



# Development of environmentally-friendly packaging and the challenge of meeting everyone's expectations

**William Orts**  
**USDA**

January 14, 2020



# USDA Western Regional Research Center



## **Albany, California**

~400 people

~50 in Biofuels/  
& Bioproducts

Known for crop biotech.





.....our visit to Illinois, especially this morning at the State fair, was to

**bring a special message to America's farmers, one of concern and hope.**

Amid general prosperity that has brought record employment, rising incomes, and the lowest inflation in more than 20 years, some sectors of our farm economy are hurting, and their anguish is a concern

to all Americans.

*"The nine most terrifying words in the English language are: I'm from the Government, and I'm here to help." -- Ronald Reagan, 1986*



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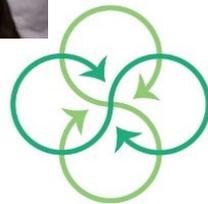
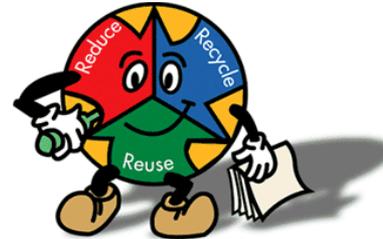
# Partnerships: Industrial Collaborators



method.



SALINAS VALLEY  
SOLID WASTE AUTHORITY  
*Promoting the Environmental Health  
of the Salinas Valley*



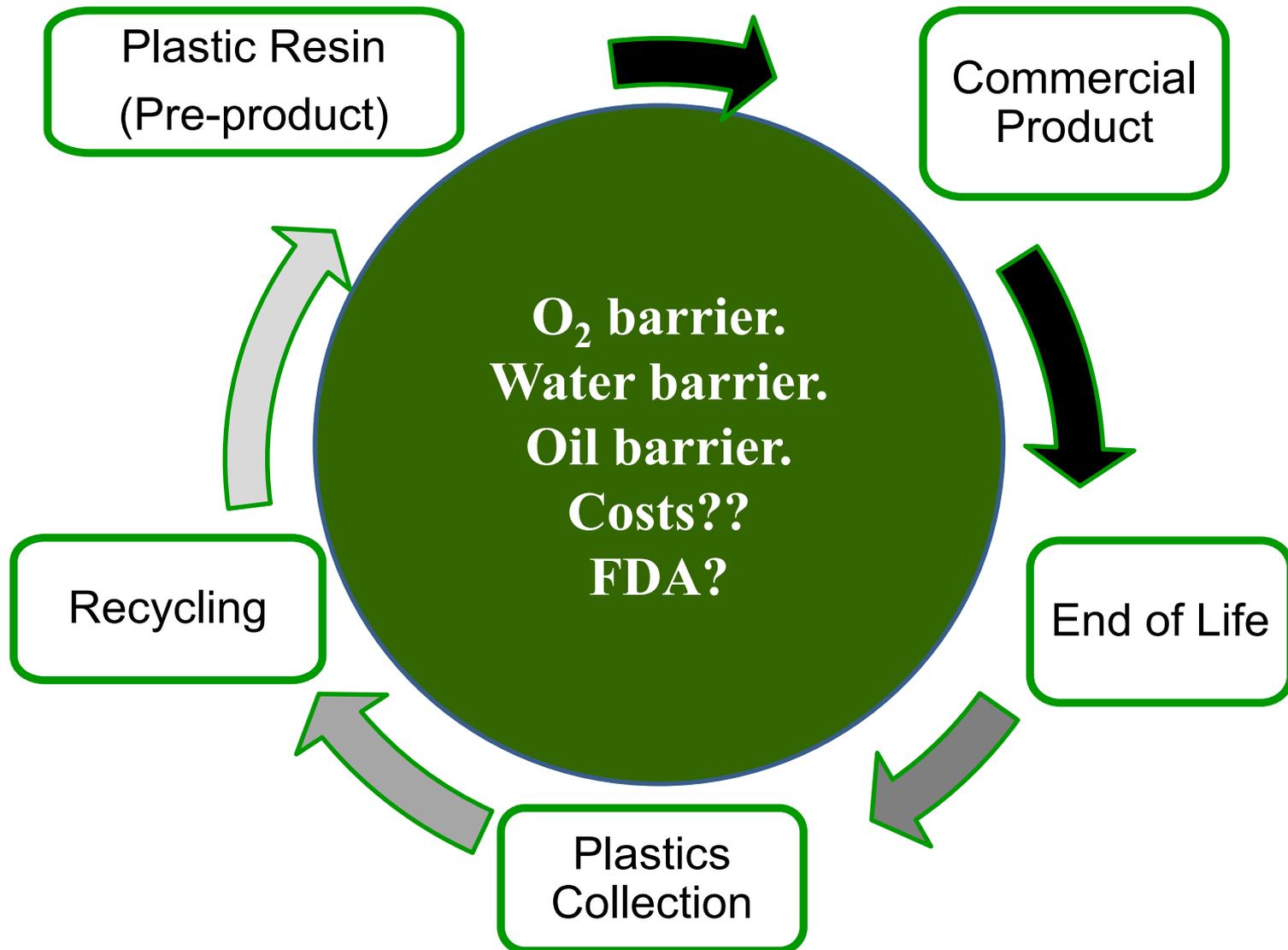
FULL CYCLE  
Bioplastics for the Circular Economy



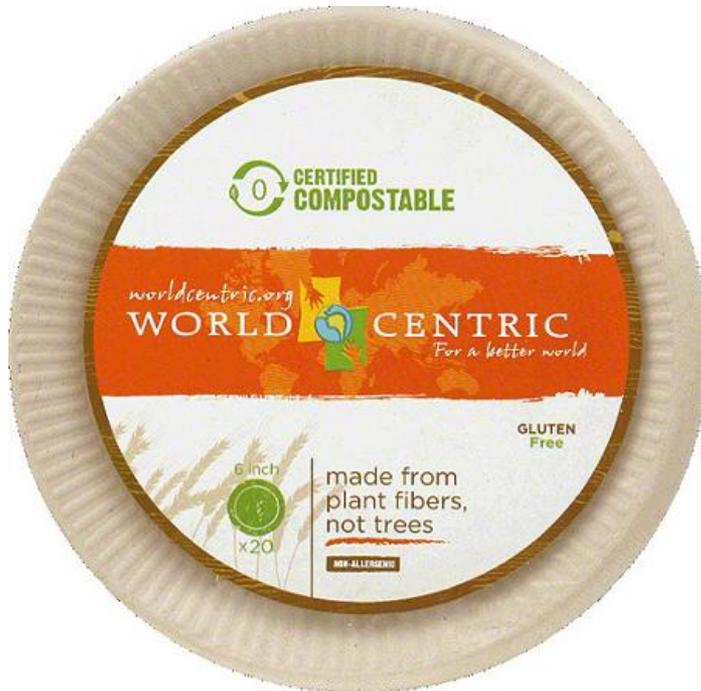
CORUMAT  
BETTER MATERIALS



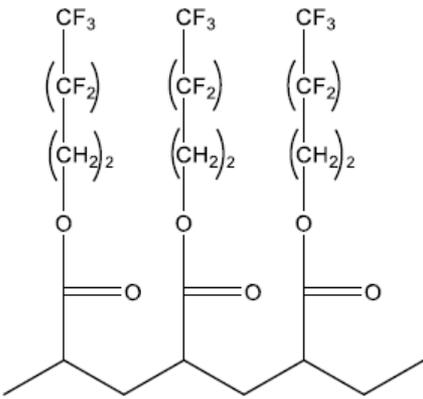
# Circular Economy of Packaging



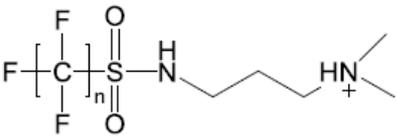
# Partnership: Single use items



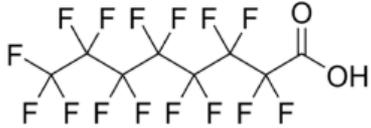
# Customer expectations are high.....



