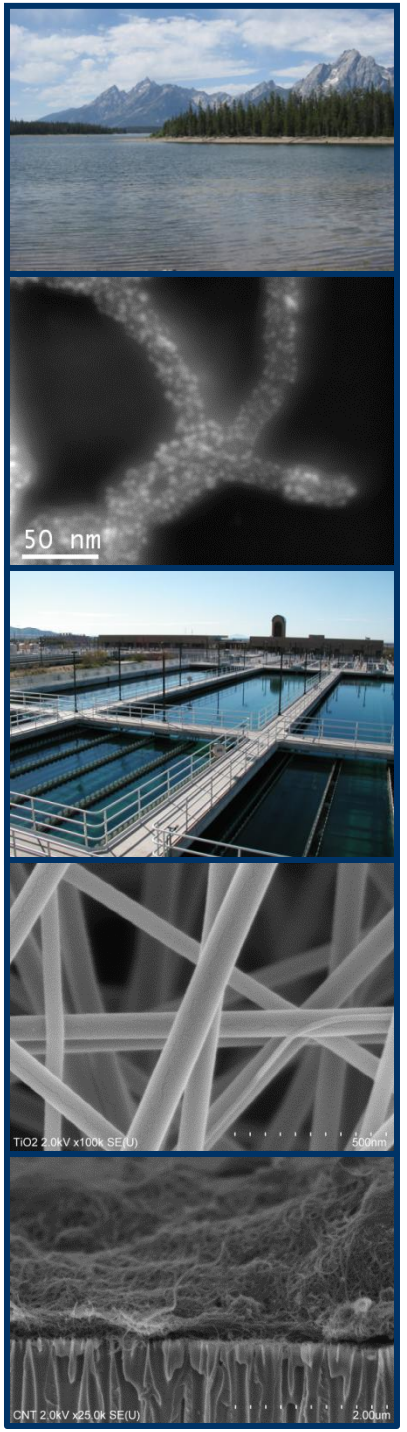
Research and Demonstration of Electrospun Nanofiber Filters: Multifunctional, Chemically Active Filtration Technologies for Small-Scale Water Treatment Systems

David Cwiertny,[1] Nosang Myung,[2] and Gene Parkin[1]

[1]University of Iowa, Department of Civil & Environmental Engineering

[2]U.C. Riverside, Department of Chemical and Environmental Engineering

Students: Katie Greenstein, Michael Nalbandian, Danmeng Shuai, Kathy Peter



This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD835177

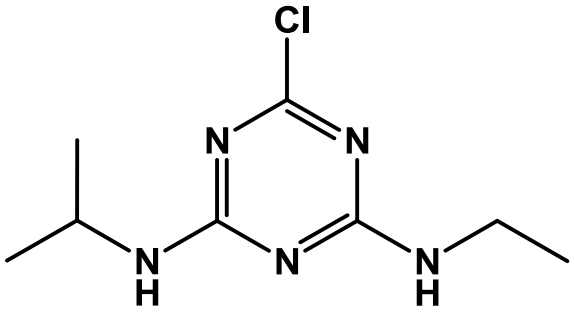
Our motivation: Water quality in Iowa small drinking water systems

Arsenic

(8% samples > MCL)

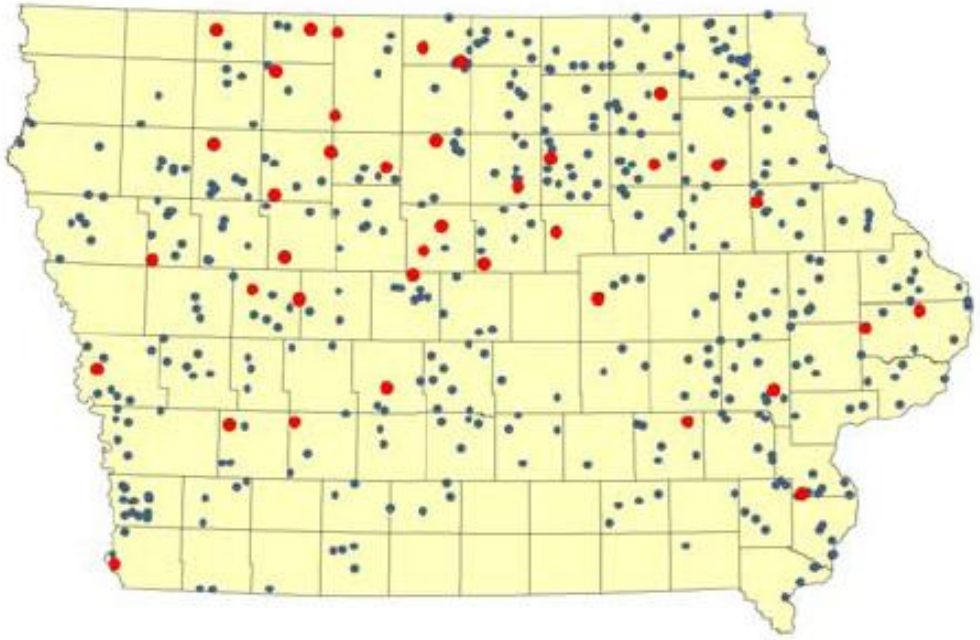
Red: ≥ 0.01 mg/L (MCL)

Blue: 0.001-0.009 mg/L



Atrazine

(8% of samples)



Iowa Statewide Rural Well Water Survey Phase 2 (SWRL2): Results and Analysis. UI Center for Health Effects of Environmental Contaminants (2009)

There is a niche for nanotechnology in small systems

A Water Treatment Engineers Introduction to Reactive Nanomaterials

Must harness	How?	Water quality benefit
High reactivity	Specific surface area & size effects	Efficiency toward historically **recalcitrant pollutants**
Scale	Size- & morphology-directed synthesis	"Small" promotes **point-of-use** & **decentralized** technologies
Tunable properties	Surface & bulk chemical modification	**Tailored treatment** to source water quality
"Bottom up" processing	Design & fabrication of hetero-nanostructures	**Multi-functionality** shrinks the process train

Caveats:

1. *Nanomaterials will not fulfill promise in treatment applications as suspensions*
2. *The most reactive nanomaterial may not be optimal for application*

