

**The 40th 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 7-11, 2017

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 \$1,600. 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 7, 2017

- 08:30 - 10:00 Kinetics of Free Radical-Initiated Polymerization (F. J. Schork)
10:00 - 10:30 Coffee Break
10:30 - 12:00 Emulsion Polymerization Mechanisms and Kinetics (G. W. Poehlein)
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 (M. S. El-Aasser)

TUESDAY, August 8, 2017

- 08:30 - 10:00 Engineering of Emulsion Polymerization Reactors (G. W. Poehlein)
10:00 - 10:30 Coffee Break
10:30 - 12:00 Branching and Grafting in Emulsion Polymerizations (P. A. Lovell)
16:30 - 18:00 Latex Rheology (F. J. Schork)
20:00 - 21:30 Discussion of Applications and Problems Submitted by Course Participants

WEDNESDAY, August 9, 2017

- 08:30 - 10:00 Stabilization Mechanisms in Aqueous and Non-Aqueous Latexes
(M. S. El-Aasser)
10:00 - 10:30 Coffee Break
10:30 - 12:00 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)
16:30 - 18:00 Film Formation (P. A. Lovell)
20:00 - 21:45 Miniemulsion Polymerization and Latex Systems (M. S. El-Aasser)

THURSDAY, August 10, 2017

- 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 Principles and Application Case Studies of Water-Borne Soft-Soft Nanocomposites
(P. A. Lovell)
16:30 - 18:00 Scale-up of Emulsion Polymerization Processes (M. F. Cunningham)
20:00 - 21:00 Discussion of Applications and Problems Submitted by Course Participants

FRIDAY, August 11, 2017

- 08:30 - 10:00 A Latexes for Industrial Applications and Methods of Reducing Residual
Monomer (J. W. Taylor)
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

Kinetics of Free Radical-Initiated Polymerization **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 **Gary W. Poehlein (Georgia Institute of Technology)**

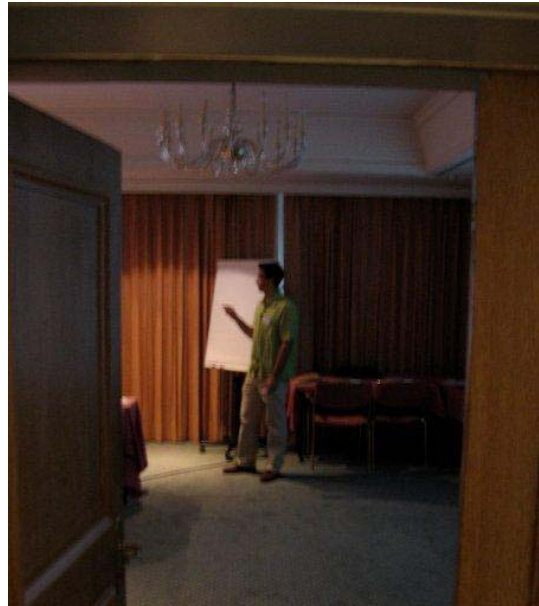
Reaction mechanisms and kinetics of free radical polymerization will be reviewed. The unique features of emulsion polymerization will be outlined and the influence of the colloidal size of the reaction sites discussed. Kinetic theories due to Smith and Ewart, Stockmayer, O'Toole, Roe, Fitch, Ugelstad,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

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.

The Role of Surfactants in Emulsion Polymerization Processes **Mohamed S. El-Aasser (Lehigh University)**

Surfactants play major roles during the particle nucleation and growth stages, with direct impact on latex particle size, size distribution, polymerization rate, 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 in determining the particle number according to the various nucleation mechanisms will be described. Three alternatives to conventional surfactants will be reviewed.



Engineering of Emulsion Polymerization Reactors
Gary W. Poehlein (Georgia Institute of Technology)

The various types of reactors (batch, semi-batch and continuous), used to produce synthetic latexes will be reviewed. Pros and cons of various types of processes will be discussed and theoretical reactor models will be presented where appropriate. Reactor design and operating factors that influence product properties will also be reviewed.

Branching and Grafting in Emulsion Polymerizations
Peter 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.

Latex Rheology
F. Joseph Schork (Georgia Institute of Technology)

This introduction to the rheology of latexes covers the type of rheological measurements that can be made and the effects of the many variables found in latexes; solids concentration, particle size and distribution, surface charges, adsorbed surfactants, particle aggregation, non-spherical particle morphology, swellable particles, and the use of water-soluble polymer thickeners.

Stabilization Mechanisms in Aqueous and Non-Aqueous Latexes
Mohamed S. El-Aasser (Lehigh University)

The basic concepts and terminology of colloid science will be introduced. The principles of electrostatic and steric stabilization mechanisms will then be reviewed. The inverse problem of coagulating and flocculating latexes will also be discussed.

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)

This talk discusses factors that control the evaporation rate of water from acrylic latexes and solvents 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.

