

**Center for Filtration Research (CFR)
53rd Review Meeting, April 24-25, 2018
In conjunction with AFS FiltCon
Mystic Lake Conference Center, Minnesota**

David Y. H. Pui

Member of National Academy of Engineering
Distinguished McKnight University Professor
LM Fingerson/TSI Inc Chair in Mechanical Engineering
Director of the Center for Filtration Research
University of Minnesota



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53rd Semi-Annual Review Meeting of the Center for Filtration Research (CFR)

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|--------------|---|
| 8:00 | <i>CFR Research Overview, David Pui</i> |
| 8:25 | Technical Program Session (I): New Initiatives (Closed Session) |
| 9:15 | AFS FiltCon Open Session (II): <i>Plenary Lecture by David Pui</i> |
| 10:00 | <i>Refreshing Break; all are welcome to Exhibit Hall</i> |
| 10:20 | AFS FiltCon Open Session (II): -- Continued |
| 12:00 | <i>Lunch Break; CFR Representatives' Meeting (2 reps each to meeting room)</i> |
| 1:15 | Technical Program Session (III): New Initiatives (Closed Session) |
| 3:00 | <i>Refreshing Break; all are welcome to Exhibit Hall</i> |
| 3:30 | Technical Program Session (IV): Modeling, Loading, Instrument (Closed) |
| 5:30 | Center Planning Meeting |
| 5:40 | <i>Adjournment</i> |



UMN Center for Filtration Research (CFR)



The member companies of CFR have **\$28 billion annual sales** (est.) in filtration industry. Applications include

- Removal of PM_{2.5} pollutants
- Engine emission removal
- Cabin air filter for automobiles/airplanes
- Respirator and personal protection equip



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Faculty, Senior Staff and Visitors

Name	Title	Affiliation
David Pui*	Professor & CFR Director	UMN Mechanical Engineering
Benjamin Liu	Professor Emeritus & CFR Co-Founder	UMN Mechanical Engineering
David Kittelson*	Professor	UMN Mechanical Engineering
Thomas Kuehn*	Professor	UMN Mechanical Engineering
Peter McMurry	Professor	UMN Mechanical Engineering
Jake Swanson*	Assistant Professor	Minnesota State University, Mankato
Chris Hogan	Associate Professor	UMN Mechanical Engineering
Da-Ren Chen*	Chair Professor	Virginia Commonwealth University
Christoph Asbach	International Collaborator	IUTA, Duisburg, Germany
Jing Sun*	International Collaborator	Shanghai Institute of Ceramics, China
Jing (Jimmy) Wang*	Associate Professor	ETH Zurich, Switzerland
Peter Raynor	Associate Professor	UMN School of Public Health
Seong Chan Kim*	Senior Research Scientist	UMN Mechanical Engineering
Shawn Chen*	Assistant Professor	Virginia Commonwealth University
Qisheng Ou*	Post-doctoral Research Associate	UMN Mechanical Engineering
Min Tang*	Post-doctoral Research Associate	UMN Mechanical Engineering
Doris Segets*	Member of Engineering of Adv Materials	Univ. of Erlangen-Nuremberg, Germany
Cheng Chang*	Post-doc (November, 2017)	China University of Petroleum
Yun Liang*	Visiting Professor (December, 2017)	Pulp & Paper Key Lab, SCUT, China
H. Young Chung*	Visiting Scientist	UMN Mechanical Engineering