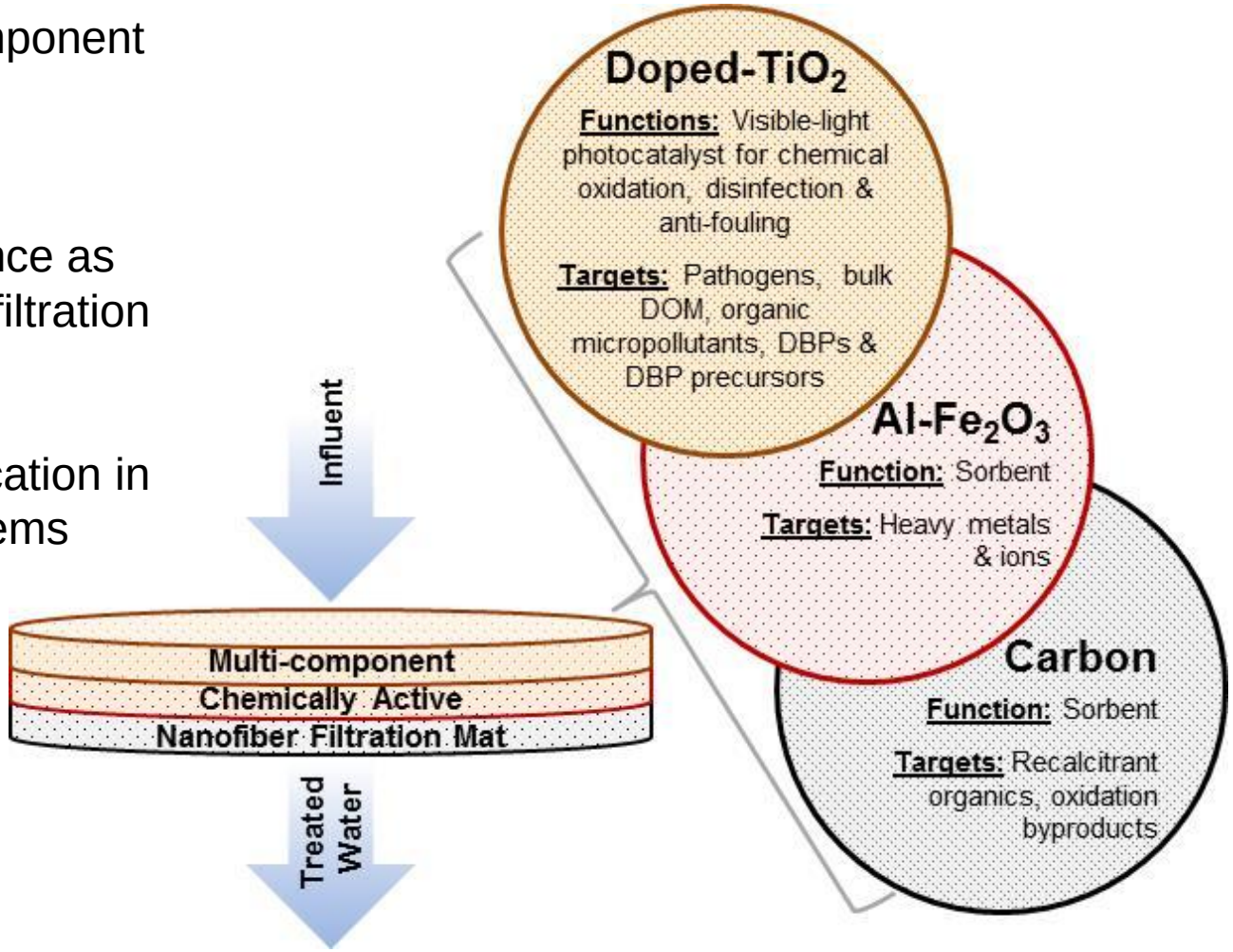
EPA STAR Small Systems Project: Chemically reactive filtration technologies

Overarching objectives:

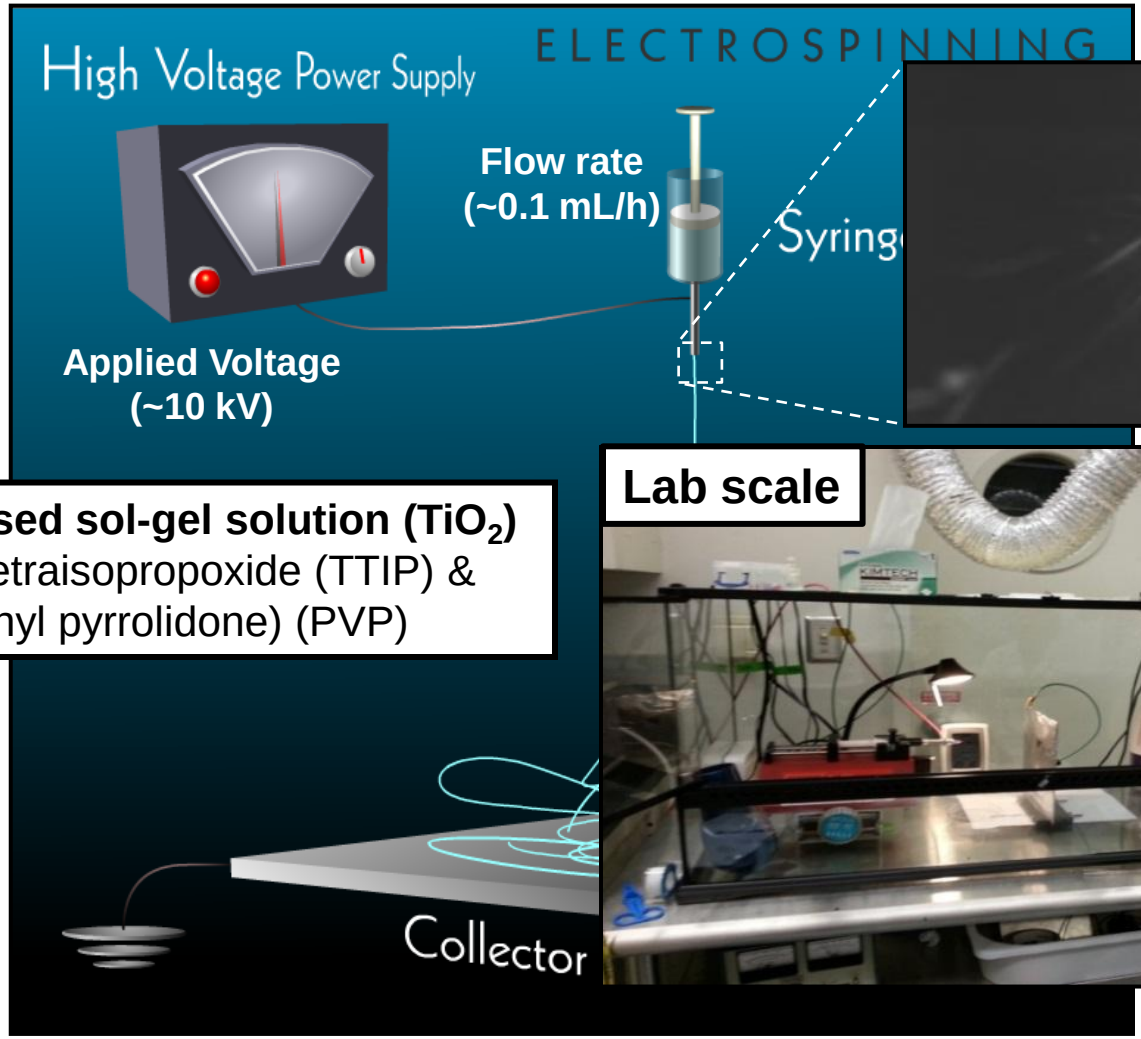
1) **Fabricate** multi-component nanofiber mats via electrospinning,

