

The 42nd Annual Short Course

"ADVANCES IN EMULSION POLYMERIZATION AND LATEX TECHNOLOGY"

A One-Week Short Course
held at the Hotel Belvédère
in the Davos resort area
of Switzerland

August 19-23, 2019

COURSE DIRECTORS

Dr. Mohamed S. El-Aasser
Professor of
Chemical & Biomolecular Engineering,
Lehigh University

Dr. F. Joseph Schork
Professor of
Chemical & Biomolecular Engineering
Georgia Institute of Technology



COURSE DESIGN

The course is an in-depth study of the synthesis, characterization, and properties of high polymer latexes. The subject matter includes a balance of theory and practical problems. Lectures will begin with introductory material and will progress through recent research results. Lectures will be given in English, and are held in the morning, the late afternoon, and the evening, with a large break in the afternoon to enjoy the recreational activities of the area and allow for interactions between the participants. Organized hikes and visits to points of interest in and around Davos will be arranged for some of the afternoons.

PARTICIPANTS

The course is designed for engineers and scientists who are actively involved in emulsion work, as well as for those who wish to develop expertise in the area. A basic background in chemistry will be assumed. All participants will receive a set of course notes for the lectures.



COURSE FEE

The Registration Fee for the short course is US \$1,650. The Registration Fee will cover attendance, coffee breaks, a welcome reception Sunday evening, a final reception on Thursday evening, and a set of course notes. Payment may be made by check, wire transfer or credit card. Please contact us at DavosCourse@gmail.com for information on wire transfer or credit card payment.

Course Fee is due on June 30. Refund requests received before this date will be honored in full.



COURSE SCHEDULE

MONDAY, August 19, 2019

- 08:30 - 10:00 Free Radical Polymerization Mechanisms and Kinetics (F. J. Schork)
10:00 - 10:30 Coffee Break
10:30 - 12:00 Emulsion Polymerization Mechanisms and Kinetics (F. J. Schork)
16:30 - 18:00 Semi-Continuous Emulsion Polymerization and Structured Latexes (M. F. Cunningham)
20:00 - 21:45 The Role of Surfactants in Emulsion Polymerization Processes and Kinetics
(M. S. El-Aasser)

TUESDAY, August 20, 2019

- 08:30 - 10:00 Film Formation P. A. Lovell
10:00 - 10:30 Coffee Break
10:30 - 12:00 Experimental Methods for the Characterization of Latex Particle Size (C. A. Silebi)
16:30 - 18:00 A Mechanistic Study of Water Evaporation from Wet Acrylic Latex Films / Glass
Transition Evolution of Plasticized Latex Films: An Important Process in the
Application of Everyday Latex Paints (J. W. Taylor)
20:00 - 21:30 Discussion of Applications and Problems Submitted by Course Participants

WEDNESDAY, August 21, 2019

- 08:30 - 10:00 Colloidal Stabilization and Destabilization Mechanisms of Latex Systems
(M. S. El-Aasser)
10:00 - 10:30 Coffee Break
10:30 - 12:00 Latex Rheology (C. A. Silebi)
16:30 - 18:00 Branching and Grafting in Emulsion Polymerization (P. A. Lovell)
20:00 - 21:45 Miniemulsions and their Latex Systems via Polymerization in Monomer Droplets
and Direct Emulsification of Polymer Solutions (M. S. El-Aasser)

THURSDAY, August 22, 2019

- 08:30 - 10:00 Living Radical Polymerization and Recent Advances in Emulsion Polymerization
(M. F. Cunningham)
10:00 - 10:30 Coffee Break
10:30 - 12:00 Water-Borne Soft-Soft Nanocomposites: Principles and Application Case Studies
(P. A. Lovell)
16:30 - 18:00 Latexes for Industrial Applications and Methods of Reducing Residual Monomer
(J. W. Taylor)
20:00 - 21:00 Discussion of Applications and Problems Submitted by Course Participants

FRIDAY, August 23, 2019

- 08:30 - 10:00 Reactor Design and Scale-up of Emulsion Polymerization (M. F. Cunningham)
10:00 - 10:30 Coffee Break
10:30 - 12:00 Sensors and Control of Emulsion Polymerization Reactors (F. J. Schork)
12:00 End of Course

LOCATION

The course will be held at the Hotel Belvédère in Davos Platz in the Graubünden resort area of Switzerland. Numerous recreational opportunities are available to both participants and their guests during the short course.