Fluoroacrylate Polymers



Polyfluorinated Alkyl Chain

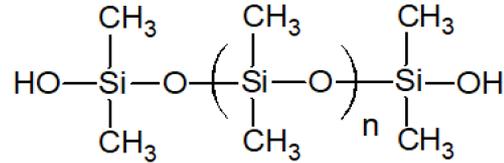


Perfluorinated Alkyl Chain



# Grease Resistant Coatings – Silicon derivatives

- Siloxanes/ silanes



- Treated “nanoclays”

- Pure silicone vs hybrids



The European Chemicals Agency (ECHA) and their sub-group, Committee for Socio-Economic Analysis (SEAC), adopted its final opinion to restrict

- octamethylcyclotetrasiloxane (D4, CAS 556-67-2) and
- decamethylcyclopentasiloxane (D5, CAS 541-02-6).

D4 and D5 are high volume chemicals (HPVCs) with persistent, bioaccumulative and toxic (PBT) properties.

# Greener (?) Grease Resistant Coatings

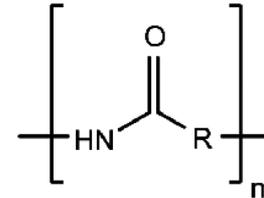
- Prolamines
- Treated cellulose/  
regenerated cellulose
- Cellulose nanofibrils/  
microfibrils.
- Biopolymers



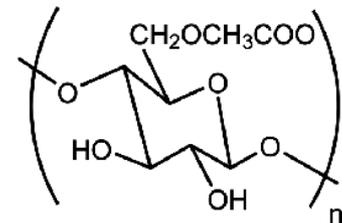
PROTEAN™  
Grease Barrier

<https://www.hsmgrp.com/products/grease-resistant/>

**Zein**



**CA**



Possibilities:

- Poly(lactide) PLA, P(3HB)
- Microbial Polyesters & Blends

# PFAS Free Options

## Greener Solutions to Fluorinated Durable Water Repellency

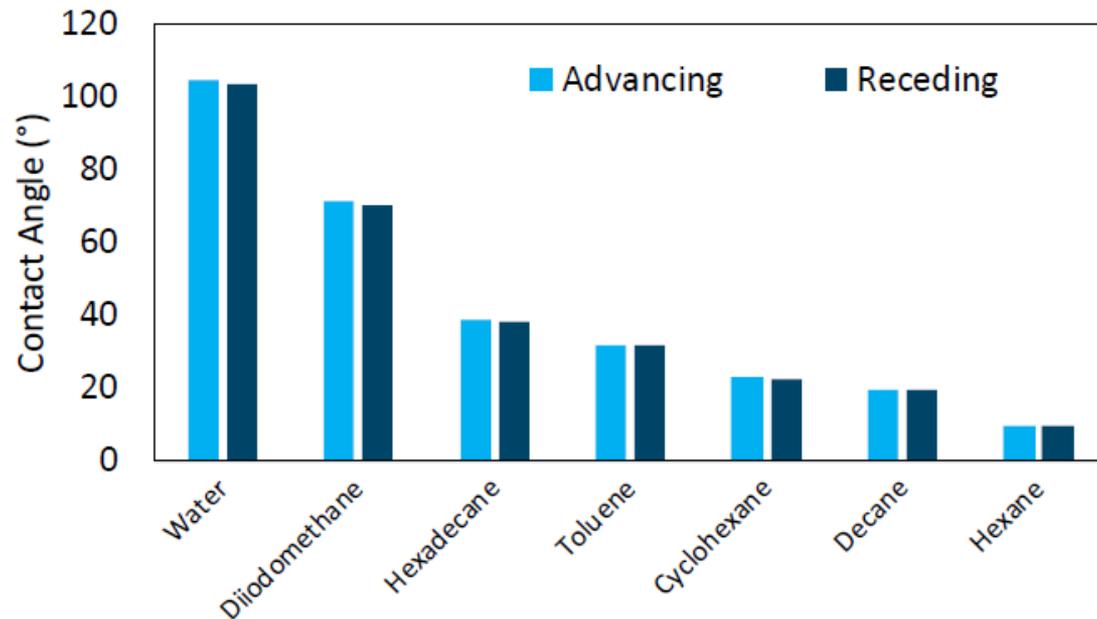
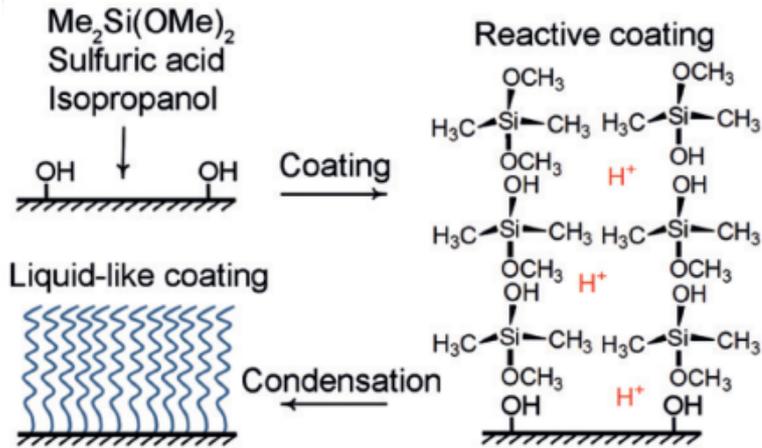
Marianna Augustine, Emily Cook, Erin Creel, Sumana Raj, John Wright



