

# Multilayer Flexible Packaging

Second Edition

Edited by:  
John R. Wagner, Jr.

# MULTILAYER FLEXIBLE PACKAGING

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## Preface to the First Edition

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In the beginning of this project, I had expected to complete it in less than a year. Now, four years later, it has finally come to completion. Along the road, the pressures of limited resources and conflicting objectives changed the timeline and contributors.

This book had ambitious goals set. What has resulted is an incomplete description of multilayer films and the technology to produce them. It is a snapshot that gives a comprehensive view of multilayer film designs and technology used. As in any evolving system, things change and what we can describe today may be somewhat different tomorrow. The value this book brings is that it will help interested parties to understand what is being made and how it is produced. This will help them deal with current problems and issues and move forward to invent new products and processes that will meet future challenges.

The authors who have contributed their time and extensive knowledge are industry experts and respected educators from around the world. They have shared their thoughts and ideas with you so that you can better understand this important technology and improve your contributions in your area of expertise.

The book is organized as follows:

### Introduction

### Raw materials

- Resins
- Additives
- Rheology

### Die design

- Flat
- Blown

### Process considerations

### Technologies

- Blown film, cast film, and lamination processes
- Machine direction orientation process
- Biaxial orientation
- Blending
- Coating technologies
- Vacuum-deposited coating

### Multilayer film designs

- PE-based film
- Oriented films

### Appendix: Writing guide for describing multilayer film structures.

As the technology of multilayer films is constantly developing, it is virtually impossible to have an up-to-the minute description of every multilayer film and technology used. So, this book, by definition, is only a snapshot of what is available. By reading this book, whether you are a manager, purchasing agent, user, engineer or technician, you can improve your knowledge and insight into this important technology that provides safety, freshness, and visual appeal for point of sale awareness.

The introduction starts by presenting a historical perspective of the materials used to produce flexible plastic films. Then a look at how the markets for flexible plastic films have grown along with an extrapolation to 2020. The main body of this book is divided into three sections:

- materials
- hardware and processes
- multilayer film designs with applications

In the materials section, there are chapters about polyethylene and polypropylene, the two major materials used for flexible film, a comprehensive chapter on additives used to make polymers functional and then a chapter on rheology which presents important concepts needed to understand non-Newtonian viscoelastic flow.

The hardware and process section begins with a chapter that describes the dies used to produce multilayer film. Annular dies are used for blown processes. The several ways multilayer dies can be designed are presented. Flat dies are used for cast and oriented films. Multilayer structures can be produced with multicavity dies, feedblocks and by combining feedblocks with multicavity dies.

There is a special chapter on process engineering and how important this function is to producing multilayer films that meet specifications and cost targets.

Then there follow chapters about the technologies used to produce multilayer films. The areas covered are production of multilayer films, laminating films to produce a structure that cannot be produced in a single step and coating processes. The chapter on blending is especially useful as blending technology is widely used and not always easy to understand.

The last section presents PE based and oriented film-based multilayer structures. In these two chapters, you will learn about many different structures and their applications.

The appendix presents a nomenclature or shorthand language that can be used to describe multilayer films.

*Read, Learn, Enjoy.*

## Preface to the Second Edition

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It is now six years after the first edition went to press and we have listened to reviewers of this book and added three new chapters. While this book is still an incomplete description of multilayer films and the technology to produce them, it is an updated and more comprehensive edition.

The new chapters are on:

- Bio Polymers
- Winding
- Food regulations

The new table of contents is:

- Introduction
- PE [new author]
- PP
- Biopolymers [new author]
- Rheology

- Blown Film Dies
- Process Engineering [new author]
- Polymer blends
- Coating Technology
- Vacuum Metallizing
- Winding [new author]
- PE Films
- Regulatory Aspects of Food Packaging — A Global Matter [new author]
- Appendix

The updates include new information and improved grammar for easier reading.

I trust you will find these additions, updates, and improvements useful in your work.

*Read, Learn, Enjoy.*





## Acknowledgments

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It is unfortunate in today's economy that everyone is very busy and such was the case with this second edition. I am extremely grateful to the authors who have contributed their time and shared their knowledge so that you, our readers, can do your jobs more effectively and efficiently.

While plastic overall is a positive contributor to our health and well-being, plastic has a negative connotation due to the pollution that occurs in our environment. We need to be painfully

aware of this issue and engineer products that are more sustainable, nontoxic, and economically viable.

We also need to educate people not to pollute and to establish programs to clean our oceans and water ways of plastic.

We all need to be part of the solution, not part of the problem.