2) **Optimize** performance as chemically reactive filtration materials

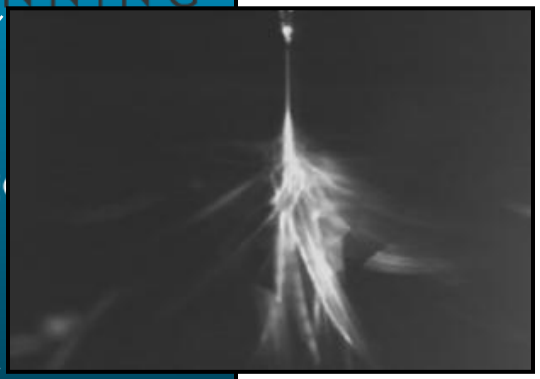
3) **Demonstrate** application in POU and POE systems



Electrospinning of chemically active (inorganic) nanofibers for treatment



Jet Spray



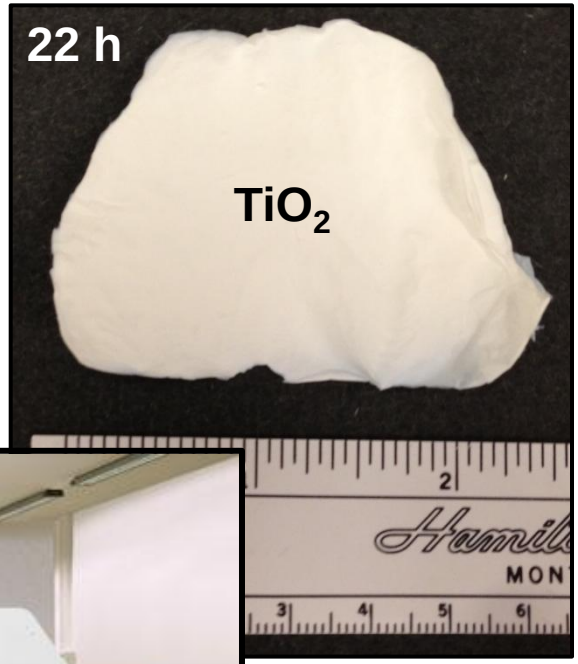
Polymer based sol-gel solution (TiO_2)
Titanium tetraisopropoxide (TTIP) & poly(vinyl pyrrolidone) (PVP)

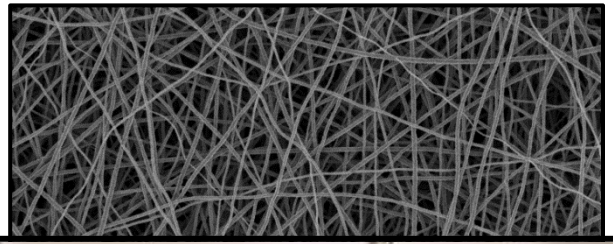
Lab scale

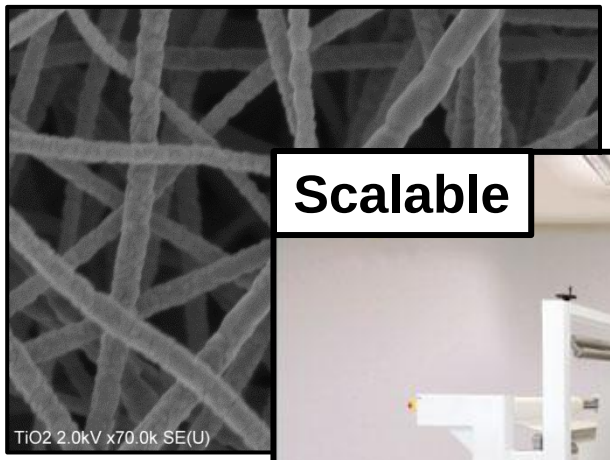
Annealing into Oxide

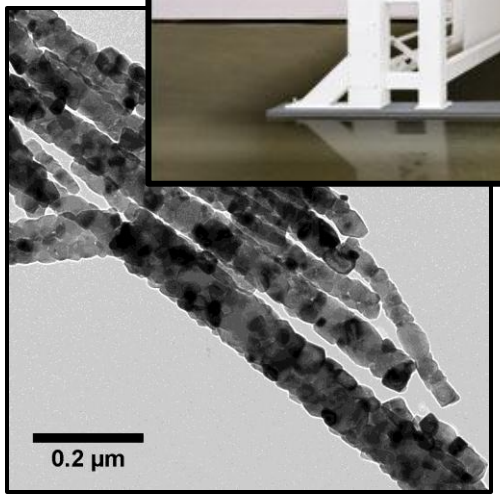
http://nano.mtu.edu/electrospining_start.html

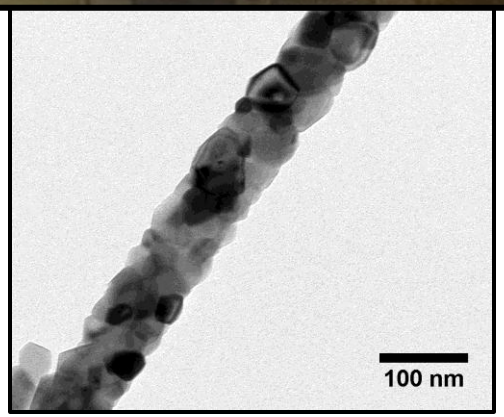
Electrospinning yields mats ideal as reactive coatings