The Steigenberger Belvédère Hotel is a five-star hotel located in the center of Davos, 0.8 km from the railway station. The hotel, built in 1875, is a harmonious combination of grand past with lively present, of international standards with traditional Swiss hospitality. The view is magnificent in any season in this sumptuously appointed hotel centrally located near all of Davos' many attractions and sports facilities. Spacious, comfortable rooms decorated in romantic-rustic fashion with wooden paneling or in an elegant, modern style, wish you a warm and homely welcome. Large commons areas allow informal conversations between course participants and course lecturers outside of the formal sessions.



Davos is about 100 km north of St. Moritz in southeastern Switzerland. It can be reached by air by flying into Zurich, and then taking Swiss Rail to Davos Platz, with a change of trains in Landquart. From northern Europe, the most common rail route is via Zurich and Landquart to Davos Platz. Driving to Davos should be no problem, since the roads into Davos, although mountainous, are good.

HOTEL RATES

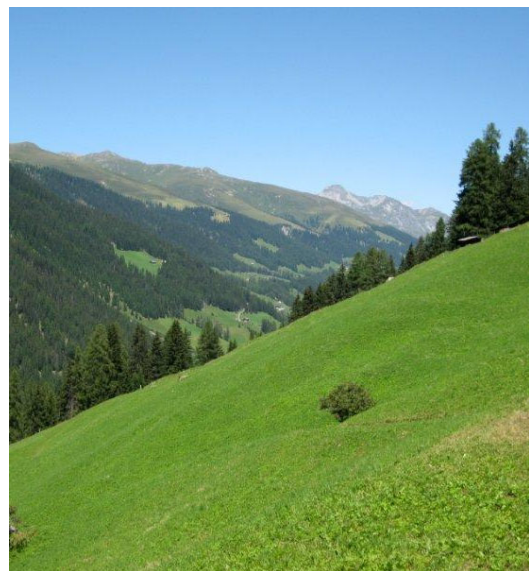
Short Course room rates are:

CHF 172 for standard rooms with bath
(Superior room rates available from the hotel.)

CHF 136 supplement for a double room (second person)

Rates for children are available from the hotel.

Rates include a buffet breakfast, a three course fixed-menu dinner elegantly served in the Main Dining Room with the course participants, free WiFi and free use of the public transportation system in Davos (including selected mountain railways and cable cars). Conference rates will also apply for early arrival or extended stays.



LECTURE ABSTRACTS

Semi-Continuous Emulsion Polymerization and Structured Latexes

Michael Cunningham (Queens University)

Semi-continuous (or semi-batch) polymerizations in which the monomer is added incrementally during the course of reaction are commonly used in industrial processes because they allow control of the polymerization rate, and because they can be used to control the particle morphology. "Structured latexes" are emulsion polymer particles in which the internal morphology and/or composition vary through the particle. Examples include core-shell particles, and particles with radial composition gradients between the particle core and surface. The discussion will describe how semi-continuous processes are run, the unique features of operating an emulsion polymerization in semi-continuous mode, and how structured latexes can be synthesized.