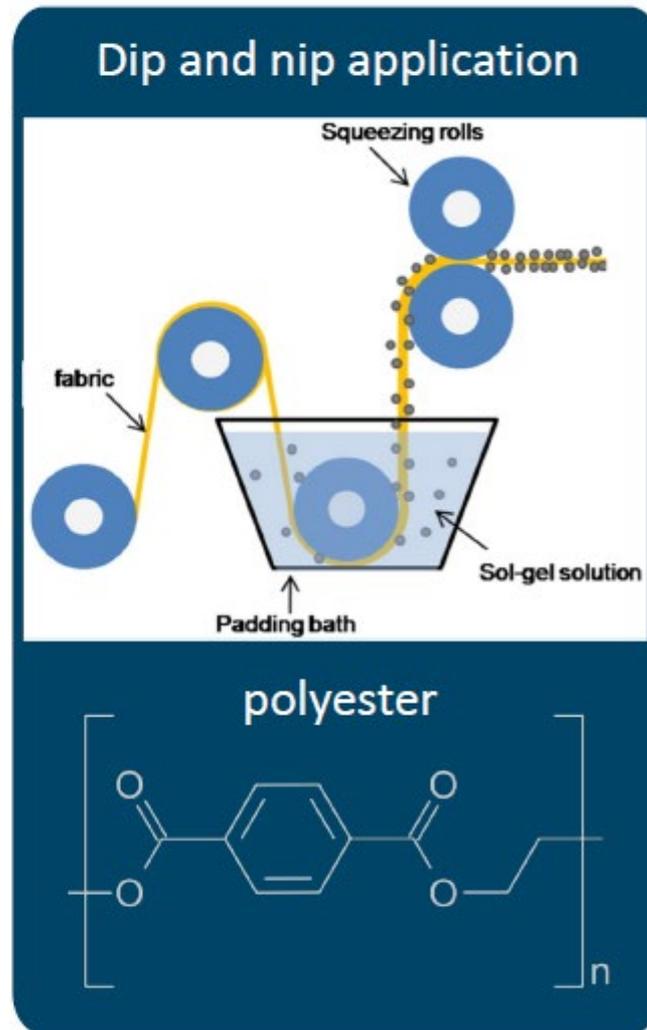
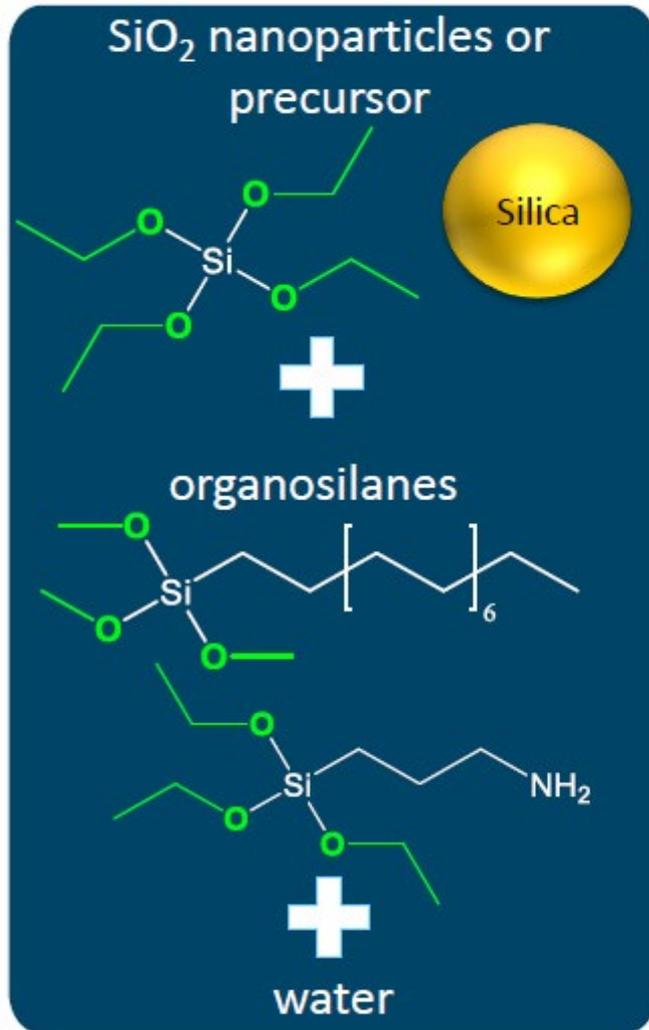
Hydrophobicity	Oleophobicity
Gore goals	Gore goals
Advancing > 115 degrees	No Penetration of high surface tension oils for 30 seconds
Receding > 95 degrees	Proxy: oil contact angle
PFAS performance:	PFAS performance:
Static: 118 degrees	<i>n</i> -heptane: 40 degrees <i>n</i> -hexadecane: 70 degrees



# Siloxane Coatings



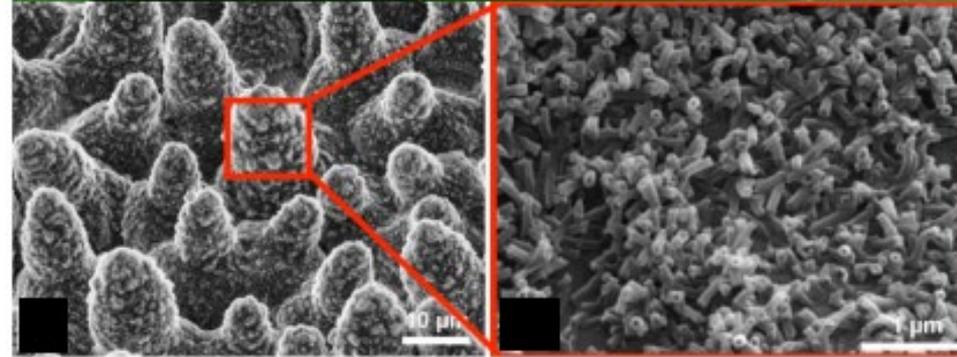
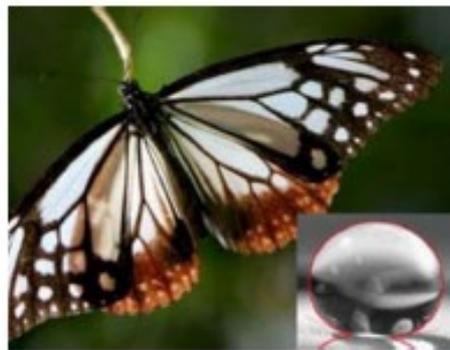
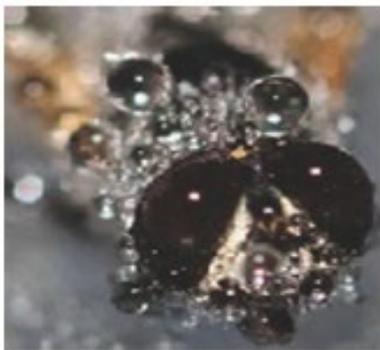
# Nanosol Coatings