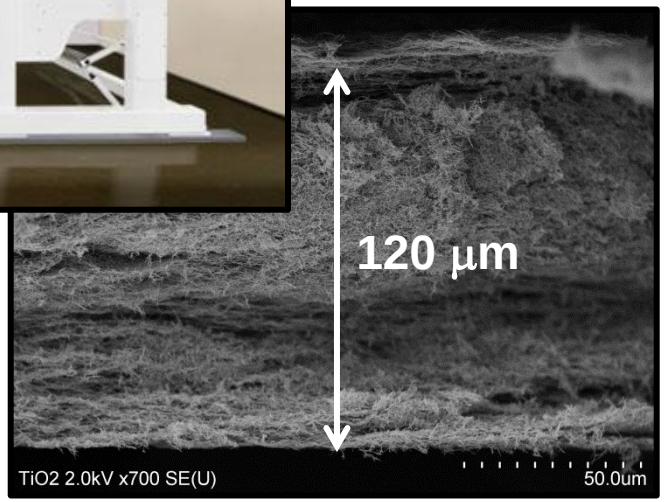








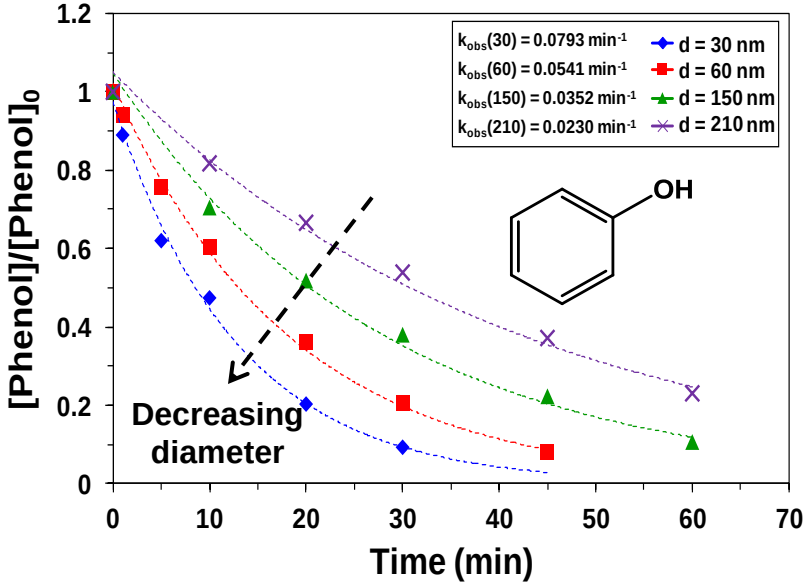


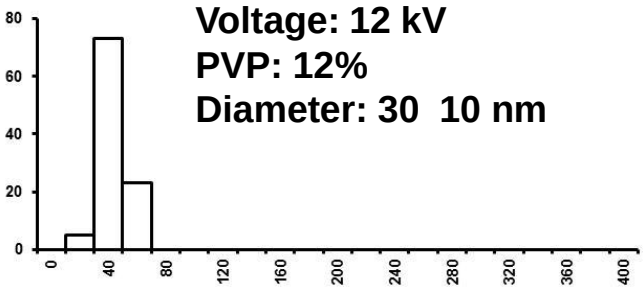


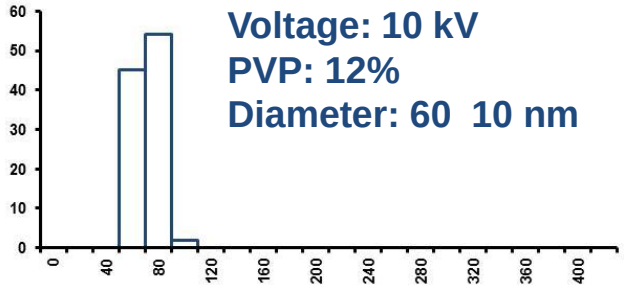
Nanofiber size can be tailored during synthesis

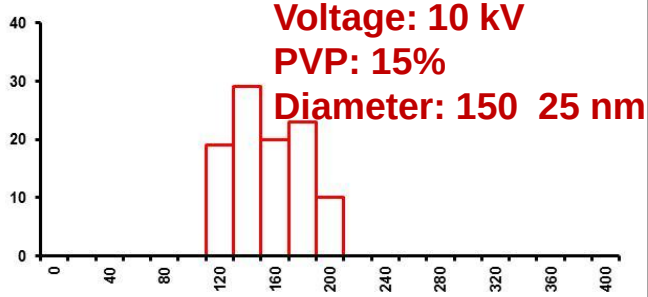
Light source:
Suntest Solar Simulator
or
1000W Xe (λ>305 nm)