Living Radical Polymerization and Recent Advances in Emulsion Polymerization

Michael Cunningham (Queens University)

While significant advances have occurred in emulsion polymerization in recent decades, in both our fundamental understanding and in practice, the basic chemistry of the process has seen little change until recently. Significant for the development of future commercial products are advances being made in polymer chemistry and catalysis that allow synthesis of polymer colloids with control of the polymer microstructure, polymer colloids made using monomers not previously polymerizable in water-based systems, and in the development of polymer colloids from renewable resources including natural polymers. As this chemistry matures, new classes of polymer colloids will emerge, possibly ushering in entirely new fields of application and considerable opportunities for product innovation. For example, "living" (or "controlled") radical polymerizations (LRP/ CRP) provide a novel and potentially inexpensive route to designing polymers with controlled microstructure (e.g. block copolymers) and narrow molecular weight distributions. Earlier studies focused on homogeneous bulk and solution living radical polymerizations, but our ability to conduct LRP in aqueous dispersed phase systems has now progressed to a point where commercial applications are feasible. This presentation introduces the three major living radical polymerization chemistries (nitroxide-mediated radical polymerization (NMRP), atom transfer radical polymerization (ATRP) and reversible-addition-fragmentation-transfer polymerization (RAFT)), and summarizes recent progress of these systems in bulk and emulsion-based systems. The emphasis will be on those aspects of operating in a heterogeneous environment that influence the polymerization rate, the molecular weight distribution and the livingness of the system. The presentation will also highlight recent advances in the use of other non-radical chemistries to make polymer colloids, and in progress to make "green" polymer colloids from renewable feedstocks and natural polymers.

Reactor Design and Scale-up in Emulsion Polymerization

M. Cunningham (Queen's University)

The principles of designing and safely operating emulsion polymerization reactors will be presented in the context of how the selection of reactor type, mode of operation (batch, semi-batch/semi-continuous, continuous) and specific reaction conditions influence latex product properties and reactor productivity. The first part of the presentation will emphasize the inter-action of the chemistry and kinetics of emulsion polymerization with the physical design and operation of the reactor. The second part of the presentation will examine the issues involved in converting a laboratory scale emulsion polymerization process to a production scale process, including consideration of reaction kinetics, heat transfer and mixing. Emulsion polymerizations often pose a difficult scaleup challenge since by their nature the

polymerization kinetics are coupled with both heat and mass transfer. Consequently almost any change to the process during scaleup is likely to impact product properties, whereas the primary goal of scaleup is to reproduce the latex properties obtained in bench scale experiments. The principles of scaling up an emulsion polymerization will be introduced, and specific challenges will be discussed.

The Role of Surfactants in Emulsion Polymerization and Kinetics

Mohamed S. El-Aasser (Lehigh University)

Surfactants play major roles in emulsion polymerization during the particle nucleation and growth stages, with direct impact on latex particle size, size distribution, polymerization rate, polymer molecular weight, and particle morphology. Surfactants are also essential during post-polymerization processes: stripping, storage, shipping, and formulation for several applications. The general characteristics of surfactants and their adsorption profiles on latex particles will be reviewed. The specific role of surfactants (single and mixtures of surfactants) on the kinetics of emulsion polymerization (rate of polymerization and evolution particle number as a function of polymerization time according to the various nucleation mechanisms) will be described. The influence of water-solubility of monomers, partition of the surfactant between the monomer and aqueous phases, and the use of single vs. mixtures of anionic and non-ionic surfactants on the kinetics results of emulsion polymerization will also be presented and discussed. Three alternatives to conventional surfactants, including ionic monomers, block copolymers, and the recent work on reactive surfactants in emulsion polymerization and characterization results of their loci in the final copolymer latex particles as well as properties of films cast from these latexes be discussed.

Colloidal Stabilization and Destabilization Mechanisms of Latex Systems

Mohamed S. El-Aasser (Lehigh University)

Colloidal stability are essential both during the entire course of an emulsion polymerization process in order to eliminate coagulum formation and to avoid reactor fouling. Latex stability is also essential for many of the post-polymerization processes such as storage, transportation, steam stripping of residual monomer, as well as formulation involving additives (such as pigments, fillers or coalescing aids,) and latex applications methods which may involve subjecting the latex system to mechanical shear.