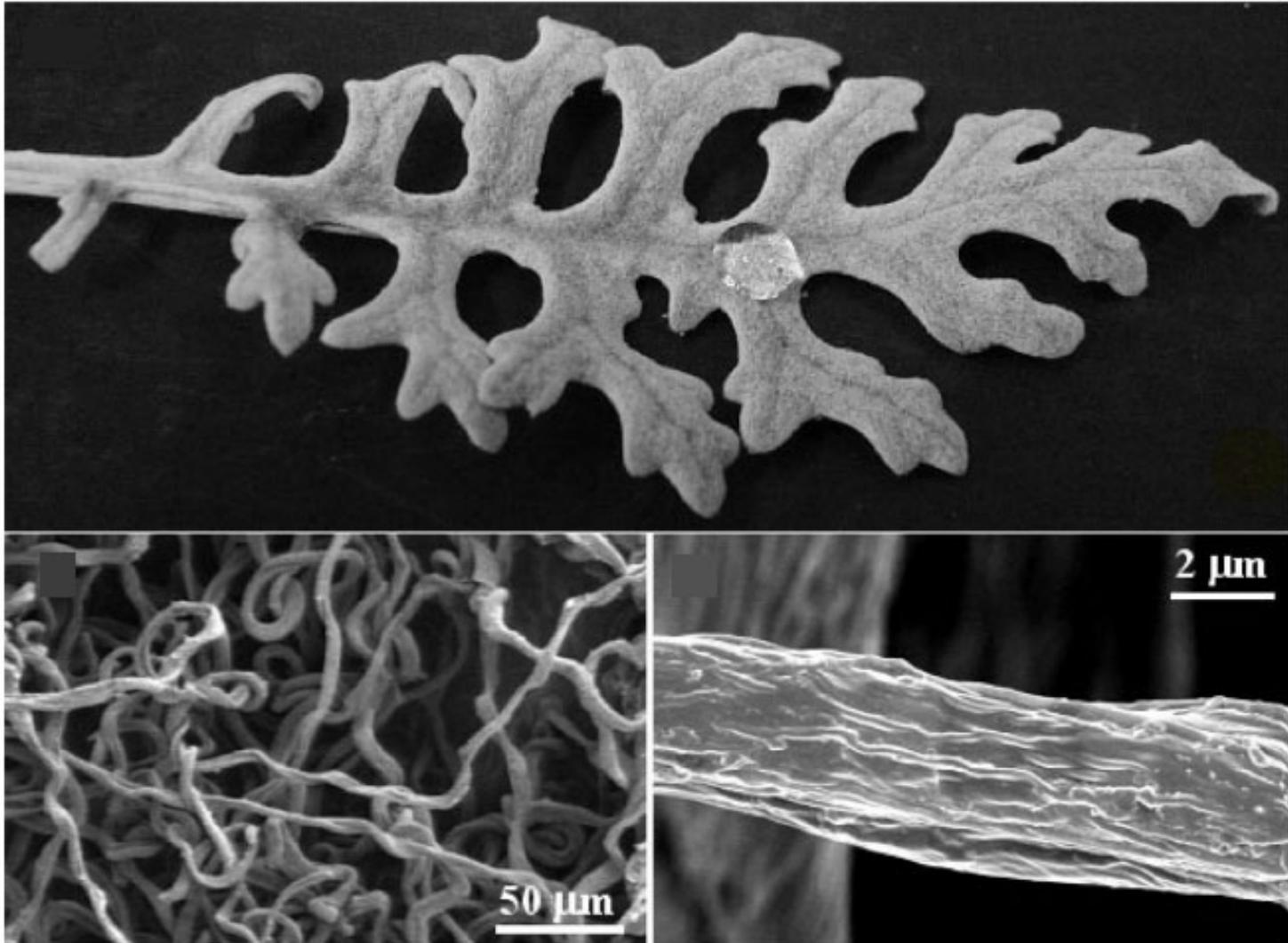
# Nanosol Hazard Profile

Compound	Human Toxicity				Environmental Toxicity		
	Mutagenicity	Organ	Respiratory	Reproductive	Persistence	Aquatic	Fate
Silica nanoparticles Amorphous Silica							Not PBT
(3-aminopropyl) triethoxysilane (APTES)		Skin, eye irritant			Not bioaccumulative	Aquatic risk	Not PBT
Hexadecyltrimethoxysilane (HDTMS)		Skin, eye irritant			Not bioaccumulative	Aquatic risk	Not PBT