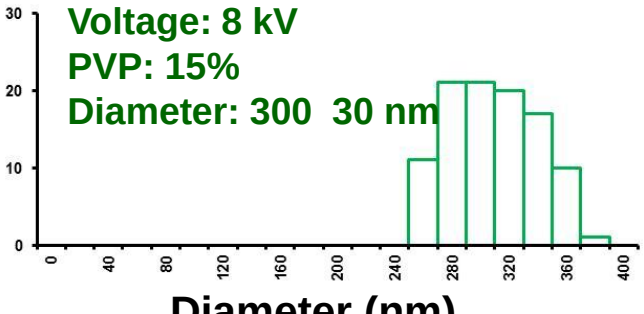
Solution:
pH 7
0.1 g/L TiO_2

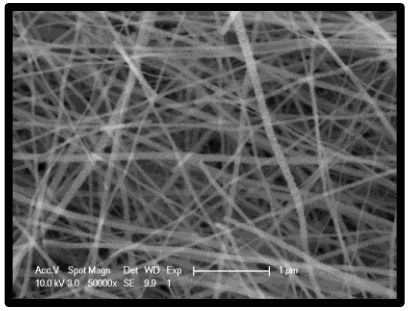


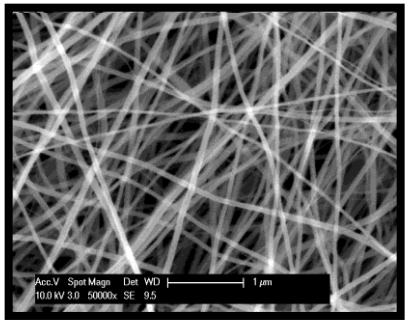


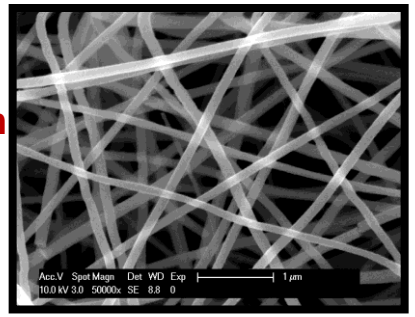


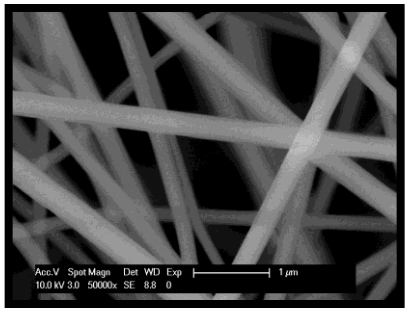




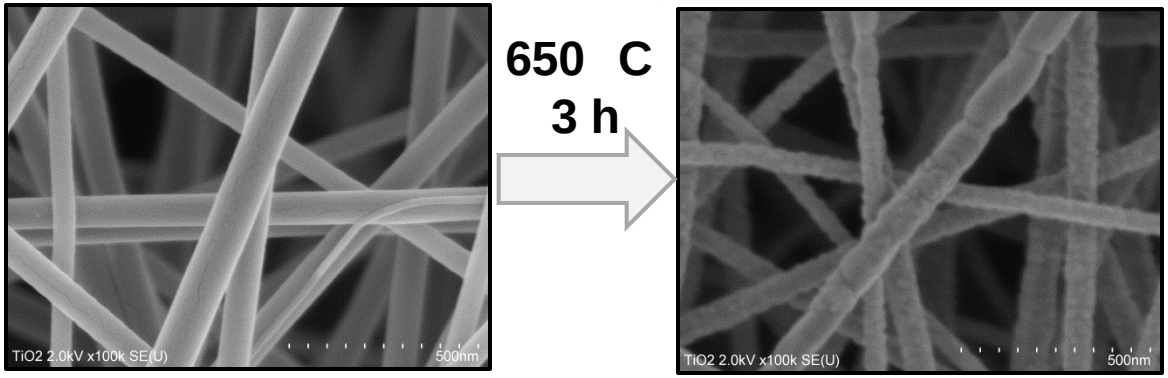


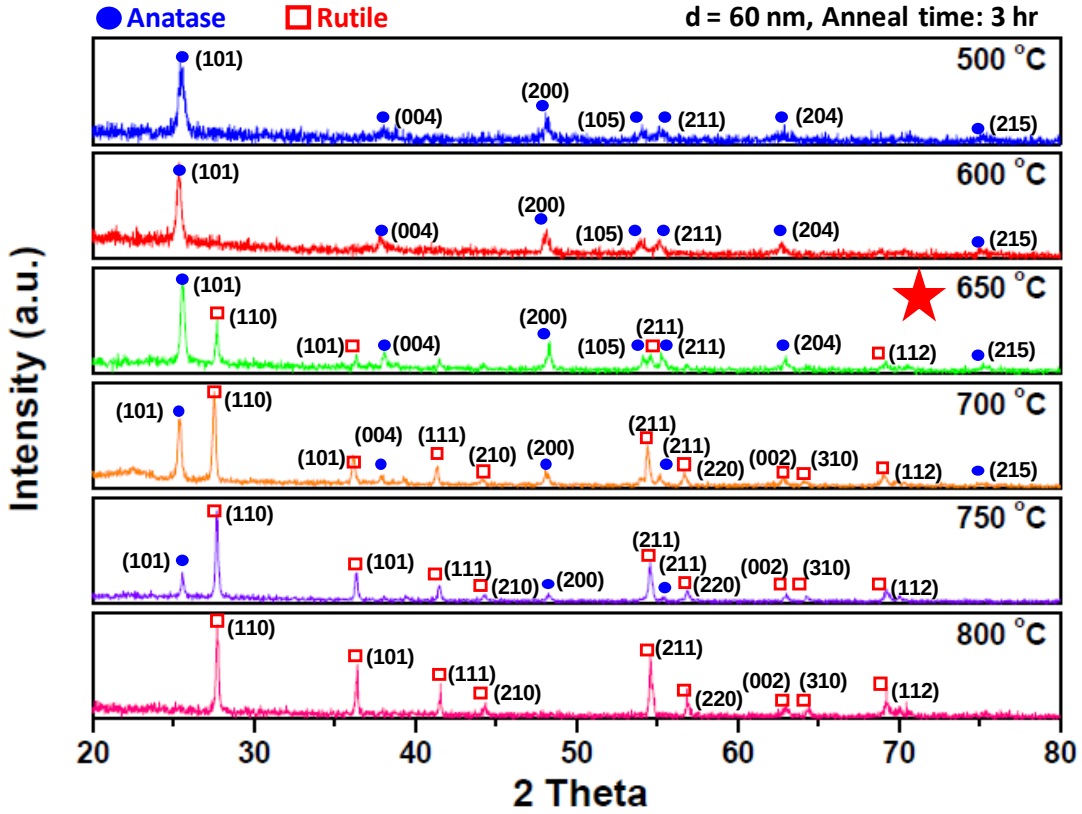






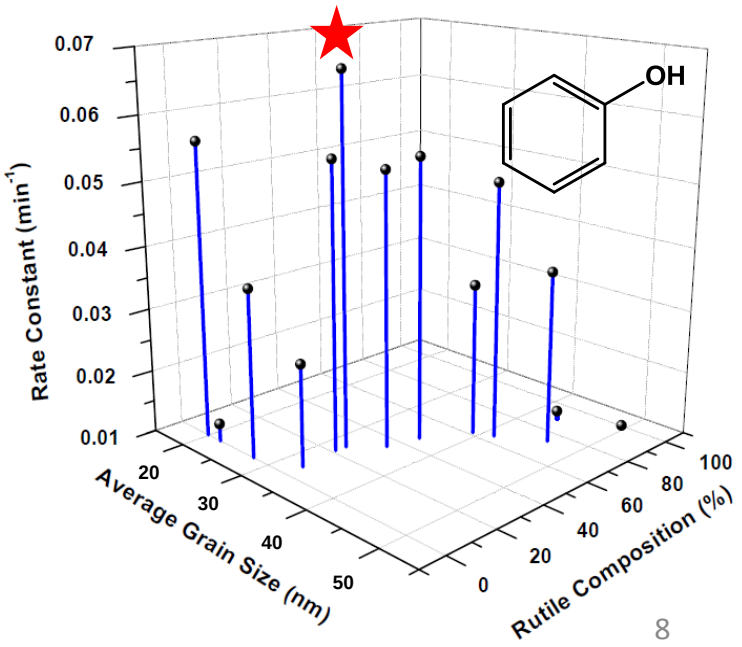
Nanofiber crystallinity and grain size tunable during annealing