In this lecture we will introduce the electrostatic and steric colloidal stabilization mechanisms of latex systems. We will discuss in details the key parameters responsible for repulsion and attraction between latex particles in light of the Derjaguin - Landau - Verwey - Overbeek (DLVO) theory, for latex particles that carry negative or positive surface charges due to adsorption of surfactants and/or chemically bound ionized functional groups. We will also discuss the entropy and enthalpy contributions to steric stabilization of latex systems in light of the 2nd law of thermodynamic, due to the presence of non-ionic species at the particle surface such as non-ionic surfactants and/or anchored polymer chain molecules with affinity to the surrounding aqueous phase. The reverse of colloidal stabilization, namely destabilization or aggregation (coagulation and flocculation) of latex systems will be discussed. In this regards, the influence of chemical additives (such as electrolytes, acids, solvents on non-solvents) on stabilization/destabilization will be presented. Also the influence of physical effects (such as agitation and mechanical shear as well as temperature changes including freeze/thaw cycles) on stabilization/destabilization will be presented. Ways to assess the critical concentrations of additives, and levels of temperature changes as well as mechanical shear that cause destabilization of a colloidal-stable latex particles will be discussed. Experimental results will be used to illustrate some of the basic concept and the influence of chemical additives and physical effects on stabilization/destabilization mechanisms of latex systems.

Miniemulsions and their Latex Systems via Polymerization in Monomer Droplets and Direct Emulsification of Polymer Solutions

Mohamed S. El-Aasser (Lehigh University)

In this lecture the early development of the miniemulsion concept will be reviewed, and current state-of-the-art including theory and practice of miniemulsions will be discussed.

The concept of miniemulsions was invented at Lehigh University in 1972. Despite the fact that the first miniemulsion polymerization was also carried out at the same time, the term "miniemulsion" was coined only in 1981. Since that time the number of publications and patents on miniemulsions has been increasing exponentially.

Miniemulsions are relatively stable oil-in-water emulsions with average droplet diameters ranging from 50 to 500 nm. These are typically prepared using a mixture of a surfactant and a low molecular weight, highly water-insoluble costabilizer (sometimes referred to as cosurfactant). In miniemulsion polymerization for the preparation of polymer colloids (latexes), since the surfactant concentration in the aqueous phase is below the CMC, the submicron monomer droplets are the main sites for particle nucleation (and growth) via free radical initiation using oil-soluble or water-soluble initiators. An alternative approach for making latexes based on miniemulsions is the direct emulsification of polymer solutions. The formation and shelf-life stability of miniemulsions are explained based Ostwald ripening and the 2nd law thermodynamics. Miniemulsions have been exploited in making new types of polymer colloids (latexes) that were difficult and sometimes impossible to make using conventional emulsification and/or emulsion polymerization processes. These include preparation of artificial latexes and hybrid latexes, high solids latexes, polymerization of highly water-insoluble monomers and macromonomers, controlled polymer microstructure and morphology, controlled polymer molecular weight distribution via living free radical polymerization, and encapsulation of liquids, inorganic particles, inorganic and organic pigments and dyes.

Film Formation

Peter A. Lovell (University of Manchester)

Understanding film formation is important for all applications where latexes are dried, which includes obvious applications such as water-borne paints, inks and adhesives, but also those which are less obvious, such as binding of non-woven fabrics, sealants and foamed products. This lecture will describe the fundamental principles underlying the process of film formation from latexes, including the key stages and the molecular processes that are necessary for the formation of coherent films. Factors that influence film formation and the quality of the films produced will be described

Water-Borne Soft-Soft Nanocomposites: Principles and Application Case Studies

Peter A. Lovell (University of Manchester)

Latex particles that comprise two or more phases/components are important both academically and industrially. They are used in a diverse range of applications, for example: toughening of plastics; adhesives; architectural coatings; inks; controlled-release of actives; and diagnostics. This lecture will build upon the "Semi-Continuous Emulsion Polymerization and Structured Latexes" lecture by describing in greater detail the parameters which control the development of particle morphology when attempting to prepare, and control the morphology of, multi-phase latex particles in which there are two or more polymer phases. The importance of thermodynamic versus kinetic control will be emphasized and strategies for achieving control of morphology will be described together with their limitations. Some examples will be given to illustrate the principles. The focus will then switch to preparation of multi-component latex particles in which there are both polymeric and non-polymeric materials present. Different approaches to preparation of multi-component latex particles will be described through examples of encapsulating non-polymeric materials, templating of particle morphology, and synthesis of surface-functionalized particles.