**Current Involvement in Center activities*



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CFR Graduates

Graduates	Degree	Date	Advisor	Employer
Ming Ouyang	Ph.D.	Jul-95	Liu	Cummins
Seong-Ho Yoo	Ph.D.	Mar-96	Liu	KLA-Tencor
Da-Ren Chen	Ph.D.	Sep-96	Pui	Virginia Commonwealth University
Kim Boelter	M.S.	Sep-96	Davidson	Ellerbe Becket
Wilson Poon	Ph.D.	Jun-97	Liu	WL Gore
Hee-Siew Han	M.S.	Jul-97	Kuehn	TSI
Laura C.F. Lin	M.S.	Jun-97	Vesley	Taiwan
Nicole Hoekstra	M.S.	Dec-97	Davidson	Seattle Community College
Poshin Lee	M.S.	Dec-97	Davidson	Entegris
Suresh Dhaniyala	Ph.D.	Jul-98	Liu	Clarkson University
Bruce Forsyth	Ph.D.	Jul-99	Liu	Boston Scientific
Scott Earnest	Ph.D.	Jul-00	Pui	NIOSH
Huaping Wang	M.S.	Apr-01	Pui	Entegris
Shintaro Sato	Ph.D.	May-01	Pui/Chen	Fujitsu
Poshin Lee	Ph.D.	Jun-02	Pui/Chen	Entegris
Choongkee Seong	M.S.	Jun-02	Kuehn	Korea
Michael Kinsley	Ph.D.	Jul-01	Davidson	State University of New York
Gong Yun	M.S.	Jun-02	Raynor	UMN Hospital
Weijia Sun	M.S.	Sep-03	Chen	JKMU Enterprise, Inc
Soo-hyung Kim	Ph.D.	Jun-03	Liu	Post-doc, NIST and U. of Maryland
Edgar Chay	M.S.	Dec-04	Chen	WWT, St. Louis
Sho Takagaki	Ph.D.	Apr-06	Liu/Pui	Post-doc at UMN BioSystems Eng.



CFR Graduates (Cont.1)

Graduates	Degree	Date	Advisor	Employer
Liming Lo	Ph.D.	Aug-06	Pui/Chen	NIOSH, Cincinnati
Luke Franklin	M.S.	Jun-06	Pui/Kuehn	Optimization of Respirator Test System
Chaolong Qi	PostDoc	Oct-08	Pui	NIOSH, Cincinnati
Dain Thul	M.S.	Sep-08	Kittelson	Crankcase Emission Measurement
Wendy Tang	Ph.D.	Sep-08	Kuehn	Intel, Phoenix
Seong Chan Kim	R.Assoc	8/1/10	Pui	Entegris, Chaska; Mechanical Engineering, UMN
Jimmy Jing Wang	ResProf	8/1/10	Pui	Assistant Professor, ETH Zurich and EMPA, Switzerland
Ta-Chih Hsiao	Ph.D.	8/1/10	Chen	Assistant Professor, National Central University, Taiwan
Weon Gyu Shin	Ph.D.	8/1/10	Pui	Assistant Professor, Chungnam National University, Korea
Nick Stanley	Ph.D.	9/1/10	Kuehn/Pui	Donaldson Company, Inc.
Luke Franklin	Ph.D.	4/1/11	Kittelson	Dow Chemical, Minnesota
Jake Swanson	Ph.D.	9/1/10	Kittelson/Pui	Mankato State University, Minnesota
Kyoungtae Kim	PostDoc	9/1/11	Pui	Contamination Engineer, Samsung Electronics, Korea
Zhun Liu	M.S.	12/31/11	Pui	Filter Modeling; Agglomerates Analysis
Jennifer Reinhart	M.S.	5/31/11	Pui	Cummins
Lin Li	Post-doc	6/1/12	Pui	MSP Corporation – a TSI Company
Qisheng Ou	Ph.D.	3/1/13	Chen	Post-doctoral Associate, CFR, UMN
Kai Xiao	M.S.	8/1/13	Kittelson/Pui	Guangdong, China
Tsz Yan Ling	Ph.D.	10/1/13	Pui	Intel, Santa Clara, CA
Gus Lindquist	M.S.	6/14/14	Hogan/Pui	HVAC



CFR Graduates (Cont.2)

Graduates	Degree	Date	Advisor	Employer
Zhili Zuo	Ph.D.	7/15/14	Kuehn/Pui	Applied Materials
Swathi Satish	M.S.	7/15/15	Kittelson/Pui	Cummins
Chang Hyuk Kim	Ph.D.	8/1/16	Pui	Postdoc at Caltech; now Assist. Prof., Pusan Natl U., Korea
Min Tang	Ph.D.	8/15/16	Liang/Pui	South China U of Technology; Post-Doc at UMN
Ningning Zhang	Scholar	9/30/16	Pui	IEECAS: PM2.5 Loading Study and SALSCS Evaluation
Maromu Yamada	Scholar	3/1/17	Pui	JNIOH: Personal Exposure Assessment using SEM
Leo N.Y. Cao	Ph.D.	12/1/17	Pui	Postdoc at FDA, St. Louis
Drew Thompson	Ph.D.	12/25/17	Pui	Electret Filter Media Modeling
Seungkoo Kang	Ph.D.	4/2/18	Pui	Postdoc at NIOSH, Cincinnati