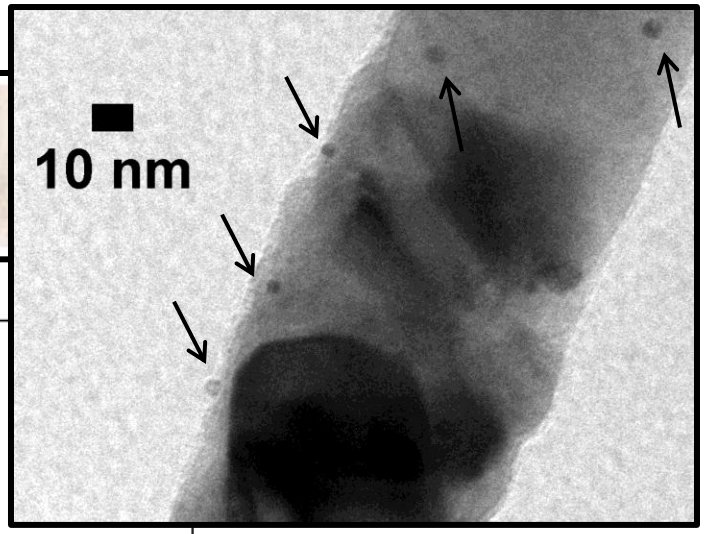


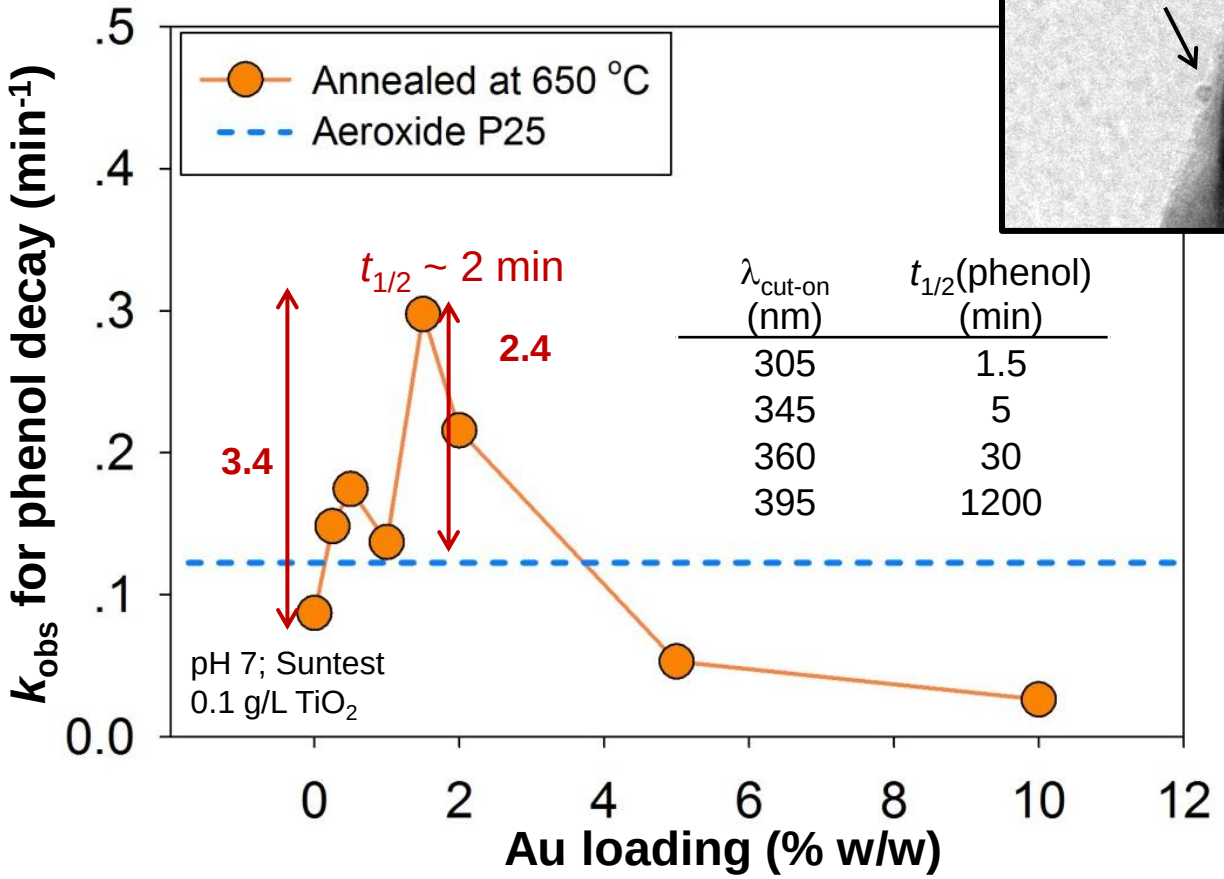
Optimal ratio:

26:74 (0.5)% rutile:anatase

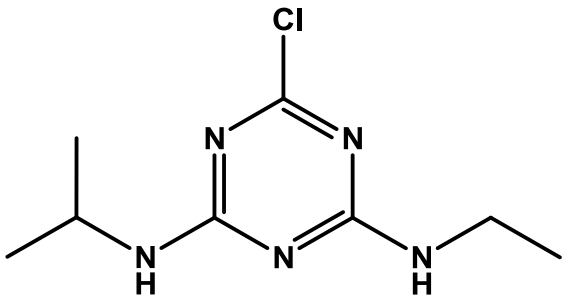


Surface-doped Au/TiO_2 is highly photoactive nanofiber catalyst for organic oxidation





$\lambda_{cut\text{-}on}$ (nm)	$t_{1/2}$(phenol) (min)
305	1.5
345	5
360	30
395	1200

