



IPRIME



Industrial
Partnership for
Research in
Interfacial and
Materials
Engineering

IPRIME History

- CIE (Center for Interfacial Engineering)
 - Funded by NSF from 1988 to 1999
 - Industrial outreach, 114 resident fellows, 393 PhDs
 - Fostered culture of integrated research, education and **industrial interaction**
- Members encouraged continued collaboration
- **IPRIME** (Industrial Partnership for Interfacial and Materials Engineering)
 - Legacy organization from CIE

Industry

A University–Industry Partnership based
on Two-Way Knowledge Exchange

University

- **Highly Interdisciplinary** (47 faculty in 9 departments)
 - Biochemistry, Molecular Biology and Biophysics
 - Biomedical Engineering
 - Bioproducts and Biosystems Engineering
 - Chemical Engineering and Materials Science
 - Chemistry
 - Electrical and Computer Engineering
 - Mechanical Engineering
 - Pharmaceuticals
 - Physics

“Knowledge is one. Its division into subjects is a concession to human weakness.”
- Halford Mackinder

- **Research is Pre-Competitive and Non-Proprietary**
- **Focus on fundamental science that underlie industrial products and processes**
- **7 Interdisciplinary Research Programs**

7 Research Programs

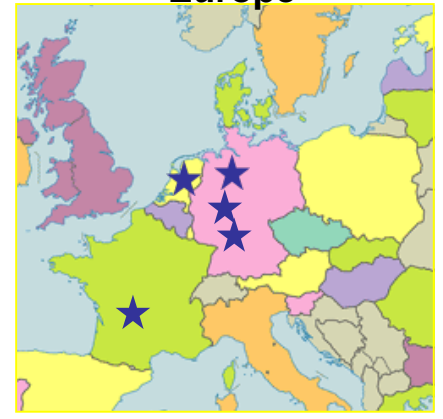
- Biocatalysis and Biotechnology (BB)
- Biomaterials and Pharmaceutical Materials (BPM)
- Coating Process Fundamentals (CPF)
- Electronic Materials and Devices (EMD)
- Flexible Electronics and Photovoltaics (FEP)
- Microstructured Polymers (MP)
- Nanostructural Materials and Processes (NMP)

Members Across the Globe



U.S.A.

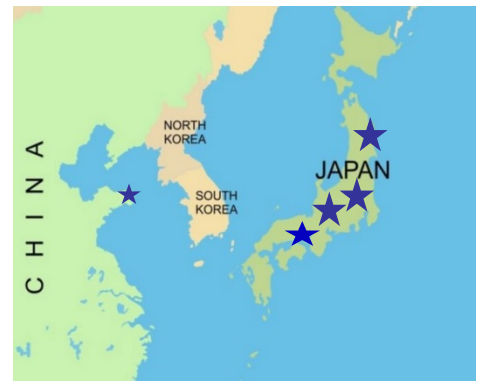
Europe



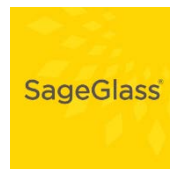
France (1) Total
Netherlands (1) DSM
Germany (3) BASF, Evonik, Henkel

China (1)
 Wanhua Chemical

Japan (4)
 Dai Nippon Printing
 Mitsui
 Toray
 Zeon



IPRIME Member Companies



Industrial Support

Contributions over \$1,500,000 per year from ~40 companies

- **Sponsor Membership** (\$60,000 per year)
 - Participation in up to 4 research programs
 - Opportunity to utilize Industrial Fellow Program
 - Representative on the Policy and Planning Board (PPB)
- **Affiliate Membership** (\$48,000 per year)
 - Focus on one 1 research program, no Industrial Fellow
- **Small company option**
 - \$7,500 minimum *or*
 - 0.03% of sales per year, up to \$48,000

Why IPRIME?