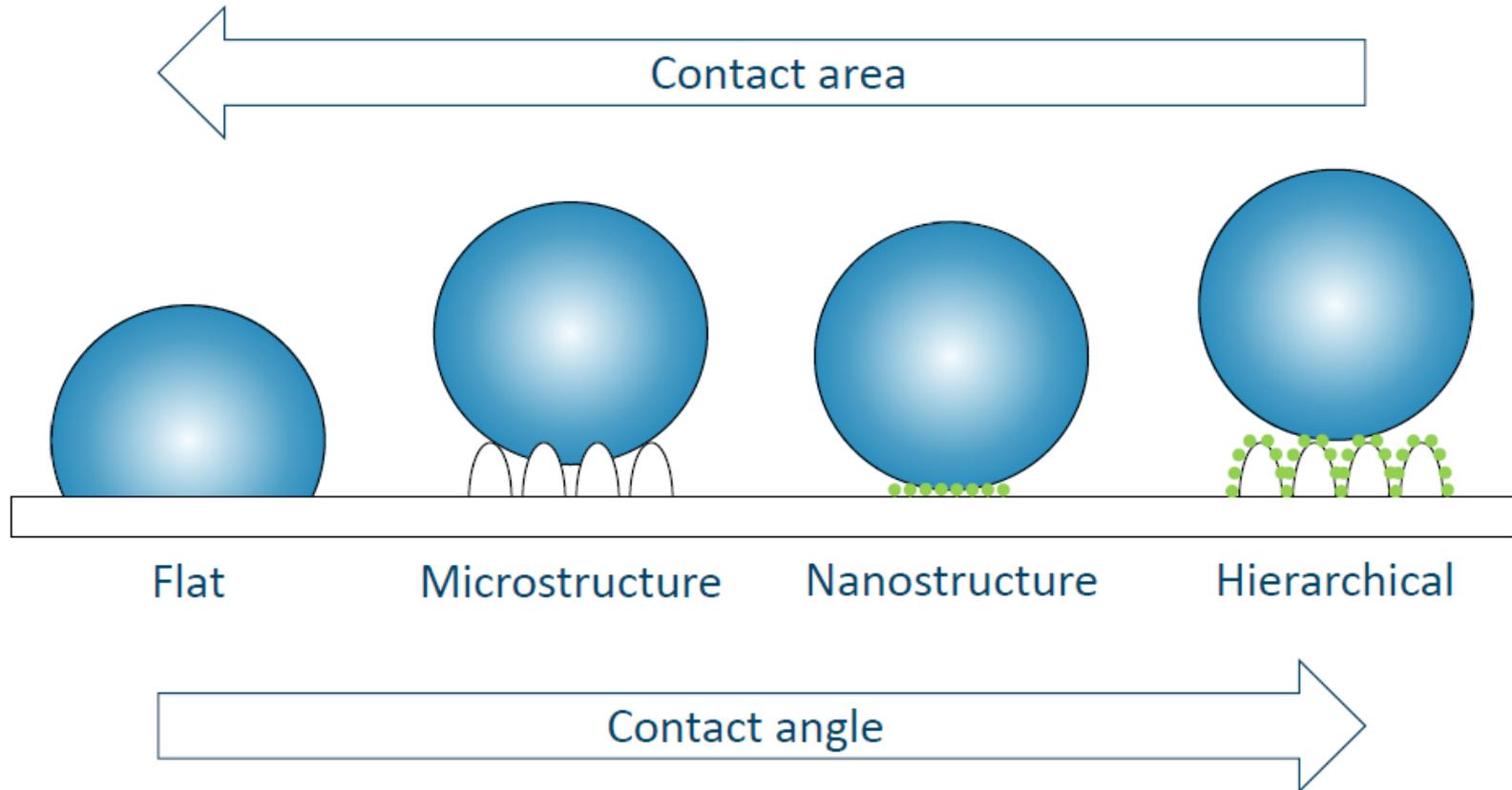
# Hydrophobicity – Inspired by Nature



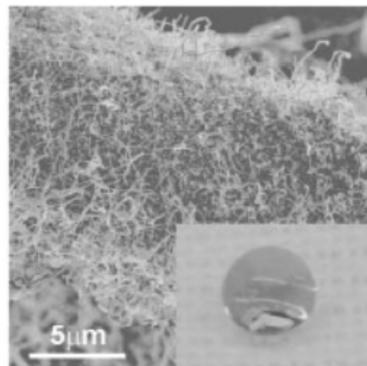
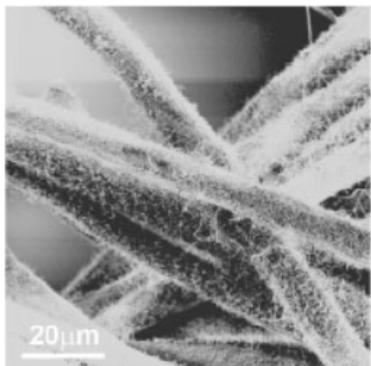
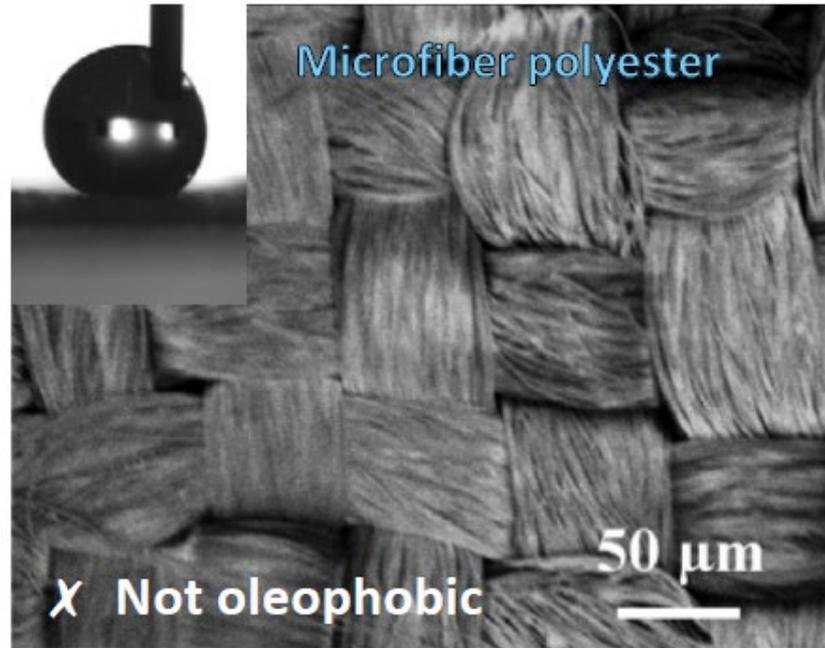
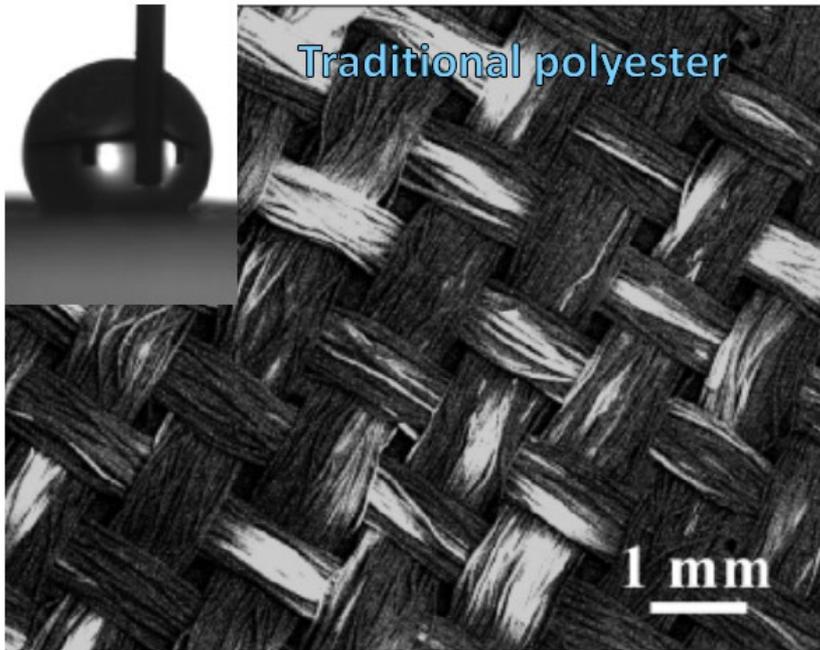
# Hydrophobicity – Inspired by Nature con't



# Nanostructure imparts hydrophobicity



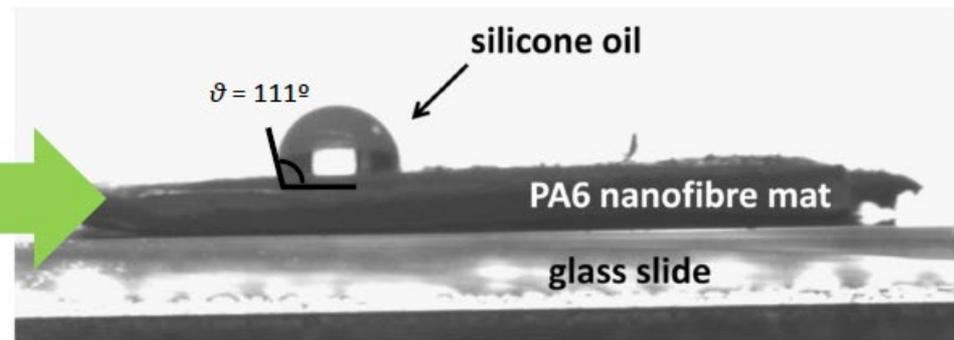
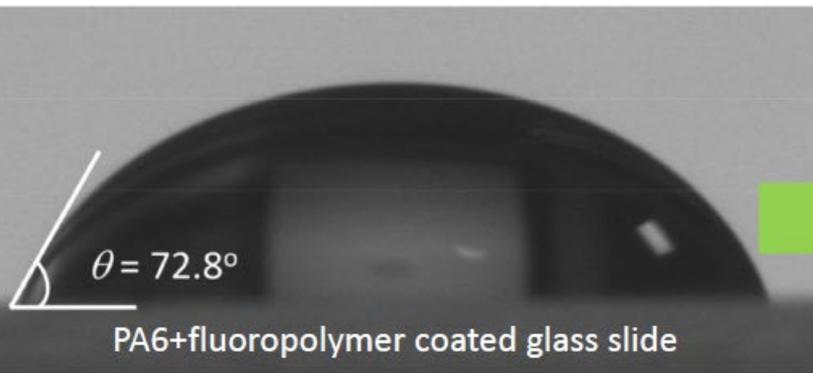
# Nanostructure imparts hydrophobicity – con't



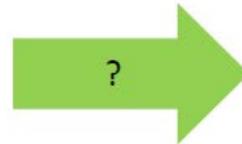
# Nanosol does not prevent oil spread

No nanosol	Sol with alkylsilane	Sol with PFAS	
			Colored water
			Coffee
			Red wine
			Colored oil

# Structure imparts oil resistance



53° contact angle on  
siloxane-coated slide



>90° contact angle on  
siloxane nanofiber mat

Stachewicz, U. *et al.* *ACS Appl. Mater. Interfaces* 2015, 7, 30, 16645-16652.