Branching and Grafting in Emulsion Polymerization

P. A. Lovell (University of Manchester)

Branching in polymers produced by free-radical polymerization arises from chain transfer to polymer and has important effects on polymer properties. In emulsion polymerization, intermolecular chain transfer to polymer can lead to grafting of water-soluble polymers to latex particles, facilitating control of colloidal stability and latex rheology. Such branching and grafting is used to good effect in the emulsion polymer industry to control the end-use performance of latexes and emulsion polymers. This lecture will begin with an overview of the chemistry of branching and grafting. Case studies of branching in acrylate and vinyl acetate homopolymerizations and synergistic effects in copolymerization will then be presented, together with strategies for controlling the level of branching. This will provide the basis for considering grafting of water-soluble polymers used as colloid stabilizers in emulsion polymerizations. The chemical processes which the most commonly-used water-soluble polymers may undergo during emulsion polymerization will be illustrated through case studies that highlight the key principles for their control.

Free Radical Polymerization Mechanisms and Kinetics

F. Joseph Schork (Georgia Institute of Technology)

A review of the principles of free radical-initiated polymerization, including the basic reactions of initiation, propagation, termination and transfer; inhibition; molecular weight and molecular weight distribution, effect of temperature and pressure, auto-acceleration and diffusion control of termination and propagation, and copolymerization including copolymerization reactivity ratios and copolymer sequence distribution.

Emulsion Polymerization Mechanisms and Kinetics

F. Joseph Schork (Georgia Institute of Technology)

Reaction mechanisms and kinetics of free radical polymerization will be reviewed. The unique features of emulsion polymerization will be outlined and the influence of the colloidal size of the reaction sites discussed. Kinetic theories due to Smith and Ewart, Stockmayer, and Ugelstad will be discussed.

Sensors and Control of Emulsion Polymerization Reactors

F. Joseph Schork (Georgia Institute of Technology)

Recent developments in the area of on-line sensors, coupled with the availability of high-performance digital control systems has opened up new opportunities for the efficient operation and control of latex reactors. Available sensors for on-line analysis will be discussed. The use of such measurements in the application of advanced control techniques to batch and continuous polymerization reactors will be reviewed, with special emphasis on controlling the undesirable process dynamics associated with continuous emulsion polymerization, and optimizing controllers for batch polymerization.

Latex Rheology

C. A. Silebi (Lehigh University)

Review of experimental studies illustrating the various factors that influence the rheological properties of latexes. Topics to be covered include the effects of solids concentration, particle size and distribution, electrolyte content, particle aggregation, adsorbed surfactants, non-spherical particle morphology, particle swelling, and the use of water-soluble associative and non-associative polymeric thickeners. Consideration will also be given to thickened latexes and variables affecting their rheological flow curves.

Experimental Methods for the Characterization of Latex Particle Size

Cesar A. Silebi (Lehigh University)

The application of fractionation and non-fractionation methods for the determination of particle size distribution, the range of applicability, and advantages and disadvantages and their on-line measurement capability will be discussed. Among the methods examined are: classical and dynamic light scattering, sedimentation, disc centrifugation, electrozone sensing, sedimentation field flow fractionation, capillary hydrodynamic fractionation, and recent advances in hybrid methods of analysis. Comparisons of several of these methods will be used to illustrate problems often encountered in the particle size distribution determination of latexes.