- **Partnership**
- **Future employees**
- **Facilities**
- **Knowledge Transfer**

Partnership

Companies

- Scientific exchange with academic sector
- Influence research directions
- Leverage government funding (NSF, NIH, DOE)
- Portal/referral to other U resources/capabilities
- Industrial Fellows

Faculty & Students

- Ready source of “hard problems”
- Funding support
- Technology implementation
- Fosters faculty interactions
- Industrial Fellows



Industrial Fellows

<u>Company</u>	<u>Employee</u>	<u>Research Topic</u>	<u>Faculty</u>
Abbott	Sarah Hankins	Thickness Characterization of Thin Coatings Commonly Used in Medical Devices	Lorraine Francis/ Greg Haugstad
Boston Scientific	Greg Sherwood	High sensitivity alpha-particle detectors	Steve Koester
Dai Nippon Printing	Koichi Nakano	Coating flow of non-Newtonian liquid in tensioned-web-over-slot die coating	Lorraine Francis/ Satish Kumar
Ecolab	Stephan Hubig	Evaluation of Nano Coatings for Surface Modification: Development of a tool kit for performance testing.	Alon McCormick
Mitsui	Ryohei Ogawa	Synthesis of cross-linkable aliphatic polyester elastomers derived from castor oil	Mark Hillmyer
Sherwin Williams	Gunnar Duner	New Methods for Adhesion of Coatings using AFM	Greg Haugstad
Toray	Kei Nomura	Multiblock compatibilizers for reuse/recycling of multilayer film	Chris Ellison
Wanhua Chemical	Shao-Jie Wang	Post polymerization modification	Mark Hillmyer
Wanhua Chemical	Xueshun Ji	Cryo-SEM observation of Dispersions by Pre-polymer Synthesis Method	Lorraine Francis
Zeon Corporation	Kousuke Isobe	TBD	Lorraine Francis/ Satish Kumar

Future Employees

Companies

- Early access to PhD students
- Most graduates work at IPRIME companies



Annual Meeting Poster Session

Faculty & Students

- Early student access to employers
- Learn industrial research process and interactions
- Hone communication skills
- Resumes distributed

Supporting Facilities

Companies

- CharFac*
(training + analysis)
- Imaging Center
- Polymer Characterization Facility*
- Polymer Synthesis
- Coating Process and Visualization Lab
- Tissue Mechanics*

Faculty and Students

- In-kind equipment contributions
- Industrial utilization of facilities



University of Minnesota Characterization Facility

- >\$20 million of equipment (replacement value)
- ❖ Electron microscopes: 6 TEM, 5 SEM/FIB, cryogenic/analytical
- ❖ X-ray scattering: 8 wide-, 2 small-angle, 2 micro, variable Temp
- ❖ Proximal nanoprobes: 4 AFM, STM, profilom., 4 indentors
- ❖ Surface analytical: XPS/UPS/Auger, sputter, microtensiom.
- ❖ Chemical spectro/microscopy: confocal Raman, FTIR/ATR
- ❖ Thin film analysis: RBS w/PIXE/FReS, spectrosc. ellipsom.

- 11 FTE scientific staff (permanent)
- ~600 research users/yr, ~100 external
- ~135 faculty users from ~35 UMN departments/units
- ~250 students/yr in curricular classes & short courses
- ~50 companies per year
- ~20 external academic institutions per year

www.charfac.umn.edu

- ❖ Hard & soft materials, liquids, bio/medical, enviro/geo/anthro
- ❖ Expert analytical services, custom methodologies
- ❖ External collaborations
- ❖ Workshops & short courses

Other pertinent facilities on campus:

State-of-the-art light microscopy (superresolution, etc.) → **University Imaging Center**
Rheology/DSC/TGA, NMR, Mass spectrom., X-ray tomography/electron microprobe
Micro-/Nano-fabrication, Bioprocessing (fermentation, etc.)

Newest systems



Dual-beam FIB/SEM



XPS, UPS, cluster beam

Small-angle X-ray scattering



Clientele: "Like a national lab"



CharFac instruments: data-generating systems (38)

Scanning & Transmission Electron Microscopes & FIB (11)

- JEOL 6500 FE-SEM (BS, EDS, EBSD, cathodoluminescence)
- JEOL 6700 FE-SEM (high-resolution)
- Hitachi SU8220 FE-SEM (ThermoNoran EDS, high-res., cryo, BS/mix)
- Hitachi S-4700 FE-SEM (cryo, BS)
- FEI Helios NanoLab G4 dual-beam FIB/FE-SEM (just added)
- JEOL 1200 EX Bio-TEM (LaB₆)
- FEI Tecnai G2 Spirit Bio-Twin (cryo/bio) (LaB₆)
- FEI T12 TEM (LaB₆ with EDS)
- FEI Tecnai G2 F30 FEG-TEM (EF-TEM, cryo/bio, 2-axis tilt for tomog.)
- FEI Tecnai G2 F30 FEG-TEM (EELS, EDS, STEM, HAADF)
- FEI Titan aberration-corrected FEG-TEM (EDX, EELS, STEM, HAADF)
- Two full suites of specimen prep tools (for SEM/TEM + AFM/Raman): hard and soft materials, biological; two cryo-microtomes