High Voltage Power Supply



Syringe



Collector



Start Solution

Zoom enabled

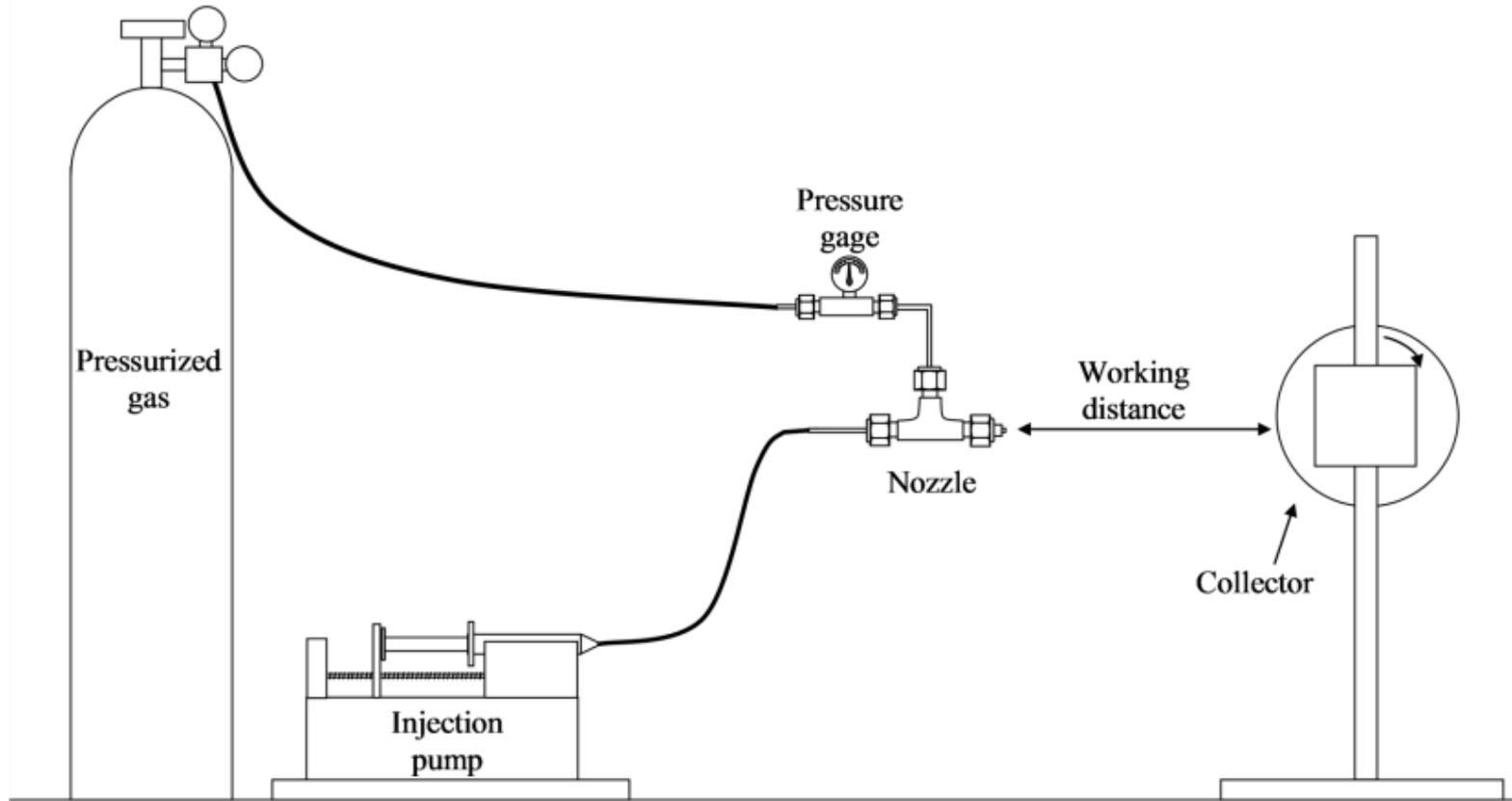
drip to jet

Start Voltage



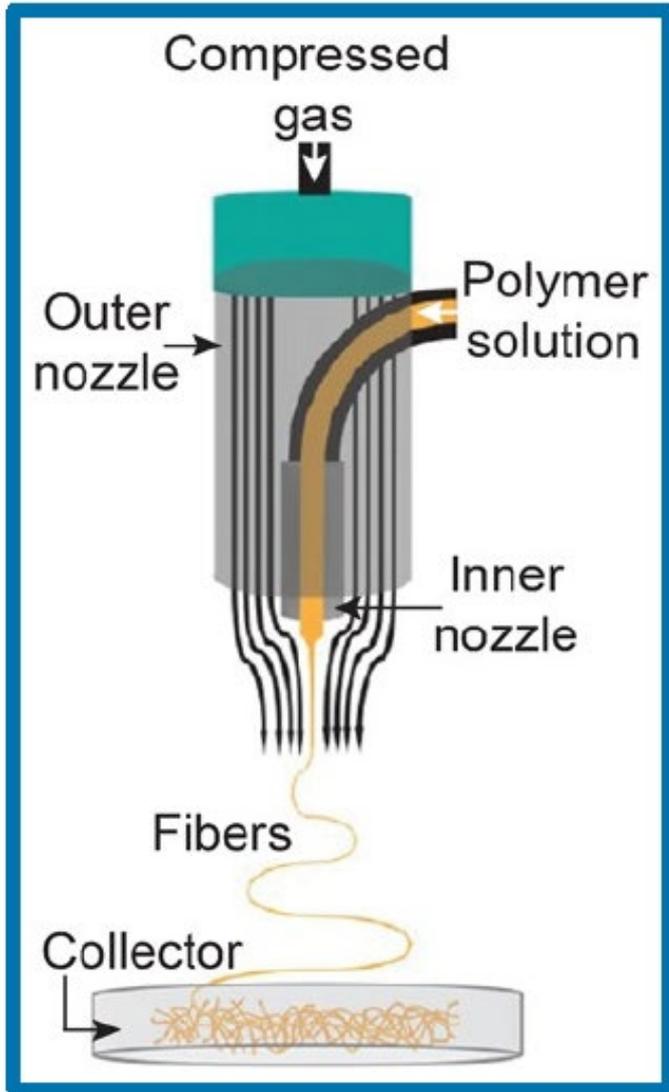
About

# Solution Blow Spinning



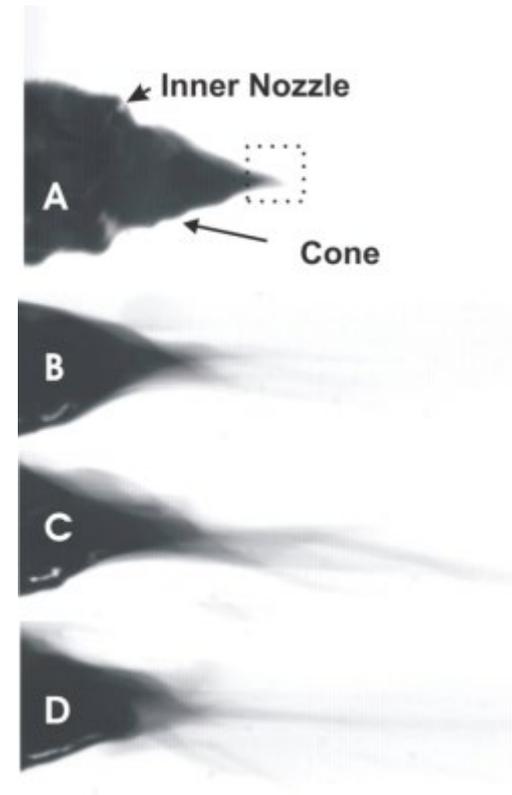
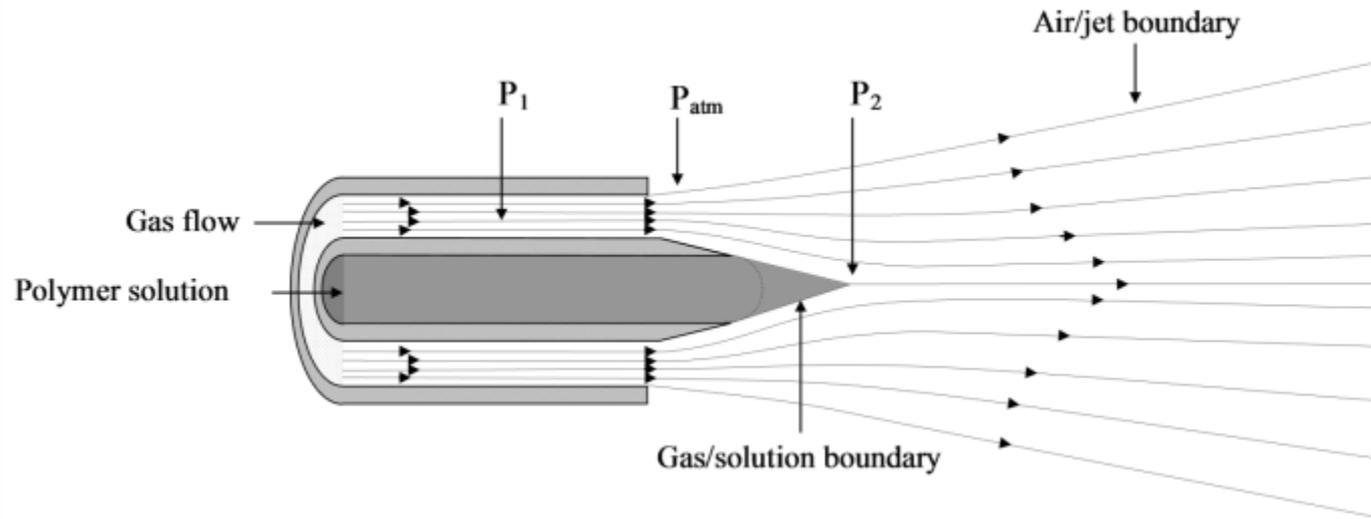
Medeiros, ES; Glenn, GM; Klamczynski, AP; Orts, WJ; Mattoso, LH  
