macromolecules **2013**, 46, 2984, DOI: 10.1021/ma4001995

Patents pending: WO2013016594/US2012048425, US20140302267

VCU/PEG Ice-release Model

New concept: importance of **mesosurface**



Theory: Eqs

Peak Removal Force in shear, $P_{c\text{-}s}$ $P_c \propto A\left(\frac{2w_a K}{t}\right)^{1/2}$ Kendall, K. *J. Physics D Applied Physics* **1971**, *4*, 1186-1195.

$RE \propto \frac{\sqrt{K w_a} A^{7/4}}{t^2}$ Removal Energy (VCU, theoretical work underway)

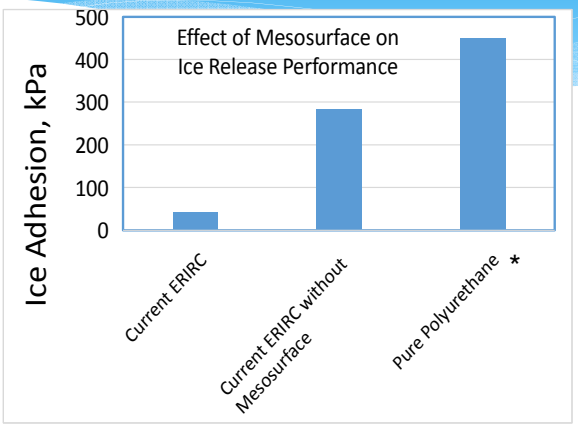
Rigid Adherent-Resistant Elastomers (RARE): Nano-, Meso-, and Micro-scale Tuning of Hybrid Fluorous Polyoxetane – Polyurethane Blend Coatings, Souvik Chakrabarty, Chenyu Wang, Wei Zhang, and Kenneth J. Wynne, *Macromolecules* **2013**, DOI: 10.1021/ma4001995

Surface and Mechanical properties of Some Materials

Materials	Surface Energy (mJ/m²)
PHFPP (Poly-hexafluoropropylene)	12.4
PTFE	19.1
Polyethylene	33.5
Epoxy	46.2
PVC	41.5
Water	72.2
Aluminum Oxide	169

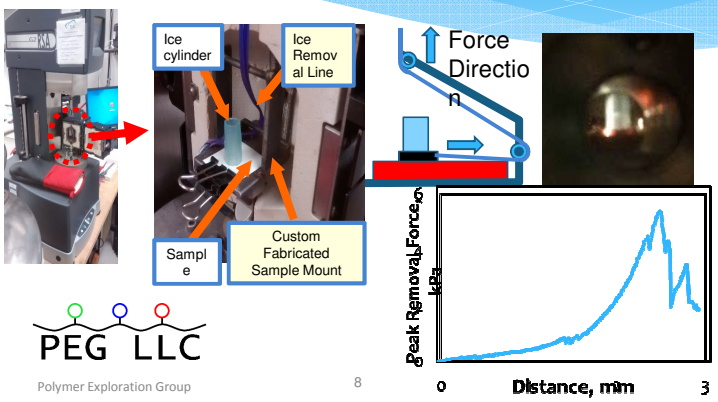
Materials	Modulus
Silicone Rubber	1-100 MPa
Plastics	100 MPA-10 Gpa
Composites	10-100 Gpa
Aluminum	~50 Gpa
Steel	~200 Gpa