Proximal nanoprobes: AFM, nanoindentors & related (10)

- Omicron ultrahigh vacuum STM/STS LT system (coming soon)
- Two Bruker Nanoscope V Multimode 8 SPMs (with PeakForce QNM, EFM, MFM, KPFM, FMM, fast force volume)
- Intermodulation Products add-on to Bruker SPMs (just added)
- Two Keysight 5500's (closed loop scanners, current sensing, T/RH control, easy fluid cells, multifrequency); inverted light microscope
- WITec digital pulsed force mode add-on to Keysight 5500
- Anasys nanoTA2 + SThM add-on (heated tip) to Keysight 5500s.
- LabView / custom methods (setpoint ramping, FT shear modulation)
- Hysitron Triboindenter (mapping)
- Hysitron Picoindenter (in situ indentation, inside TEM)
- Keysight Nanoindenter XP (AC loading, storage/loss modulus)
- Custom-built micromechanical tester (IBM MMT)
- Tencor stylus profilometer (up to 14" wide, 2" thick samples)

X-ray Diffraction & Scattering (8)

- Bruker AXS (Siemens) D5005 XRD
- Pananalytical X'pert Pro high-angular resolution XRD (reflectivity, in-plain diffr, rocking curves, reciprocal space maps)
- Bruker AXS micro-XRD (2D detector, 2-axis sample tilt)
- Bruker D8 Discover micro-XRD (2D detector, 2-axis sample tilt)
- Bruker D8 Advance XRD with temperature and humidity control
- Laue diffractometer (crystal orientation)
- Xenocs/SAXSLAB Ganesha SAXS/WAXS/GISAXS (coming soon)

Ion Beam Analysis (elemental composition, depth profiles)

- Rutherford backscattering (RBS); RFeS, PIXE/PIGE, NRA
- NEC 5.1 MeV accelerator, He⁺, He²⁺ and H⁺ beams
- Goniometer, channeling : depth/element-specific crystallinity

Surface analytical (elemental, chemical, sputter-profiling)

- Phi versaProbe III XPS/ESCA with UPS: monochromated, small spot, angle resolved; cluster beam sputter profiling (just added)
- SSI XPS (monochromated)
- Auger spectroscopy (AES; scanning microscope, depth profiling)
- Micro contact angle system with high-speed camera (dynamic)

Vibrational spectroscopy (chemical, 3D imaging)

- Thermo FTIR spectrometer (DTGS and MCT detectors), Transm., Refl., ATR, DRIFTS; FTIR microscope
- Witec confocal Raman spectrometer/microscope; full spectroscopic imaging in XY and XZ; 532-nm and 785-nm lasers with dedicated spectrometers; down to 30 cm⁻¹ vibrations

Visible light based analysis & imaging (also see U Imaging Ctr)

- Woollam spectroscopic ellipsometer (film thickness and optical constant characterization over $\lambda=200-1100$ nm)
- Nikon light microscope - bright/dark field, polarization, phase, fluorescence, differential interference contrast (DIC)

CharFac Technical Staff

13 professionals (11.15 FTE) manage 3-site capabilities.
Includes expert analytical services, education/training,
assistance/consultation, methods development, collaboration.