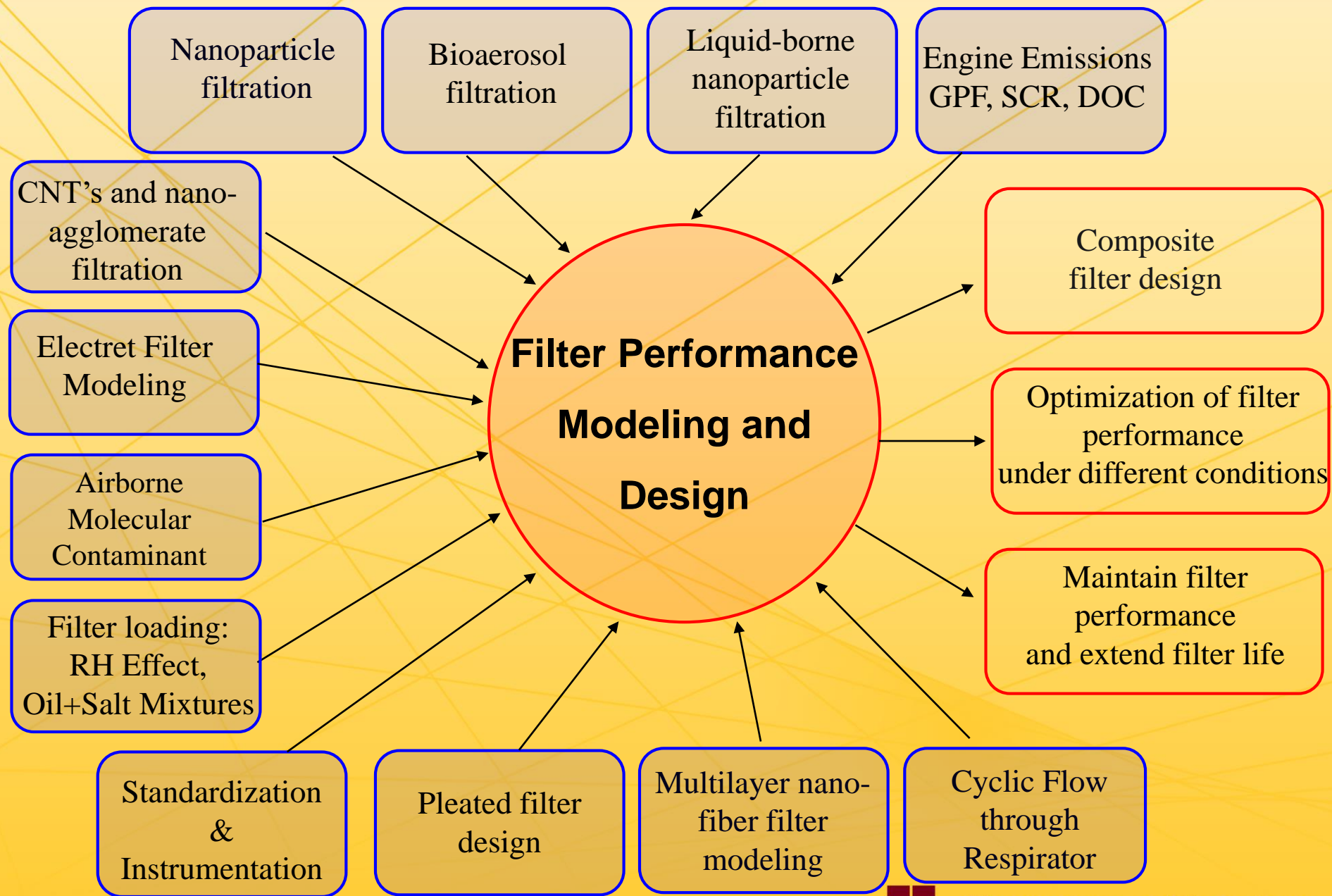


CFR Current Students/Scholars

Students	Degree	Date	Advisor	Project
Sarka Drdova	Ph.D.	10/15/19	Wang	Catalyst Filter for Airborne VOCs Decomposition
Peng Wang	Ph.D.	6/15/20	Chen	Respiratory Filter Media Study
Qingfeng Cao	Ph.D.	6/15/18	Pui/Shen	SALSCS Modeling by CFD and WRF; PIV Flow Field
Handol Lee	Ph.D.	6/15/18	Pui	Fundamental Study of Liquid Filtration; DDF Recipient
Chenxing Pei	Ph.D.	6/15/19	Pui	HVAC Filter Loading with Salt and Soot Particles
Dong-Bin Kwak	Ph.D.	6/15/21	Pui	ME Fellowship student from Hanyang Univeristy, Korea
Xinjiao Tian	Ph.D.	2/28/19	Pui/Tang	CSC student from China Northeastern University
Lipeng Su	Ph.D.	11/18/18	Pui/Ou	CSC student from Harbin Institute of Technology
Wei qi Chen	Ph.D.	9/1/21	Kittelson/Pui	Combustion Emission Control