The second part of this lecture focuses on the use of filming aids or solvents during the film formation process of latex paints. 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 water-borne latex-based formulations and can provide important criteria for optimizing particle composition and morphology.

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.

Miniemulsion Polymerization and Latex Systems

Mohamed S. El-Aasser (Lehigh University)

Despite the fact that the first miniemulsion polymerization was carried out at Lehigh University in 1972, the word “miniemulsion” was coined only in 1981. The number of publications on miniemulsions has been increasing exponentially over the past decade, including a few patents.

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 (referred to as cosurfactant). In miniemulsion polymerization, the submicron size monomer droplets are the main sites for particle nucleation and growth via free radical initiation using oil-soluble or water-soluble initiators. The theory of miniemulsions has been developed based on the well-known concepts of Ostwald ripening and thermodynamics. Miniemulsions have been exploited in making new types of polymer colloids (latexes) that were difficult and sometimes impossible to make by using conventional emulsification 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, encapsulation of pigments and dyes, and controlled molecular weight via living free radical polymerization. In this lecture both the theory and practice of miniemulsions will be discussed.

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.

Principles and Application Case Studies of Water-Borne Soft-Soft Nanocomposites Peter A. Lovell (University of Manchester)

Many applications of water-borne polymers prepared by emulsion polymerisation require use of soft polymers with glass transition temperatures below room temperature so that films can be formed. In this lecture an overview of the principles underlying the soft-soft nanocomposite concept for enhancing the performance of soft films produced from water-borne polymers prepared by methods of emulsion polymerisation will be presented and then exemplified through three commercially-relevant application case studies: (i) water-borne pressure-sensitive adhesives; (ii) polybutadiene films as models for nitrile rubber glove applications; and (iii) acrylic latexes for use as binders in surface coatings.

Scale-up of Emulsion Polymerization Processes M. Cunningham (Queen’s University)

Converting a laboratory scale emulsion polymerization process to a production scale process requires consideration of a range of issues including reaction kinetics, heat transfer and mixing (mass transfer). 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. Typical challenges encountered in scaleup include inability to obtain the desired latex properties, coagulum formation, and problems controlling the reactor temperature. The principles of scaling up an emulsion polymerization will be introduced, and these specific challenges will be discussed.

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

Latexes for Industrial Applications: More than 10 million metric tons (more than 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 backsizeing (~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 industrial applications will be discussed. Furthermore, industrial latexes will be grouped in terms of their T_g ranges for various applications. They are also 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 Monomers: 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 further polymerized (i.e., cooked down) in their post-polymerization steps by using hydrophobic initiators, such as tertiary butyl hydroperoxide, 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 demands and regulations. For example, in some cases where the post-polymerization cook-down alone may not be sufficient to meet the demands, the cook-down approach must be either combined with nitrogen stripping or entirely switched to steam-stripping. This part of talk will discuss the mechanisms for both batch and continuous steam-stripping processes, the post-polymerization cook-down mechanisms, various initiator systems for the cook-down, and other considerations.

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.

LECTURERS

Michael Cunningham **Professor of Chemical Engineering, Queens University, Kingston, Ontario**

Ph.D. in Chemical Engineering from the University of Waterloo. Industrial experience with the Xerox Corporate Research Group developing new processes for small, composite particles. Research program is in polymer reaction engineering, with an emphasis on emulsion polymerization. Primary focus of current research is living radical polymerization in heterogeneous systems, and the design of functionalized latex particles for applications such as bioseparations.

Mohamed S. El-Aasser **Professor of Chemical Engineering, Lehigh University**

Ph.D. from McGill University and Pulp and Paper Research Institute in 1972. Research interests include emulsion polymerization, emulsification, surface and colloidal properties of latexes, and latex film formation, adsorption from solutions, and stabilization of colloids.

Peter A. Lovell **Professor of Polymer Science in the School of Materials, University of Manchester, UK**

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 fictionalization and the lead role in a European collaborative research program for development of high-performance water-borne pressure-sensitive adhesives.

Gary W. Poehlein

Professor Emeritus of Chemical & Biomolecular Engineering, Georgia Institute of Technology

Ph.D. in Chemical Engineering from Purdue University. Industrial experience with the Proctor and Gamble Company. Research interests include kinetics of emulsion polymerization and continuous reactor systems.

F. Joseph Schork

Professor of Chemical & Biomolecular Engineering, Georgia Institute of Technology

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.

James W. Taylor

Principal Scientist, BASF (retired)

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 USA
Fax: (815) 301-9729
E-mail: DavosCourse@gmail.com
or joseph.schork@chbe.gatech.edu

OR

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

<http://www.DavosCourse.com>



REGISTRATION FORM
"ADVANCES IN EMULSION POLYMERIZATION AND LATEX TECHNOLOGY"
August 7-11, 2017

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, Georgia, USA 30115
Fax: (815) 301-9729
Email: DavosCourse@gmail.com or
Joseph.Schork@chbe.gatech.edu