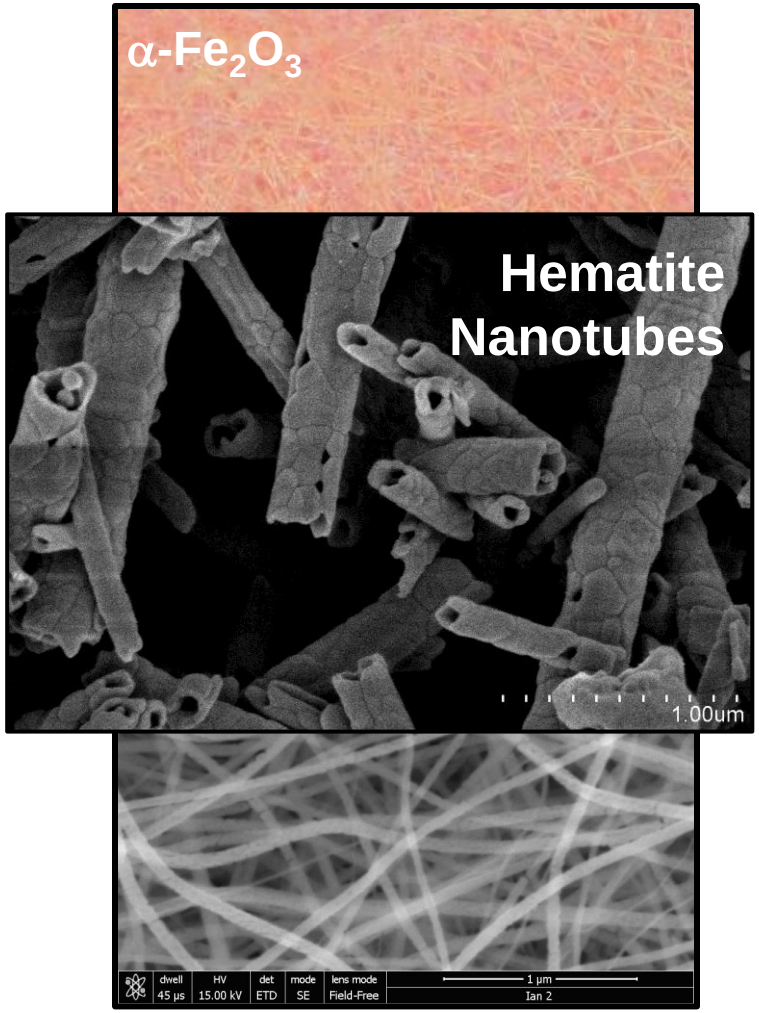


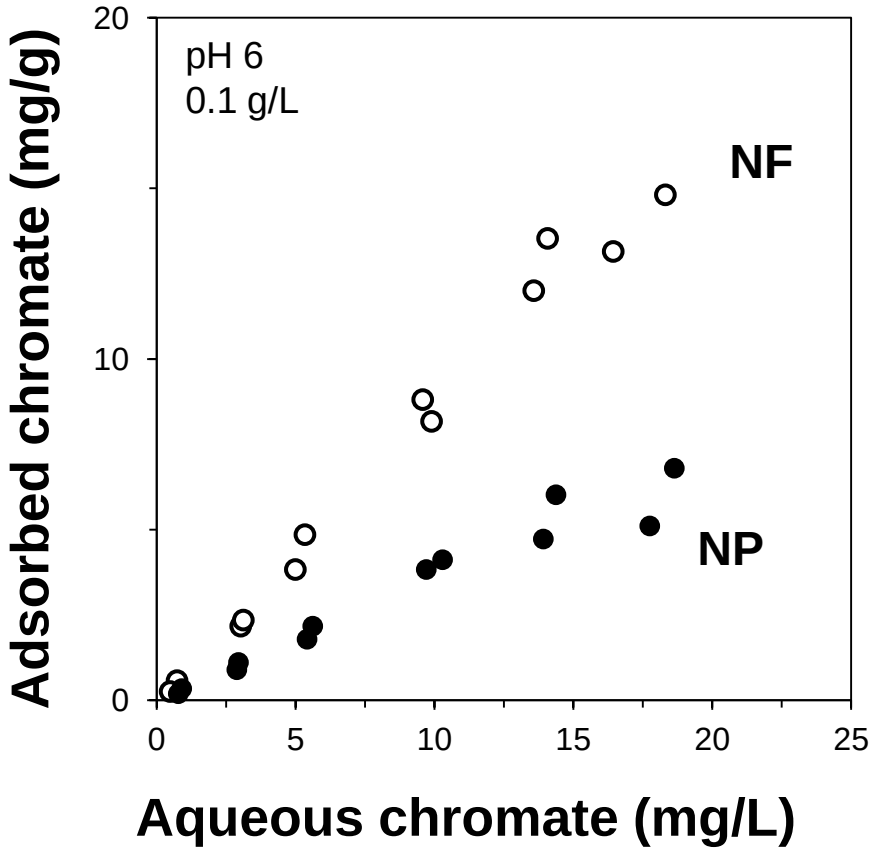
Atrazine

$t_{1/2}$(P25): 10 min

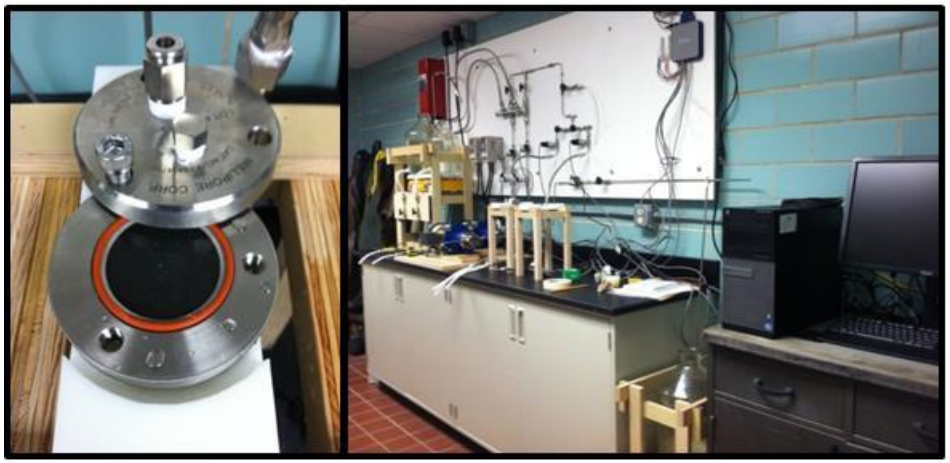
$t_{1/2}$(1.5% Au/TiO_2): 15 min

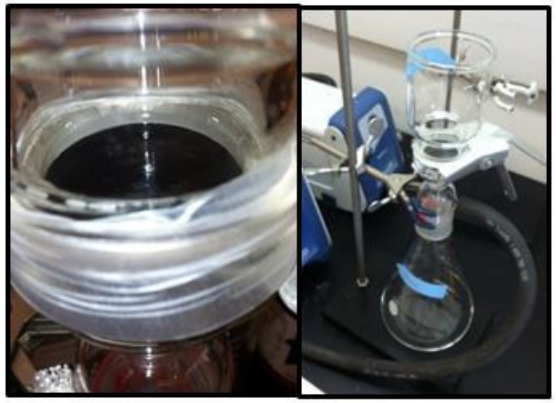
Ongoing work: Iron oxide and carbon sorbent nanofibers