Solution blow spinning. US Patent 8,641,960, B1, (2014).

# Solution Blow Spinning - con't

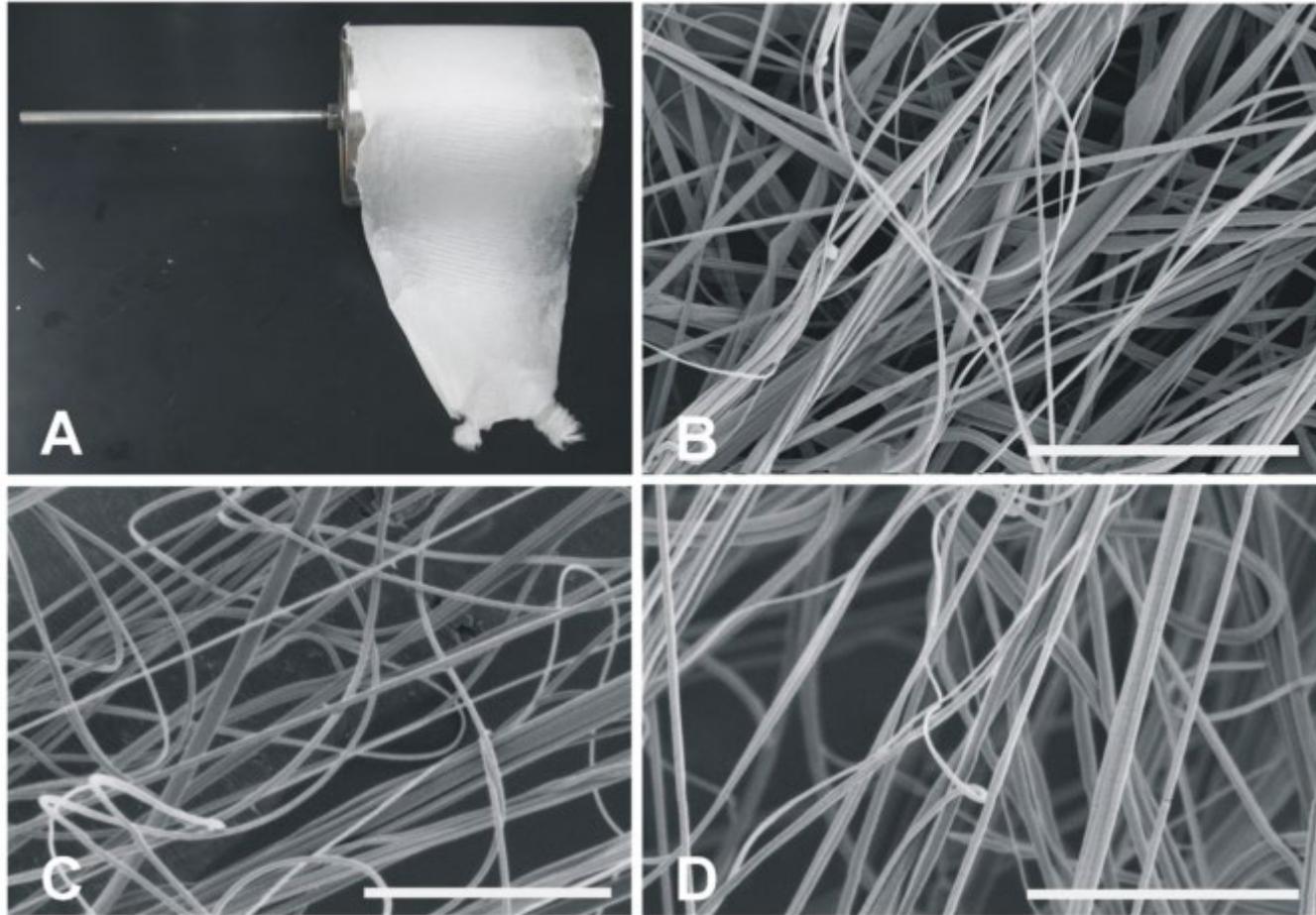


Medeiros, E.S., Glenn, G.M., Klamczynski, A.P., Orts, W.J. and Mattoso, L.H.C. (2009), Solution blow spinning: A new method to produce micro- and nanofibers from polymer solutions. *J. Appl. Polym. Sci.*, 113: 2322-2330. doi:[10.1002/app.30275](https://doi.org/10.1002/app.30275)