Best to you,  
John R. Wagner, Jr



## List of Contributors

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## Contributors

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### Joachim Bayer

Joachim Bayer joined Songwon in June 2007 as director of technical sales for Europe and Middle East. Joachim has 13 years of experience in antioxidants, UV additives, dispersing agents, and antistats. Joachim acquired key competences in physical forms and polymer conversion processes. He held various positions in R&D, TS, Marketing and Sales. Before Songwon, he worked for Hoechst (D), Clariant (D), Great Lakes (CH), and Chemtura (CH).

### Charles A. Bishop

Charles left school at 16 and completed an engineering apprenticeship as a toolmaker. He took a degree in Materials Technology at Loughborough University. He then moved to the Physics Department and completed his Masters and Doctorate degrees by research into vacuum deposition onto polymer webs. After a brief time as a post doctoral researcher and consultant, he moved into industry working for ICI and DuPont for 15 years before setting up his own consultancy business in 1998.

He authored the book *Vacuum deposition onto webs, films and foils* and authored or co-authored over 60 papers and 5 patents. He jointly runs a vacuum training website ([www.VacuumCoatingTraining.com](http://www.VacuumCoatingTraining.com)) and edits the AIMCAL Blog [www.vacuumcoatingblog.com](http://www.vacuumcoatingblog.com) and is on their panel of "Experts" to answer problems members send in. He received the SVC Mentor Award 2008.

### Jürgen Breil, PhD

Dr Jürgen Breil graduated from the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen in 1980. He remained at RWTH Aachen and was employed in the field of science and industrial projects in the faculty of Mechanical Engineering. He focused on automating extrusion lines and received his PhD from the Institute for Plastic Processing (IKV).

At Krauss Maffei Kunststofftechnik, Munich, he worked on automating injection-molding machines. He joined Brückner Maschinenbau GmbH in 1986 and worked on several automation projects. He was promoted to department leader for technology and automation and, in 1993, he became responsible for the Research and Development department. Since 2002, he has been the head of division Process Technology and R&D.

Dr Breil is the author of 14 papers and 9 patents on orientation technologies.

### Thomas Butler

Thomas I. (Tom) Butler received his BS in Chemical Engineering from New Mexico State University. He has over 39 years of experience in the development of application and products for the plastics and chemical industry. Tom now provides consulting services with his company Blown Film Technology, LLC. Tom retired from The Dow Chemical Company in 2004 where he made significant contributions in the development of polyethylene polymers and processing technology while in the Polyethylene Technical Service and Development Group. His interests include expertise in extrusion process design and control, coextrusion technology and blown film process technology. He has been involved in film application development for film liners, stretch cling, grocery sacks, adhesive resins, sealant resins, skin packaging, snack food applications, processed meat packaging, hygiene applications, and produce packaging.

### Allison Calhoun, PhD

Dr Allison Calhoun is Associate Professor of Chemistry and teaches courses in general and physical chemistry and the applications of physical chemistry in environmental and polymeric systems at Whitman College in Washington state. Prior to joining the faculty at Whitman, she worked for five years in the polymer industry and holds

three patents for the use of mineral additives in polymeric thin films. She is the co-author of a polymer science textbook and her current research projects examine the oxidation of polyolefins and the impact of this oxidation on the interface of minerals in polymers. She received her PhD from the University of Georgia with a focus in physical chemistry. She sits on the Board of Directors for the Flexible Packaging Division of the Society of Plastics Engineering and is a member of the Physical Chemistry Test Writing Committee through the American Chemical Society.

#### **Edward D. Cohen**

Dr Cohen is a technical consultant in all aspects of the web coating process. He received a PhD from the University of Delaware and a BS in Chemical Engineering from Tufts University. His expertise is in the coating and drying of thin films, coating process development and scale-up, coating defects and new product development.

He has over 45 years' experience in coating research and manufacturing technology with the DuPont Company and as an independent consultant. He has extensive publications in coating drying technology. Currently, he is Technical Consultant for AIMCAL.

#### **Sina Ebnesajjad**

Dr. Sina Ebnesajjad is the President and Founder of FLUOROCONSULTANTS GROUP, LLC. He had worked for nearly 24 years for the DuPont Fluoroproducts before retiring at the end of 2005. He has extensive experience with fluoropolymer products and technologies using granular, fine powder and dispersion PTFE (Teflon<sup>®</sup>), additives and melt processable fluoropolymers including PFA, FEP, ETFE, PVDF, ECTFE, PVF, PCTFE, and films.

Dr. Ebnesajjad authored over a dozen books including the incumbent handbooks of fluoropolymer technologies all published by Elsevier.