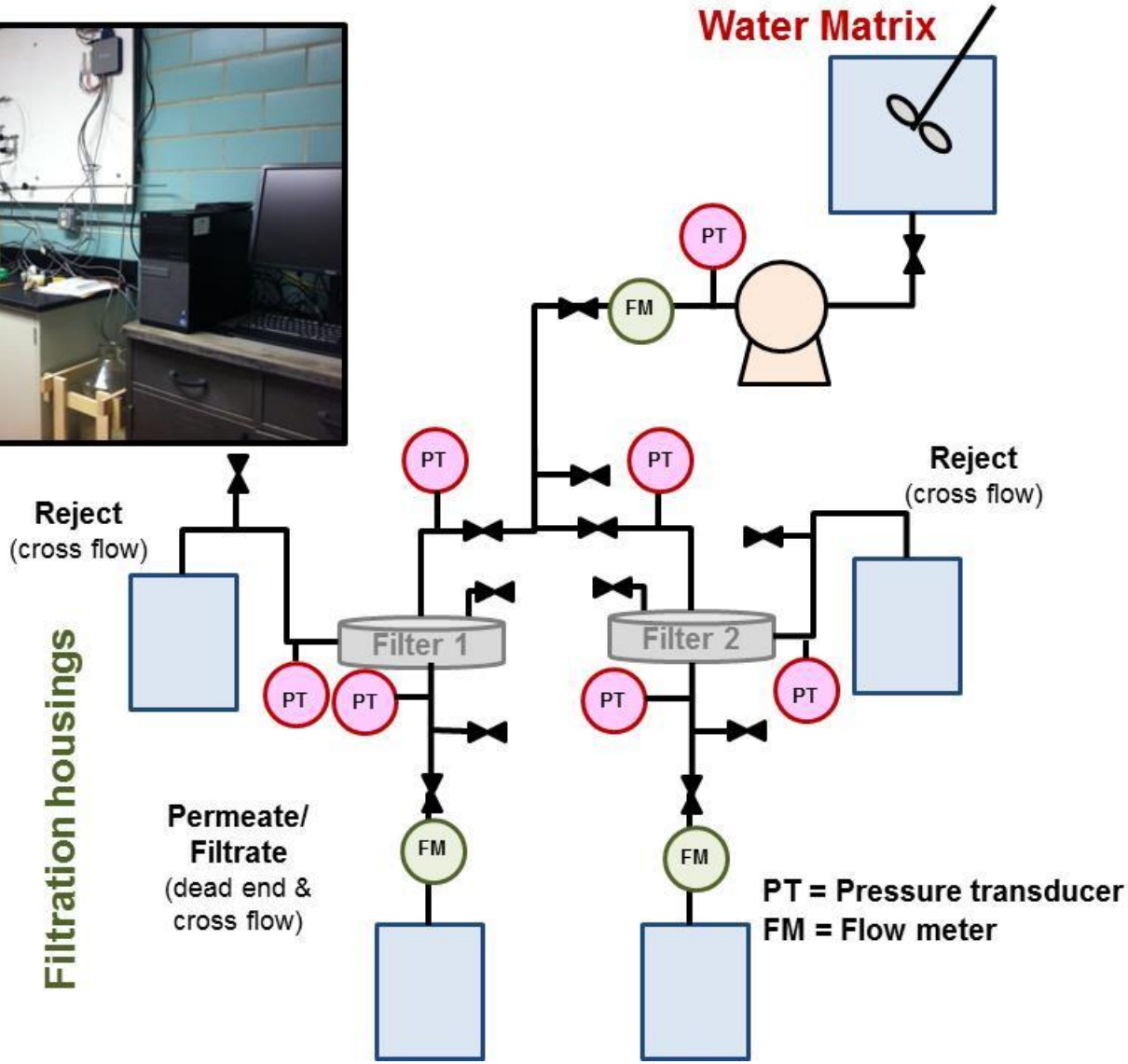




Ongoing: performance testing in flow through systems







Take home points on progress to date

- Electrospinning is highly versatile and scalable route to reactive nanofiber mats
- Nanofiber routes may be a responsible route to environmental applications of nanotechnology
- Challenges remain in optimizing reactivity (e.g., surface area) and robustness
- Future work will explore long term performance testing, reactive longevity and regeneration

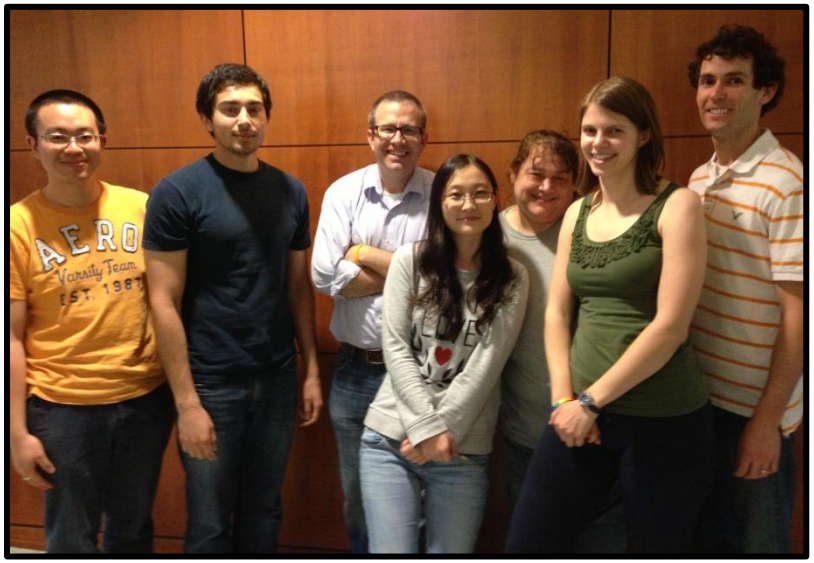
Acknowledgements

Cwiertny Group members

Dr. Danmeng Shuai: Electrospinning
Rebekah L. Oulton: CNT/O_3
Edgard M. Verdugo: CNT DBP
Katie Greenstein: Electrospinning
Jason Haase: CNT microfiltration
Kathy Peter: Electrospinning
Caylyn Lanzl: Nano iron oxide reactivity
Dr. Shen Qu: Cattle growth promoters
Undergrads: Connor Redmond, Matt Tarnoff, Sara Kaalberg, Meaghan O'Connor

Collaborators

Dr. Howard Fairbrother: Johns Hopkins
Dr. Nosang Myung: U.C. Riverside
Dr. Yong-Ho Choa: Hanyang University (Korea)
Dr. Rich Valentine: Iowa
Dr. Gene Parkin: Iowa
Dr. Tim Mattes: Iowa
Dr. Vicki Grassian: Iowa
Jon Durst: Iowa
Michael J. Nalbandian: U.C. Riverside
Kevin Wepasnick: Johns Hopkins
Dr. Jonas Baltrusaitis: Iowa CMRF
Dr. Gayan Rubasinghe: Iowa



Funding