The importance of mesosurface



* Pure Polyurethane did not release ice. Substrate slide out of sample holder

High Throughput In-House Ice-Release Testing



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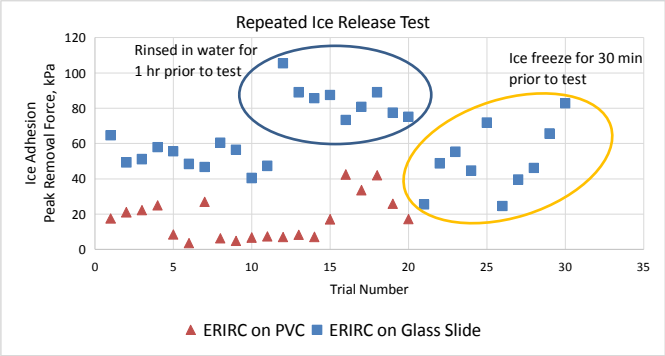
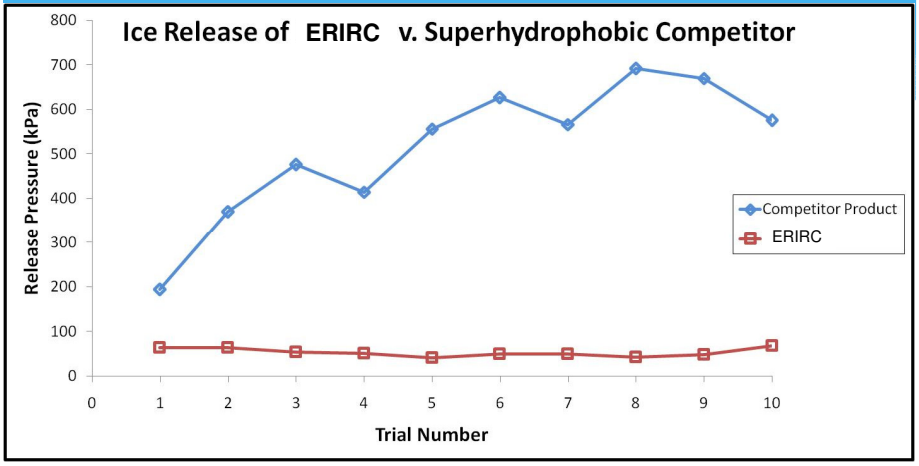
Durability Demonstration by Repeated Ice Release Trials



Each data point represents a subsequent ice release trial at the same location on a single sample

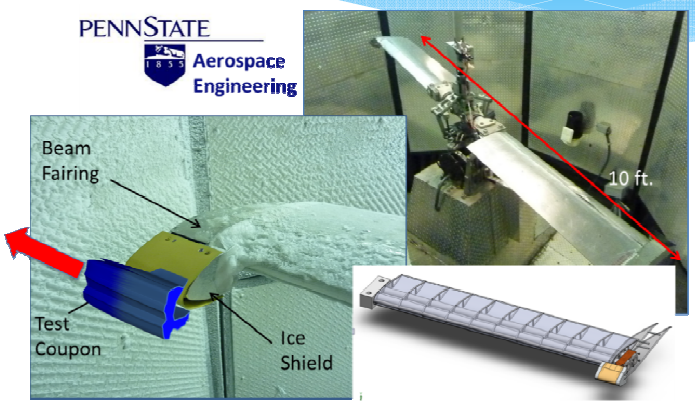
ERIRC ice release performance vs. super-hydrophobic competitor



Ice release of commercially available competitor product was often too high to measure with available instrumentation.

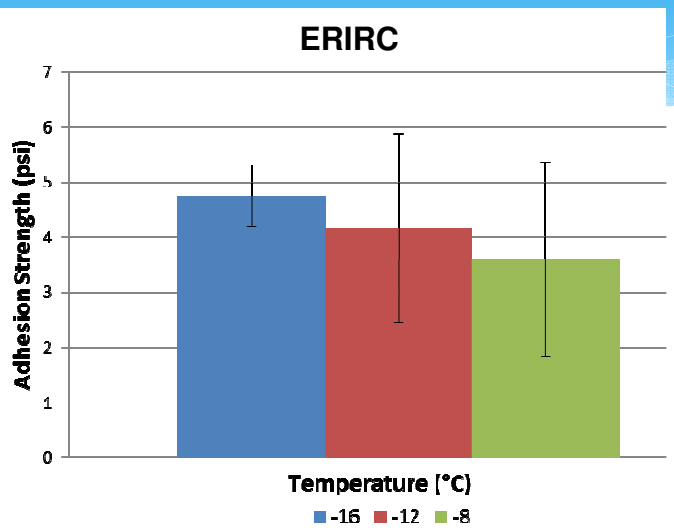
Third Party Test at Penn State

PENNSTATE Aerospace Engineering



White Coating Post Shed Images (- 16 Deg. C)

Third Party Test at Penn State



Results from PSU

PENNSTATE Aerospace Engineering

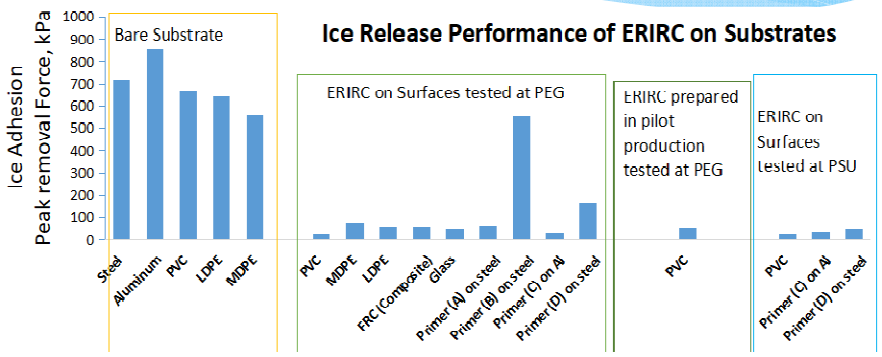
ERIRC

Temp (°C)	-8	-16		ER-Coat-W -8	-16
Test 1 Blade 1 (psi)	3.36	2.65		5.34	4.57
Test 1 Blade 2 (psi)	2.62	2.29		4.97	5.71
Test 3 Blade 1 (psi)	5.32	--		5.99	5.73
Test 4 Blade 2 (psi)	4.98	5.59		4.23	7.8