Electron microscopy
X-ray scattering
Proximal probes
Vibrational spectroscopy
Surface Analytical
Thin film analysis

Chris Frethem	SEM (cryo and bio/soft material emphasis)
Dr. Javier Garcia-Barriocanal	XRD, Small-angle X-Ray scattering, IBA, ellipsometry
Dr. Bob Hafner	High-contrast and cryo TEM (bio, soft materials)
Dr. Greg Haugstad	AFM, Ion beam analysis (IBA: RBS, PIXE, FReS & related)
Dr. Han Seung Lee	SEM/TEM (cryo emphasis)
Dr. Bing Luo	Confocal Raman/FTIR, XPS/Auger, micro-contact angle
Dr. Jason Myers	FEG-TEM (HR/STEM/EDS/EELS), FIB
Dr. John Nelson (0.1 FTE)	Nano/micro-mechanical, profilometry
Dr. Geoff Rojas	Auger/XPS, STM/AFM, TEM
Dr. Nick Seaton	Materials SEM, EDS/EBSD/cathodoluminescence
Dr. Seema Thakral (0.6 FTE)	XRD, Small-angle X-Ray scattering
Dr. Wei Zhang (0.45 FTE)	Cryo FEG-TEM, 3D reconstruction, tomography
Fang Zhou, MS	Bio EM specimen prep, (cryo)microtomy, TEM (bio, soft material)

Contact Information at www.charfac.umn.edu/staff

Sought usage of the Characterization Facility by Industry

Analytical services (proprietary/commercial)

- Sample analysis by facility staff. (High commercial charge rates.)
- 1/3 discount on *instrument time* with IPRIME consortium membership.

Hands-on (proprietary/commercial)

- Obtain training for independent use of instruments (at high charge rates).

Sponsored projects (full overhead-bearing; well-defined contract)

- Fund grad student, postdoc and/or staff scientist(s) under University principal investigator. (Low internal charge rates.)

IPRIME consortium collaborations (no overhead, no contract or deliverables)

- Collaborate on publishable research with an IPRIME principal investigator and his/her colleagues, no hands-on usage of CharFac. (**Low internal charge rates.**)
- Become an **industrial fellow** in collaboration with IPRIME principal investigator on publishable research. **May include hands-on usage at low internal charge rates.**

Methods development collaboration (no UMN overhead, no contract or deliverables)

- Fund CharFac technical staff member(s) on publishable methods research (*academic* instrument rates, no hands-on). Modeled after IPRIME industrial fellow program.

Knowledge Transfer

Annual Meeting* (May 29 – 31, 2018)

- Workshops
- Program Reviews
- Two-Night Poster Session
- Plenary Luncheon
- TAC & PPB Meetings



* Free to members

Mid-Year Workshops*

- January 9 - 10, 2018

Website with members-only features*

- Webcasts, Research Information, Exclusive Presentations

Short Courses (member discounts)

- Coating Process Fundamentals (May 22 -24, 2018)
- Rheological Measurements (August 12-17, 2018)
- CharFac Workshop and Demonstrations (August 28-29, 2017)

Industrial Fellows (non-proprietary) & Special Projects (proprietary research)



2018 Annual Meeting

May 29-31, 2018

Featuring presentations on:

- Droplet-Based Coating and Printing
- Polymer Nanocomposites: Preparation, Structure, & Properties
- Bio Polymers and Materials
- Preparation & Processing of Biomedical & Pharmaceutical Materials
- Advances in Flexible Electronics and OLED Displays
- Material Options for Transparent Conductive Oxides
- Characterization-focused Industrial Fellow Collaborative Projects: Examples, Opportunities, & Challenges

Mid-Year Workshops

January 9-10, 2018

- “3D Printing of Polymers: Materials and Processes” (CPF & MP) Jan 9, 2018
- “Remote Imaging of Implanted Biomaterials and Theranostics” (BPM) Jan 10, 2018

Short Courses

- Coating Process Fundamentals Short Course (May 22- 24, 2018)
- Rheology Short Course (August 12-17, 2018)
- CharFac Workshop (August 20-21, 2018)

2017 Annual Meeting

May 30-June 1, 2017

Featuring presentations on:

- Characterization of Coatings: Needs & Opportunities
- Polymers at Surfaces & Interfaces
- Innovations in Organic & Flexible Electronics for Display, Sensing & Energy Conversion Devices
- Unsolved Problems in Biomedical Materials
- Enzyme Technology for Cleanup

Mid-Year Workshops

January 10-11, 2017

- “Color and Appearance of Coatings” CPF
- “Nanomaterials for Protein, Genetic Material, and Small Molecule Delivery to Cells” NMP/BPM

Short Courses

- Coating Process Fundamentals Short Course (May 23- 25, 2017)
- CharFac Workshop (August 28-29, 2017)



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IPRIME
 Industrial Partnership for Research in Interfacial & Materials Engineering

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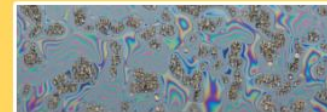
[Learn About IPRIME](#)



Welcome to IPRIME

IPRIME focuses on creating opportunities for professionals in industry to collaborate with students and researchers at the University of Minnesota. This exchange provides a productive environment for addressing key areas in interfacial and materials science.