#### **Edgar B. Gutoff**

Edgar B. Gutoff, ScD, PE, has been a consultant on coating and drying since 1988. He organized the first of the 14 International Coating Symposia at the AIChE Spring 1982 meeting and was the founding Secretary of the International Society for Coating Science and Technology, which now sponsors them. He has organized a number of coating

courses and seminars and has co-authored *Coating and Drying Defects*, *Modern Coating and Drying Technology* and *The Application of Statistical Process Control to Roll Products*. In 1994, he was awarded the AIChE John A. Tallmadge Award for Contributions to Coating Technology. He is a fellow of the AIChE and IS&T and is on AIMCAL's Technical Advisory Panel. He worked for Polaroid for 28 years and now is an Adjunct Professor at Northeastern University. He received an ScD and an SM from MIT and a BChE from CCNY.

#### **Eric Hatfield**

Eric Hatfield is co-owner of MDO Engineering which specializes in Machine Direction Orientors (MDO). He just recently was a Partner and the Managing Director of Operations Technology at FlexTech Packaging Ltd, an MDO & high barrier based film company where he was responsible for Engineering and Process Technologies. Formally, Eric was the manager of Process and Equipment Development for James River's Flexible Packaging Group. Duties there included design of combining adapters, flat and round dies, MDOs and the creation and commercialization of process equipment and technologies. Eric has a BS in Chemical Engineering from the Illinois Institute of Technology and an MBA from Keller Graduate School. He also has several patents.

#### **Duk-Suk Jung**

Duk-Suk Jung received an education as chemist and process engineer in South Korea. Duk-Suk is team leader and the manager of the technical department in Songwon's homebase Ulsan (South Korea). His responsibility involves the process engineering of all synthesis plants. He has over 24 years' experience in technical service in Asian countries in antioxidants, UV absorbers, HALS, and PVC stabilizers.

#### **Sung-Leal Jung**

Sung-Leal Jung received an education as chemist and process engineer in South Korea. Sung-Leal currently holds the position of manager of the Asian technical service group for PVC stabilizers, based in Ulsan (South Korea). For this product group, he has more than 15 years of experience. Before that, he was involved in the engineering of Songwon's stabilizer plants.

**Klaus Keck-Antoine**

Klaus Keck-Antoine studied Polymer Chemistry at FH Reutlingen in Germany until 1991. He joined Songwon in September 2007 after an extensive career in plastic stabilizers and additives. In the past 16 years, he worked on antioxidants, UV additives, inhibitors, dispersing agents and anti-stats for polyolefins, engineering resins and non-polymeric substrates. Before Songwon, he worked for Hoechst (Germany), Hoechst Celanese (USA), Clariant (USA), Great Lakes (USA and Belgium), and shortly for Chemtura (Belgium). Currently, he is in charge of implementing Songwon's Global Application and Technical Service Community (GATSC). GATSC is a global forum of and network for industry experts and scientific laboratories to enhance the systematic understanding of polymer additives and provide this service and knowledge to Songwon's customers. He holds various patents and has published frequently on above-mentioned topics.

**Els Lievens**

Els Lievens is a professional bachelor of chemistry from the Karel De Grote Hogeschool in Hoboken (B). She started her career in 1992 with Shell Chemicals in the application research group for polypropylene (PP) in Louvain La Neuve (B), more particular PP film applications. In 1995, she started doing application development work on additives for PP throughout all applications. Later, after the merger of Shell into respectively Montell and Basell, she became responsible for the upscaling of new PP additives in the northern European plants and technical qualification of new additives. In 2002, she joined Great Lakes — later on Chemtura — to be project leader for application development of polymer stabilizers. Since 2007, she has held the position of chemical sourcing manager in the chemistry research department of Agfa Graphics in Mortsels (B).

**John Mara**

John Mara is the Technical Sales Manager for Songwon International — Americas, a position he has held since 2007. During this time, his primary responsibility has been to grow Songwon's polymer stabilizer business in the Americas providing commercial and technical support to a broad range of customers. Prior to joining Songwon, John managed the Advanced Polymer Technologies Group at

Excel Polymers where his research focused on Rubber Nanocomposites. Prior to Excel, John provided technical support to BASF's Light Stabilizer Business, managed commercial and technical activities involving polymer stabilizers with Great Lakes Chemical Company and managed the Polymer Science Analytical Group at Chevron Chemical Company. John received his PhD in Polymer Science/Plastics Engineering from the University of Massachusetts-Lowell (1992) where he studied the synthesis and characterization of novel liquid crystalline polymers. John also holds a Six-Sigma Black belt from the University of Akron (2007) and has authored and co-authored over a dozen technical papers on polymer stabilization.

**Scott B. Marks**

Scott Marks was educated at Rutgers University where he earned degrees in Mechanical Engineering and Business Administration. He is employed by E.I. DuPont de Nemours & Company, starting initially as a Construction Engineer and then, in 1984, transferred into the Polymers business unit working in the Flexible Packaging industry. He has held Market Development and Technical Service positions concentrating on the Asia-Pacific and North American regions the majority of his career, but also has supported Latin American and Europe.