Comprehensive Filter Modeling and Design



Software Solution for Filter Analysis

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Twin Cities • Duluth • Morris • Crookston • Rochester • Other Locations

CFR Filter Analysis Dust Loading Pleating Design

Particle Size
Range: 0.01 - 10 μm
Step: 0.005 μm
Temperature: 293.15 K
Primary Particle Density: 1 g/cm³

Flow Parameters
Face Velocity: 10 cm/s
Gas Viscosity: 0.000181 g/cm*s
Gas Mean Free Path (STP): 0.066 μm
☒ Fibrous ☐ Nuclepore

Agglomerate
Fractal Dimension: 3

Layer: New Layer Add Layer

Efficiency FOM Graph

Filter 1 Filter 2 Filter 3

Layer1 remove layer (X)

Filter Parameters
 τ : 1 mm
 α : 0.0E
fs: 5 μm

Legend
 τ : Thickness
 α : Solidity
fs: Fiber Size

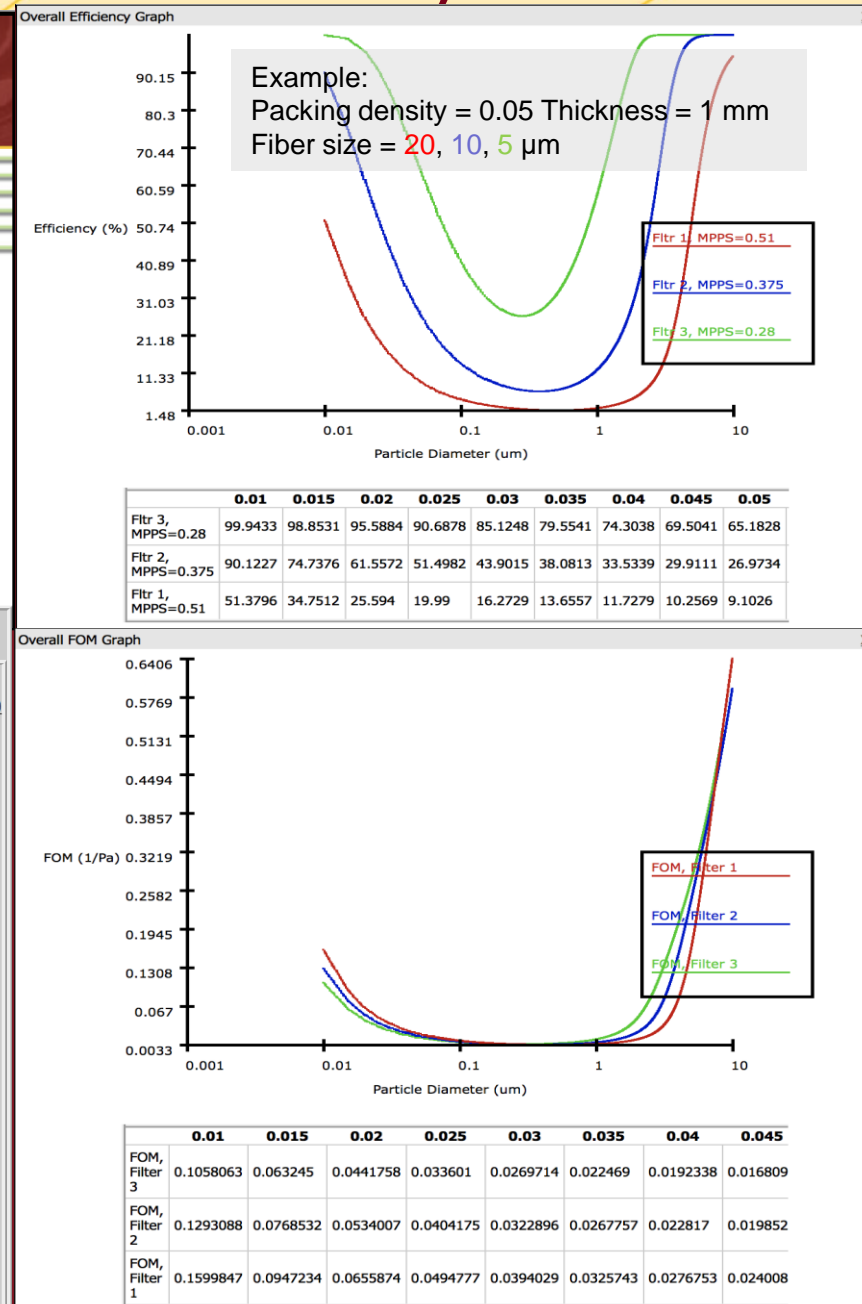
Interception-Diffusion-Interaction Term
☐ Ignore Mechanism
☒ Equation One Show