Research Programs



Coating Process
Fundamentals (CPF)



IPRIME Overview



News & More



Upcoming Events

Save the Date!

7 Research Programs

- Biocatalysis and Biotechnology (BB)
- Biomaterials and Pharmaceutical Materials (BPM)
- Coating Process Fundamentals (CPF)
- Electronic Materials and Devices (EMD)
- Flexible Electronics and Photovoltaics (FEP)
- Microstructured Polymers (MP)
- Nanostructural Materials and Processes (NMP)

Biocatalysis and Biotechnology (BB)

<u>Investigator</u>	<u>Department</u>	<u>Expertise</u>
Ping Wang*	BBE	Enzymology and biocatalysis, bioconversion and biosynthesis, biomaterials and functional coatings, bioelectrochemical processing, biosensors.
Mark Distefano	Chem	Organic and biochem., protein conjugates for therapeutic and biotechnology applications.
Mikael Elias	Biochem	Protein engineering and evolution, molecular modelling and recognition, bioremediation and quorum quenching strategies.
Wei-Shou Hu	CEMS	Systems biotechnology, biochemical engineering, cell culture bioprocessing, stem cell technology
Romas Kazlauskas	Biochem	Biocatalytic synthesis of chemical intermediates and biofuels, enzyme modification for new reactions.
Lawrence Wackett	Biochem	Enzymes in biotechnology, immobilization technology, bioremediation, computer prediction tools for biocatalysis
Kechun Zhang	CEMS	Synthetic biology, metabolic engineering, protein engineering, biofuels, renewable chemicals.

**Program Leader (Email: ping@umn.edu; Phone: 612-624-4792)*

Chemical and fuel bioprocessing; Biocatalyst engineering; Biotransformation and Bioremediation; Enzyme evolution; Bio-based polymers and biocoatings; Pathway engineering; Synthetic biology; Systems biotechnology; Cell culture bioprocessing

Biomedical and Pharmaceutical Materials (BPM)

<u>Investigator</u>	<u>Department</u>	<u>Expertise</u>
Ron Siegel*	Phm ¹ /BME ²	hydrogels, drug delivery systems, microfabrication
Effi Kokkoli	CEMS³	bioadhesion and drug targeting
Jayanth Panyam	Phm	multifunctional nanodelivery vehicles
Wei Shen	BME	bioactive materials
Calvin Sun	Phm	drug crystal and particle engineering
Raj Suryanarayanan	Phm	solid state properties of drugs, stability of drug/biomaterial formulations
Bob Tranquillo	BME/CEMS	fabrication and characterization of bioartificial cardiovascular replacement tissues
Chun Wang	BME	bio-molecular materials, polymer-based DNA and drug delivery, protein-based tissue scaffolds

**Program Leader (Email:siege017@umn.edu)*

Affiliated Investigators: *Chris Macosko, Marc Hillmyer, Theresa Reineke, Tom Hoye,*

Pharmaceutics; Biomedical Engineering; Chemical Engineering and Materials Science, Chemistry

- **Biomaterials for drug delivery, medical device coatings, and tissue engineering**
- **Drug/medical device combinations, characterization of drug/materials interactions**
- **Cell-based fabrication of bioartificial tissues**
- **Novel tissue mechanical testing and analysis methods**

Coating Process Fundamentals — CPF

Investigator	Expertise
Lorraine F. Francis*	Solidification, stress development, microstructure, printing
Marcio S. Carvalho**	Fluid mechanics, rheology, numerical methods
Satish Kumar	Transport processes, interfacial phenomena, microfluidics
Alon V. McCormick	Curing, thermodynamics & kinetics, NMR, stress development
C. Daniel Frisbie	Printing processes, printed electronics
Chris W. Macosko	Rheology, polymer processing
Xiang Cheng	Colloids, polymers, rheology, visualization
Michael Tsapatsis	Zeolite and particulate coatings, membranes, separations
Wieslaw Suszynski***	Coating process experiments, apparatus, flow visualization