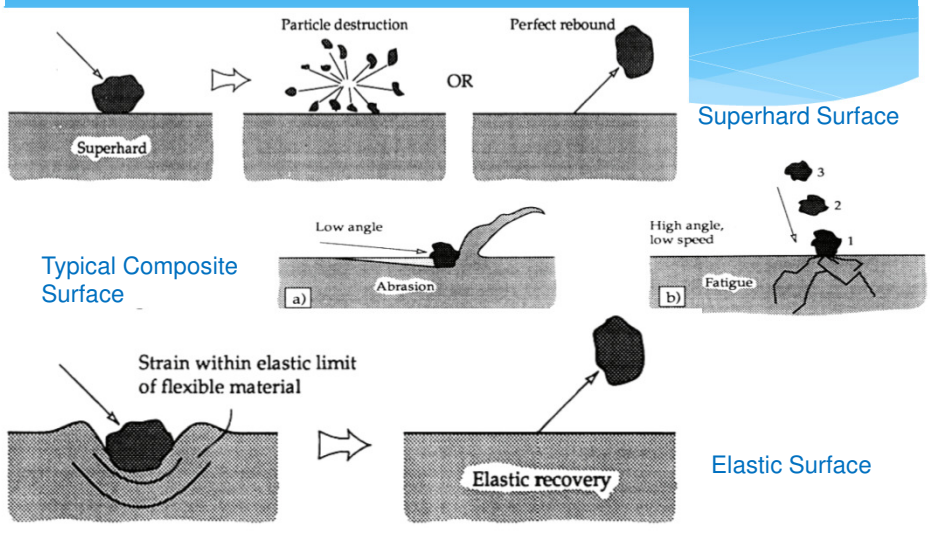
Cloud Parameters	
LWC (g/m^3)	2
MVD (μ)	20
Air Pressure (psi)	20
RPM	400

All coatings are first tested at -16°C, then -8°C

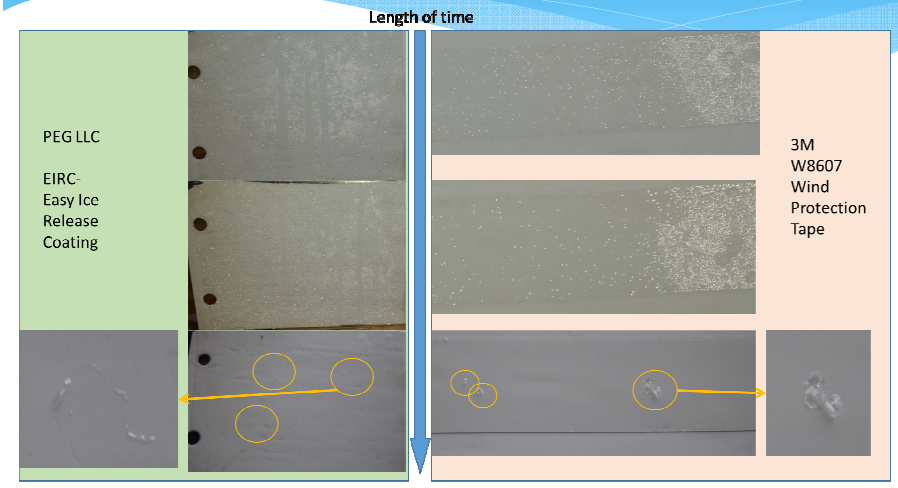
Ice Release Performance of EIRC on Substrates