A Mechanistic Study of Water Evaporation from Wet Acrylic Latex Films / Glass Transition

Evolution of Plasticized Latex Films: An Important Process in the Application of Everyday Latex

Paints James W. Taylor (Principal Scientist, BASF, retired)

I. This talk discusses factors that control the evaporation rate of water from acrylic latexes during the film formation process. For stage 1 of the film formation process a mechanistic model is developed that shows that the instantaneous drying rate of either latex decreases linearly as the fractional-surface area of water decreases during the drying process. This mechanistic model postulates acrylic particles at the liquid-air interface that inhibit the evaporation of water. At 42 to 45% solids the initial instantaneous drying rate for the two latexes is ~26% less than that of pure water. At 75% solids a change in slope of the instantaneous drying rate as a function of time identifies stage 2 of the drying process.

II. The commercialization of latexes in 1946 created a need for understanding film formation from discrete polymeric particles. Aided by technological advances and pushed by environmental considerations, there has since been a steady shift from solvent-borne to water-borne polymers. Early

film formation theories focused on solvent-free waterborne latexes. However, significant levels of filming aids or solvents are used to optimize the performance of industrial and maintenance coatings. Better understanding of the role filming aids play in the film formation process will aid in the selection of the most efficient filming aid combination for optimizing coating performance.

This lecture focuses on important parameters such as the glass transition temperature of filming aids and polymers, the volatility of filming aids in the presence of water and polymeric particles, the distribution coefficients of filming aids, and the Fox-Flory equation are used to predict the MFT of latex particles at deformation. A new experimental method that obtains the activity coefficients of filming aids during the drying process of latex films is demonstrated. These activity coefficients are used to predict the total solvent loss during the wet evaporation stage of the film formation process. Additionally, the clear film composition is modeled for the ensuing "volatility-controlled" stage that defines the time line where solvent evaporation is not diffusion controlled. The ability of the model to predict or follow the Tg of a "drying system" is demonstrated. The model presented can assist in the selection of filming aids for waterborne latex-based formulations and can provide important criteria for optimizing particle composition and morphology.

Latexes for Industrial Applications and Methods of Reducing Residual Monomers **James W. Taylor (Principal Scientist, BASF, retired)**

Industrial Uses of Latexes: About 10 million metric tons (~20 billion pounds) of dry latex polymers are being consumed annually in a very large number of industrial applications, including paints and coatings (~26% of the total annual latex consumption), paper and paperboard applications (~24%), adhesives (~23%), carpet backsizing (~10%), etc. This part of the talk will review the major industrial applications and types of latexes, and then the important latex variables affecting the properties of latexes for various applications will be discussed. Furthermore, industrial latexes will be grouped in terms of their Tg ranges for various applications which are in turn grouped in terms of filler levels. Finally, some specific applications will be highlighted and their latex requirements and future needs will be discussed.

Methods of Reducing Residual Monomer: Historically, butadiene-containing copolymer latexes, such as gel-free SBR (styrene butadiene rubber) and crosslinked S/B latexes, have been steam stripped to remove their residual monomers, whereas the residual monomers of non-gel forming polymer latexes, such as acrylic latexes, have been burned out (i.e., cooked down) in their post-polymerization steps by using organic peroxides and reducing agents known as "chaser catalysts" in the industry. However, public demands and government regulations for ever lower amounts of residual monomers and VOC's contained in latexes and latex-containing coating formulations may require the industry to consider many different approaches to meet the challenges. For example, in some cases where the post-polymerization burnout alone may not be sufficient to meet the demands, the burnout approach must be either combined with or entirely switched to steam stripping or other approaches. This part of talk will discuss the mechanisms for both batch and continuous steam stripping processes, the post-polymerization burnout mechanisms, various initiator systems for the burnout, and other considerations.