**Program Leader*

***Pontifica Universidade Catolica, Rio de Janeiro*

****Research Engineer and Coating Process and Visualization Laboratory Manager*

Electronic Materials and Devices (EMD)

Investigator	Department	Expertise
Steven Koester*	ECE	<i>Electronic devices, semiconductors</i>
Bharat Jalan*	CEMS	<i>Complex oxides, molecular beam epitaxy</i>
Steve Campbell	ECE	Thin-film photovoltaics, 2D materials
Paul Crowell	Physics	<i>Magnetism, transport, ultra-fast spectroscopy</i>
Dan Frisbie	CEMS	Organic electronics, electrolyte gating
Chris Leighton	CEMS	<i>Electronic/magnetic properties, film/layer growth</i>

Collaborators

Andre Mkhoyan (CEMS), Xiaodong Xu (U. Washington), Ludwig Bartels (UCR), Chris Palmstrøm (UCSB), Chris Kim (ECE)

* Co-Program Directors

Synthesis, structural and chemical characterization of materials relevant for a wide range of electronic, optical and magnetic devices. Particular emphasis is placed on the understanding of the fundamentals of electronic structure and transport in electronic and magnetic materials, in addition to the materials science, physics and chemistry of the interfaces and nanostructures that play a vital role in device operation.

Flexible Electronics and Photovoltaics (FEP)

Investigator	Department	Expertise
Russell Holmes*	CEMS	Thin films, LEDs, solar cells
David Blank	CHEM	Ultrafast optical spectroscopy
Chris Douglas	CHEM	Molecular synthesis
C. Daniel Frisbie	CEMS	TFTs and printed electronics
Paul Ruden	ECE	Device modeling, transport theory

*Program Leader

Interested in the design of materials, device architectures, and processes
For the realization of flexible electronics and optoelectronics
based on organic and hybrid organic-inorganic materials

Microstructured Polymers (MP)

Investigator	Department	Expertise
Chris Ellison *	CEMS	Composites, thin films, lithography fibers, photopolymerization, & polymer processing
Frank S. Bates	CEMS	Thermodynamics, scattering, synthesis
Kevin Dorfman	CEMS	Modeling, confined polymers, DNA
Marc A. Hillmyer	CHEM	Polymer synthesis and characterization (Director: Polymer Synthesis Facility)
Timothy P. Lodge	CHEM/CEMS	Polymer dynamics, solutions, scattering
Chris Macosko	CEMS	Rheology, processing
Mahesh Mahanthappa	CEMS	Polymer Science and Engineering
David C. Morse	CEMS	Theory and modeling
Theresa Reineke	CHEM	Biomedicine, Diagnostics, Targeted Delivery

*Program leader

Collaborators include:

Lorraine Francis (CEMS), Dan Frisbie (CEMS), Tom Hoye (CHEM), Chris Leighton (CEMS), Ron Siegel (PHRM), Bill Tolman (CHEM)

Synthesis, characterization, dynamics, processing, properties, and theory

Nanostructural Materials & Processes (NMP)

Investigator	Dept	Expertise
Alon McCormick*	CEMS	Reaction Engineering of Materials Synthesis; Spectroscopy; Molecular Simulation
C. Daniel Frisbie	CEMS	Molecular Materials and Interfaces; Molecular Electronics
Wayne Gladfelter	CHEM	Materials Chemistry; Inorganic Chemistry; Scanning Probe Microscopy
Greg Haugstad	CHAR FAC	AFM Scanning Probe Microscopy (Director, Characterization Facility)
Christy Haynes	CHEM	Porous and plasmonic nanomaterials, nanoparticle toxicity
R. Lee Penn	CEMS	Environmental Solid State Chemistry
Andreas Stein	CHEM	Solid State Chemistry of Porous Materials
Michael Tsapatsis	CEMS	Materials Synthesis, Structure Elucidation and Modification
Joe Zasadzinski	CEMS	Molecular Fluids, Optical/Electron/Scanning Probe Microscopy

Associated Investigators:

Frank Bates – Lorraine Francis – Bill Gerberich – David Norris – Wei Zhang – Christy Haynes

□

Synthesis, phase behavior, structure, and performance of surfactants and self-assembled molecular and colloid systems