Scott's process expertise is in multilayer blown film, cast film, extrusion coating and sheet. He has also worked with adhesive lamination and thermal lamination. He has a broad packaging knowledge including meat, cheese, seafood, pharmaceutical and healthcare, personal care, and industrial and consumer goods markets. In addition, he has worked with non-packaging applications such as composite building panels, cable shielding, cable sheathing, and surf and boogie boards.

Scott's work is mainly with polyolefins, specializing in modified ethylene copolymers for sealants, adhesives and bulk layers in extrusions and laminations. In addition, he has worked with Nylon and ethylene vinyl alcohol coextruded with polyolefins and polyesters, polystyrenes, and newer materials such as thermoplastic starch and polylactic acid.

Scott has presented for TAPPI and SPE in North America and via other organizations in Singapore, Malaysia, Thailand, Taiwan, Australia, and New Zealand.

He is active in TAPPI's PLACE division, having served in several officer positions including



Division Chairman and division council advisor. He is an active member of the Flexible Packaging, Extrusion Coating, and Film Extrusion working committees and co-chairs the International Committee.

#### **Barry A. Morris**

Barry A. Morris is a senior technology associate with DuPont Packaging and Industrial Polymers. He received a BS in chemical engineering from the University of Virginia and a PhD from Princeton University. He also has an MBA from the University of Delaware. His research interests include polymer adhesion, blends, compounding, rheology, coextrusion and film and coating converting processes. He has over 20 years of experience in packaging technology and is widely published.

#### **Eldridge M. Mount III**

Dr Mount is an independent consultant in the extrusion, metallization and plastic film industries. Originally a chemist, he obtained ME and PhD degrees in chemical engineering at Rensselaer Polytechnic in 1979 with the experimental and theoretical study of melting mechanisms and the modeling of polymer melting in single-screw extruders. Since graduation, Eldridge has worked for ICI Americas and ExxonMobil in the areas of biaxially oriented PET and OPP films. His work encompassed process and product design where he was responsible for new screw designs, increased output, coextrusion technology and the development of new metallized and other OPP film products. Eldridge has nine US patents and many publications in the area of metallized OPP films and extrusion. A Fellow and Honored Service Member of SPE, he has been active on the Executive Committee and the Extrusion Division Board and has been a speaker at ANTEC, TAPPI and AIMCAL as well as other professional societies in the areas of metallized films, extrusion and film processing. Since June 2000, Eldridge has been an independent consultant with EMMOUNT Technologies. In his spare time he is a long standing adult Boy Scout Leader and Silver Beaver recipient. He enjoys hunting, hiking, and camping.

#### **Rajen M. Patel**

Rajen Patel joined Polyolefins R&D of the Dow chemical company in June 1991 in the materials science group and transferred to Polyolefins TS&D

of the Dow chemical company in November 2007. He has worked in various research and applications development areas including polyolefins characterization (thermal & rheological), structure-processing-properties relationships in polyolefins, and product development in variety of applications such as hygiene & medical, oriented shrink films, collation shrink film, sealants, cast stretch films, blown films, extrusion coating, tie-layers, barrier, elastic films and fibers. He has researched extensively on materials science and applications development of single-site (metallocene) catalyzed Polyolefins. He received 2 Dow Inventor of the Year Awards and The Dow Excellence in Science Award. He wrote a chapter on structure-properties and applications of Polyolefins produced by single-site catalyst technology in encyclopedia of chemical processing and design. He co-authored 22 technical peer reviewed journal publications and 4 book chapters. He is also a co-inventor of 47 granted US patents. In 2009, he was elected as Fellow of Society of Plastics Engineers (SPE) in recognition of his technical and commercial accomplishments in Polyolefins and especially in single-site catalyzed (metallocene) Polyolefins. He is currently a board member of SPE's Engineering Properties and Structure division (ESPDIV). He is currently an Associate Research Fellow in the Packaging and Specialty Plastics technical service and development (TS&D) group in the Dow Chemical Company leading packaging applications development.

Rajen Patel obtained his BS in Chemical Engineering from the University of Bombay in 1984. He joined university of Tennessee, Knoxville, USA, in September 1985 and obtained MS in December 1987 and PhD in May 1991, both in Polymer Science & Engineering.

#### **David R Roisum**

Dr. Roisum is a well-known authority in the area of web handling and converting. He has authored nine books that include Winding, Rollers and Web-Handling with his most recent being the Web Machine Buying Guide. He has coauthored or edited several others. Additionally, he has written 200 articles, conference papers and other publications. He has also written hundreds of blog posts and made one hundred YouTube instructional clips. He has been a technical editor for Converting Magazine with a monthly column entitled Web