LECTURERS

Michael Cunningham Professor of Chemical Engineering, Queens University, Kingston, Ontario
michael.cunningham@queensu.ca

Professor within the Department of Chemical Engineering, Queen's University, Kingston, Ontario, Canada. He received his Ph.D. in 1990 from the University of Waterloo where he studied chemical engineering with Prof. K.F. O'Driscoll. Prior to his joining Queen's University, he was with the Xerox Research Centre of Canada for six years. While there he conducted research into the design of composite polymer particles. This work has led to 25 U.S. patents. Among his research interests are the areas of polymer reaction engineering, emulsion/miniemulsion polymerization, and living radical polymerization

Mohamed S. El-Aasser Professor Emeritus of Chemical Engineering, Lehigh University
mse0@lehigh.edu

Professor *Emeritus* of Chemical Engineering at Lehigh University. Served Lehigh over the past 45 years as Vice President for International Affairs, Provost and Vice President for Academic Affairs, Dean of P.C. Rossin College of Engineering and Applied Science, Chairman of Chemical Engineering Department, Director of Emulsion Polymers Institute, Director of Center of Polymer Science and Engineering, and Director of the NSF Polymer Interfaces Center.

Areas of research interest include polymer colloids, emulsion polymerization, latex particle morphology, film formation, surfactants and colloidal stability. Pioneered the field of miniemulsions and related polymer latex systems. Authored more than 400 articles, edited 5 books and holds 9 U.S patents. Advised 67 & co-advised 32 PhD students, 53 Masters and 31 postdocs. Delivered numerous invited lectures at national and international conferences.

Degrees include BS & MS from Alexandria University, Egypt; Ph.D. from McGill University, Canada. Awards include 1984 NASA Inventor of the Year Award , 2002 Tess Award in Coatings ACS - Division of Polymeric Materials Science and Engineering (PMSE), the 2007 Fellow of the ACS – PMSE, the 1988 Eleanor and Joseph Libsch Research Award, in recognition of outstanding research at Lehigh University, and Lehigh University's 1999 Hillman Extraordinary Service Award.

Peter A. Lovell Professor *Emeritus* of Polymer Science in the School of Materials at The University of Manchester in the United Kingdom pete.lovell@manchester.ac.uk

He was founding Chairman of the UK Polymer Colloids Forum, which was established in 1993, and was Chairman of Macro Group UK from 2004-2007. His research focuses mainly around aspects of emulsion polymerization and related processes. Prominent in this research has been synthesis of core-shell and multi-layer particles (for applications in toughening plastics and as soft adhesives) and studies of the chemistry (and extent) of branching and grafting, including grafting to water-soluble polymeric colloid stabilizers. Recent research includes a novel chemistry for room-temperature crosslinking during latex film formation, synthesis of new nitroxides for use in controlled miniemulsion polymerization, development of click chemistry for latex particle functionalization and the lead role in a European collaborative research programme for development of high-performance water-borne pressure-sensitive adhesives.

F. Joseph Schork Professor *Emeritus* of Chemical & Biomolecular Engineering, Georgia Institute of Technology joseph.schork@chbe.gatech.edu

Ph.D. in Chemical Engineering from the University of Wisconsin working in the field of emulsion polymerization reactor dynamics. Industrial experience with E.I. DuPont de Nemours & Company in the areas of emulsion polymerization and digital process control. Research interests in polymerization reaction engineering, digital control of polymerization reactors, system dynamics and control. Consultant to various companies in the area of polymerization reaction engineering.

C. A. Silebi Professor *Emeritus* of Chemical Engineering at Lehigh University cas5@lehigh.edu

Ph.D. from Lehigh University. Research interests include particle separation processes, rheological and colloidal properties of latexes, multi-component transport in emulsions, and stability of colloidal systems.

James W. Taylor Principal Scientist, BASF (retired) jamest1950@att.net

Received his Ph.D. Degree in Chemistry from the University of Tennessee in 1982, after which he joined Union Carbide Corporation. From 1992 to 1997 he worked at Eastman Chemical Company as Research Scientist where he developed architectural and industrial coatings. From 1997 to 2008 he served as Research Scientist at Johnson Polymer where he developed applied film formation techniques for the coatings industry. He was appointed Principal Scientist in 2011 and served as the senior research scientist in the Emulsion Research group for BASF located in Wyandotte, MI. Dr. Taylor's current interests include crosslinking technology,

emulsion design, and film formation. He currently holds more than 40 patents in monomer development and crosslinking, emulsion, and photoresist technology.