Diffusion
☐ Ignore Mechanism
☐ Equation One
☒ Equation Two Show

Impaction
☐ Ignore Mechanism
☐ Equation One
☒ Equation Two Show

Interception
☐ Ignore Mechanism
☐ Equation One
☒ Equation Two Show

Pressure Drop
☐ Equation One
☒ Equation Two Show



CFR Member Requests (2018)

- Air Intake Filter Loading by Mixture of Solid and Oil Particles
- Characterization of CMP Particles using Aerosolization Method
- Ultra-high Efficiency Filter Tests
- HVAC Filter Loading by Ammonium Sulfate and Ammonium Nitrate Submicron Particles and the Effect of Mixing with Combustion Soot
- Global Air Pollutant D/B and Real-life Filter Loading Test Rig Development
- Modeling of ISO Dust Dispersers and Measurement of Size Distribution of ISO Standard Dusts by Shadowgraphy Method
- Utilizing the WRF Modeling System to Simulate Atmospheric Flow over Beijing for SALSCS Evaluation
- Effect of Wash Coatings on Wall Flow Filter Performance and Filter Structure Analysis using 3D Image Scanner
- High Loading Capacity Nanofiber Filter Media
- Microbial Growth on Filter and Insulating Materials
- Particle Loading on Two-Stage Filtration System
- Surface Particle Removal using Dry/Wet Methods
- Electret Filter Loading: Effect of Fiber Structure and Charge Density
- Liquid Filtration Modeling: Effect of Chemical and Physical Factors



Short Course Offerings

- Aerosol and Particle Measurement
- (25% discount for CFR Companies)
 - First offered in 1978
 - 42 offerings with more than 2,500 attendees
 - 43rd offering, August 20-22, 2018
 - www.cce.umn.edu/aerosol
- Air and Gas Filtration
 - Developed under NSF support; first offered in 1995
 - 11th offerings, 1995-2008
 - Combined with Aerosol Measurement as a Special Topic
- Two courses started by Tom Kuehn are now part of professional societies' certification training and exams:
 - Health Care Facility Construction Management: Indoor Air Quality
 - Mold Management in Health Care Facilities



Center for Filtration Research (CFR)
54th Review Meeting, October 25-26, 2018
Corning Incorporated Headquarter
Corning Valley, Elmira, New York

Host:
Dr. Liming Wang
Director, Corning Research Center, China