# Detail of the Nozzle



# Nanofibers



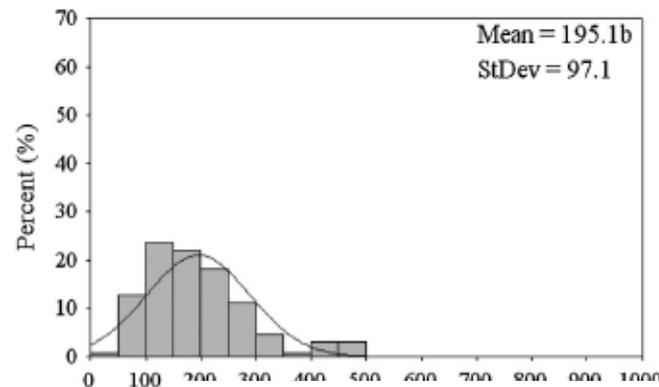
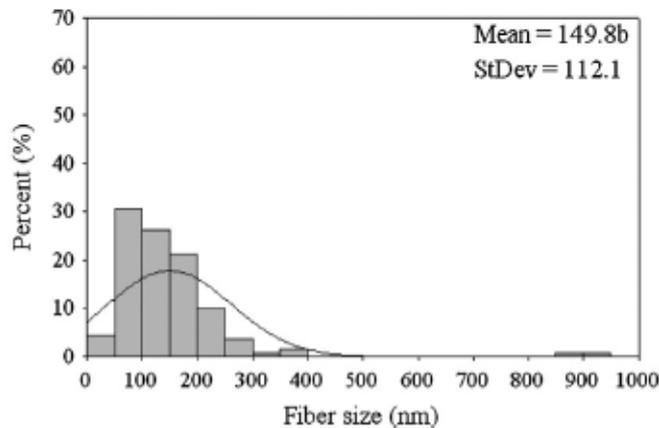
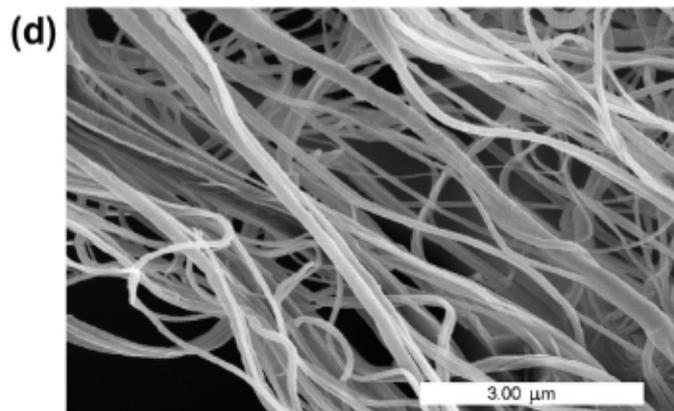
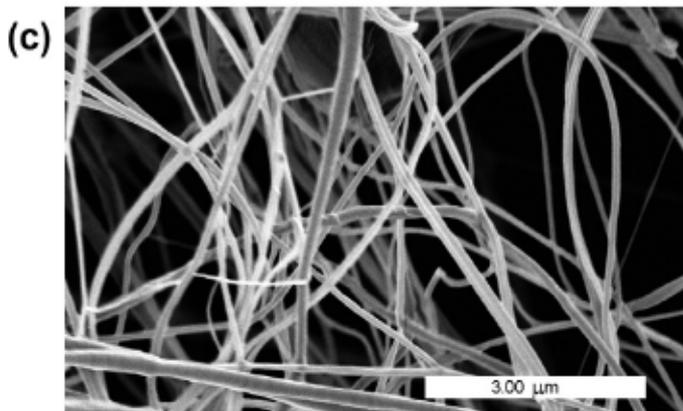
(A) Photograph of a non-woven fiber mat deposited on the drum. SEM pictures of (B) PMMA, (C) PS, and (D) PLA fibers. Note the partial alignment of the fibers as a consequence of the target rotation during spinning. Scale bar = 50  $\mu\text{m}$  for (B) and 5  $\mu\text{m}$  for (C) and (D).

# Nanoscale antimicrobial agents

Solution blow spun poly(lactic acid)/hydroxypropyl methylcellulose nanofibers with antimicrobial properties

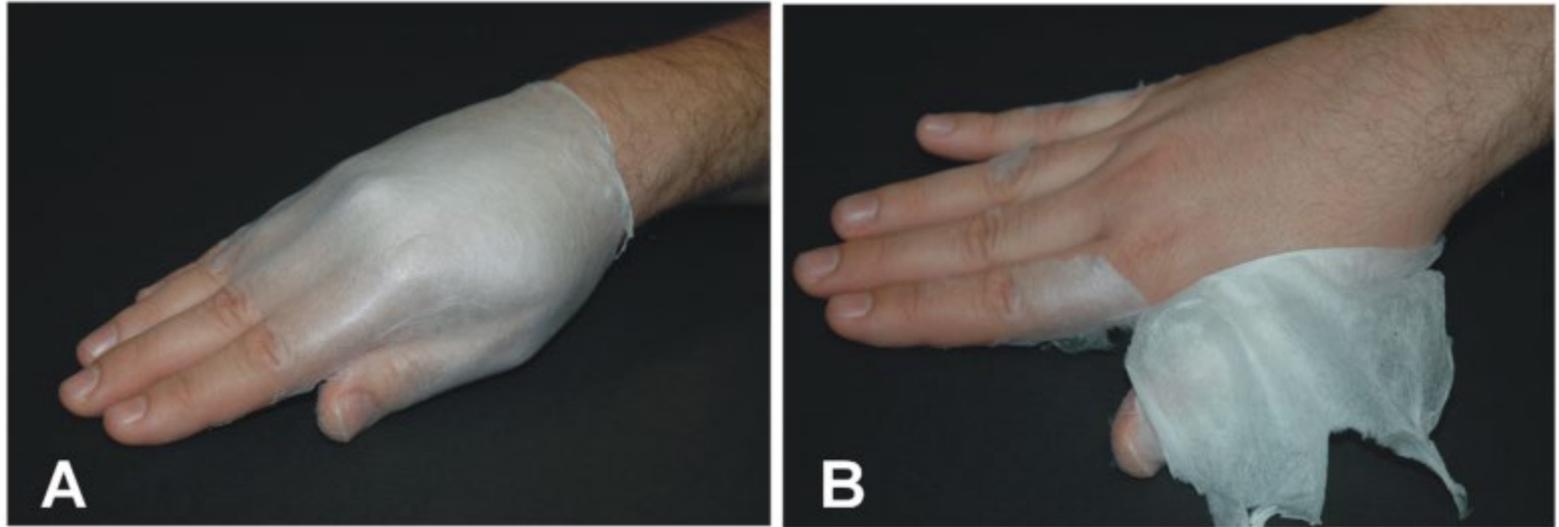


Cristina Bilbao-Sainz<sup>a</sup>, Bor-Sen Chiou<sup>a,\*</sup>, Diana Valenzuela-Medina<sup>a</sup>, Wen-Xian Du<sup>b</sup>, Kay S. Gregorski<sup>a</sup>, Tina G. Williams<sup>a</sup>, Delilah F. Wood<sup>a</sup>, Greg M. Glenn<sup>a</sup>, William J. Orts<sup>a</sup>



PLA +  
HPMC +  
Tetra-  
cycline

# Nanofibers for Wound Dressing



## Advantages of SBS:

In situ coating;

It does not use high voltage;

Up to several times faster than electrospinning;

Not limited by the dielectric constant of the solvent.

Medeiros ES, Glenn GM, Klamczynski AP, Orts WJ, Mattoso LHC.

Solution blow spinning: A new method to produce micro- and nanofibers from polymer solutions. *Journal of Applied Polymer Science* 2009;113:2322.

# Grow Plastics Technology in Packaging

## Better



Equivalent/Superior  
Strength

Thermally Stable

## Greener



100% Bio Based

Up to 80% CO<sub>2</sub>  
Reductions from  
Materials

## Lower Cost



Beat Solid Plastics  
on Price by up to 40%

# Summary....

- 
- Development of PFAS packaging may result in more use of siloxanes.
  - Viable bioplastic options are here.
    - Costs?
  - Nanostructure can impart both water and oil barrier properties.
  - This may not be simple.....

# Acknowledgements





Illustration by Y. Rook.

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