REGISTRATION

Registration will be limited to 60 course participants. A participant may register by sending the information on the attached Registration Form to Professor Schork by mail, e-mail or fax. On-line registration is available at our website (see below). Checks payable to the Emulsion Polymer Course may accompany registration requests. Alternatively, participants will be invoiced for the course fee upon receipt of a registration form. Payment by bank transfer or credit card can be arranged on request. Only the registration fee will be collected by the course organizers. The conference organizers will make hotel reservations for each participant at the time of registration. Confirmations of the reservation will be sent to the participant by the Hotel Belvédère. Participants needing changes to hotel reservations should deal directly with the Hotel Belvédère. Each participant will be charged directly by the hotel for room costs and extras.

Please register as early as possible so that a course opening can be reserved in your name.

**For more information, or to register,
please contact:**

Dr. F. Joseph Schork
Chemical & Biomolecular Engineering
Georgia Institute of Technology
311 Ferst Drive
Atlanta, Georgia, USA 30332-0100
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OR

visit our web site (including on-line registration) at:

<http://www.DavosCourse.com>



REGISTRATION FORM
"ADVANCES IN EMULSION POLYMERIZATION AND LATEX TECHNOLOGY"
August 19-23, 2019

Dr. Mr. Ms. (Circle one)

First Name: _____

Family Name: _____

Company: _____

Address: _____

Country: _____

Fax: _____

E-mail: _____

Hotel Reservations:

Arrival Date: _____ Departure Date: _____

Number of Rooms: _____

Number of Persons:

Adults: _____ Children: _____

Course Fee will be invoiced.

If possible, please attach a business card and Mail or Fax to:

Dr. F. Joseph Schork
117 Ridgemoor Trace
Canton, GA 30115
Fax: (815) 301-9729
Email: DavosCourse@gmail.com or
Joseph.Schork@chbe.gatech.edu



Emulsion polymerization involves the formation of synthetic latexes and resins by the polymerization of a monomer-in-water emulsion. The resulting polymer dispersion in water may be used in this form, such as for water-based paint, adhesives and the preparation of foam rubber. The homogenizer is used in emulsion polymerization to emulsify the monomer into the premix to the reactor. Of all the emulsion monomers, vinyl chloride polymerization is the one that most commonly uses homogenizers to prepare the mix. D. M. Considine, ed., *Chemical and Process Technology Encyclopedia* (New York: McGraw-Hill, 1974). P. J. Flory, *Principles of Polymer Chemistry* (London: Cornell University Press, 1971). Industrial emulsion polymerization processes (primarily the semibatch and continuous reactions systems). The role of various colloidal phenomena in emulsion polymerization. Important end-use properties of emulsion polymer (latex) products. He received his PhD from the Georgia Institute of Technology, and was associated with United Merchants, S.C. Johnson Wax, and Union Carbide during his industrial career. His major research interests involve nucleation, growth, and stability of latex particles during emulsion polymerization. Table of contents. Preface. 1. Introduction. 4.1. Emulsion Polymerization Kinetics. 4.2. Absorption of Free Radicals by Latex Particles. 4.3. Desorption of Free Radicals Out of Latex Particles. 4.4. Growth of Latex Particles. 4.5. Polymer Molecular Weight. Emulsion polymerization is a polymerization process with different applications on the industrial and academic scale. It involves application of emulsifier to emulsify hydrophobic polymers through aqueous phase by amphipathic emulsifier, then generation of free radicals with either a water or oil soluble initiators. It characterized by reduction of bimolecular termination of free radicals due to segregation of free radicals among the discrete monomer-swollen polymer particles. The latex particles size ranged from 10 nm to 1000 nm in a diameter and are generally spherical. A typical of particle