Erosion of Wind Turbine Blades

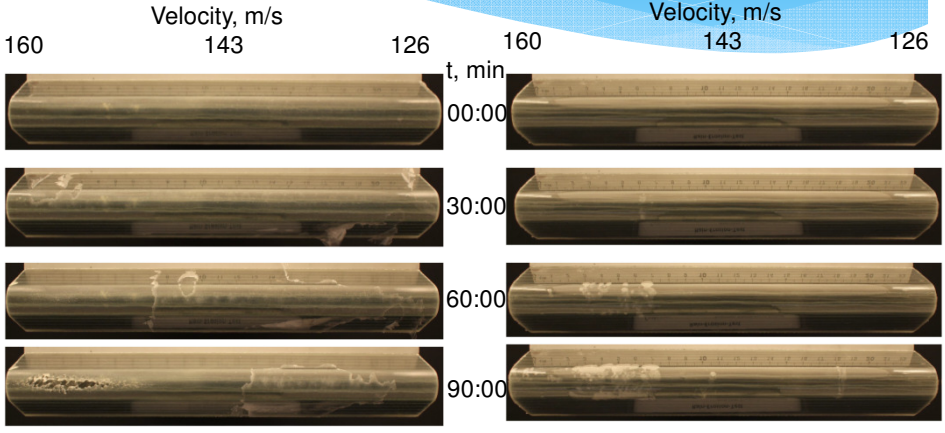


In-House Preliminary Erosion Test for ERIRC Materials



Third Party Erosion Test

PolyTech A/S, Denmark



Typical Wind Turbine Blade Tip Speed: <80 m/s

PEG LLC *Ice-Release Materials*

NSF SBIR Awards # 1248831 and 1353626

- Low ice adhesion for Easy Release (ER) from surfaces
- Non-leaching, non-compensative coating
- Easy coating process for spray or brush coating processes
- Cost effective with commercial engineering materials; durable
- Good adhesion w or w/o primer or tie coating
- Tough bulk, soft surface and durable
- Low cost to produce
- Can be transparent

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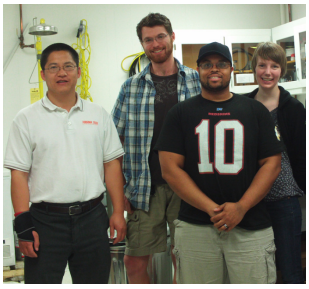

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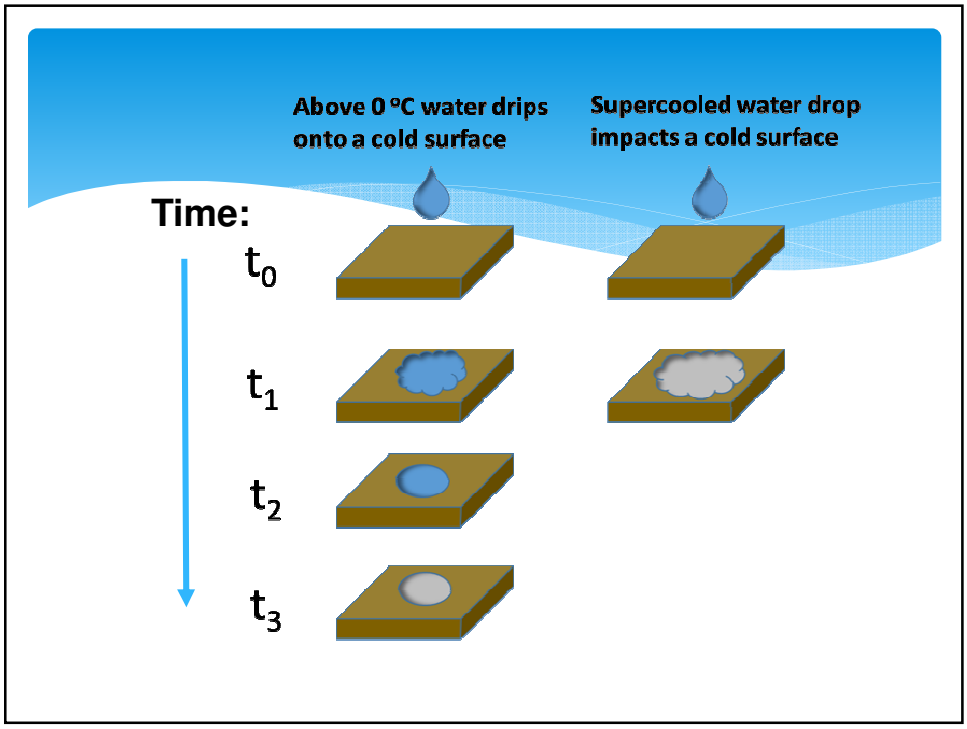
From left to right : Wei Zhang, Cameron Brinn, Kennard Brunson, and Dana Klein


Above 0 °C water drips onto a cold surface
Supercooled water drop impacts a cold surface
Time:
t_0
t_1
t_2
t_3