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TABLE OF CONTENTS

VOLUME 1

ALLOYS AND BLENDS SIG010

EFFECT OF NANOCCLAYS ON THE COMPATIBILITY OF MALEIC ANHYDRIDE-GRAFTED-POLYPROPYLENE/POLY (ETHYLENE OXIDE) BLEND.....	1
<i>Abdulhadi Al-Juhani</i>	
THE EFFECT OF RECYCLE ON THE PROPERTIES OF ENGINEERING THERMOPLASTICS	6
<i>Jim Derudder, Amanda Flores, Yuanqing He, Yuheng Yang, Wei Zhao</i>	
MINERAL REINFORCED IMPACT MODIFIED POLYCARBONATE BLENDS: EXPLORING SPECIFIC FILLER SURFACE INTERACTIONS FOR PROPERTY ENHANCEMENTS.....	16
<i>Vikram Daga, James Derudder, Yuanqing He, Amit Kulkarni, Karin Van De Wetering</i>	
PREDICTING PHASE MORPHOLOGY DEVELOPMENT OF POLYMER BLEND IN CONVERGENT-STRATGHT CHANNEL.....	21
<i>Han-Xiong Huang, You-Fa Huang, Quan-Jie Wang, Zhi-Yong Peng</i>	
SURFACE ENERGY EFFECTS OF PC/SAN/MWCNT BLENDS WITH THE ADDITION OF A REACTIVE COMPONENT	26
<i>Vicki Flaris, Cherie Fletcher, Marén Gültner, Petra Poetschke</i>	

APPLIED RHEOLOGY SIG013

EFFECT OF CLAY CONCENTRATION ON THE RHEOLOGICAL PROPERTIES OF TRIBLOCK COPOLYMERS NANOCOMPOSITES.....	29
<i>Leice Amurin, Danilo Carastan, Nicole Demarquette</i>	
THE EFFECT OF CO ₂ ON THE MELT FRACTURE BEHAVIOR OF FOAMED PLA	33
<i>Medhi Keshtkar, Lun Howe Mark, Chul Park, Mo Xu</i>	
EFFECTS OF COMPONENT VISCOSITIES AND DISPERSED PHASE VOLUME FRACTION ON RELAXATION BEHAVIOR FOR POLYMER BLENDS.....	39
<i>Zhao-Ke Chen, Han-Xiong Huang, Qiong Xu</i>	
ENHANCEMENT OF MELT ELASTICITY OF LONG-CHAIN BRANCHED POLYETHYLENE BY BLENDING A LINEAR POLYETHYLENE.....	44
<i>Naoya Mieda, Masayuki Yamaguchi</i>	
FOLLOWING CHEMICAL REACTIONS WITH RHEOMETRY AND SIMULTANEOUS FTIR-SPECTROSCOPY	48
<i>Manfred Feustel, Fabian Meyer, Jan Plog</i>	
GENERATION OF AN EMPIRICAL MODEL TO DESCRIBE THE EXPERIMENTAL EVOLUTION OF DRAG RATIO FOR A TWO PHASE HORIZONTAL PIPE FLOW OF NON-NEWTONIAN LIQUID (CARBOPOL)/AIR MIXTURE.....	51
<i>Febin Cyriac, Oparaji Onyekachi, J. M. Franco</i>	
HIGH-SHEAR-RATE RHEOLOGY OF POLYSTYRENE MELTS.....	55
<i>Wei-Sheng Guan, Han-Xiong Huang</i>	
IN-SITU COMPATIBILIZATION OF HDPE-FUMED SILICA COMPOSITES: MORPHOLOGY, RHEOLOGY AND FILM BARRIER PROPERTIES	61
<i>Sanjukta Bose, Anup Ghosh, Susanta Mitra, Sangita Nandi</i>	
MEASUREMENT AND MODELING OF PLANAR AND UNIAXIAL EXTENSIONAL VISCOSITIES FOR LDPE POLYMER MELT	66
<i>Martin Zatloukal</i>	
MISCIBILITY CHARACTERIZATION OF INDOMETHACIN AND EUDRAGIT® E PO BY RHEOLOGICAL AND THERMAL ANALYSIS	71
<i>Costas Gogos, Huiju Liu, Herman Suwardie, Peng Wang, Xueyan Zhang</i>	
NOUVEL NON-LINEAR RHEOLOGICAL PARAMETERS FOR POLYOLEFIN QUALITY CONTROL	76
<i>Susana Filipe, Katja Klimke, Anh Tran</i>	
PRACTICAL USE OF CREEP TEST TO OBTAIN THE RHEOLOGICAL DATA AT LOW FREQUENCY RANGE FOR POLYETHYLENE.....	82
<i>Yongwoo Inn, David Rohlfing</i>	
RHEOLOGY AND MELT FRACTURE OF BIODEGRADABLE POLY (ε-CAPROLACTONE) POLYESTERS	87
<i>Savvas Hatzikiriakos, Nazbanoo Noroozi, Laurel Schafer, Jaclyn Thomson</i>	

AUTOMOTIVE D31

IMPROVED SCRATCH AND CHEMICAL RESISTANCE ACRYLIC FOR AUTOMOTIVE MOLD-IN-COLOR APPLICATIONS	92
<i>H. Banyay</i>	

MEASUREMENT OF THE STRAIN-DEPENDENT POISSON'S RATIO FOR THE CRASH SIMULATION OF TECHNICAL THERMOPLASTICS	97
<i>Barbara Heesel, Christian Hopmann</i>	
A NEW POLYPROPYLENE/CLAY NANOCOMPOSITE FOR REPLACEMENT OF ENGINEERING PLASTICS IN AUTOMOTIVE APPLICATION	102
<i>Reza Bagheri, Pouyan Motamedi, Saeid Zokaei</i>	
MODEL VALIDATION FOR PREDICTING COMFORT IN AUTOMOTIVE SEATING POLYURETHANE FOAMS	110
<i>Edwardo Leyva, Yoshiaki Miyazaki, Bernard Obi, Venkat Minnikanti, Parvinder Walia</i>	

BIOPLASTICS SIG028

BIO- ACRYLONITRILE BUTADIENE STYRENE (BIO-ABS): CREATING A NEW GREEN POLYMER THROUGH MELT BLENDING	116
<i>Manjusri Misra, Amar Mohanty, Ryan Vadori</i>	
BIO-BASED POLYAMIDES WITH INNOVATIVE FIBRES FOR ENGINEERING PARTS MATERIALS – PROCESS – CHARACTERIZATION - APPLICATIONS	121
<i>Andrzej K. Bledzki, Maik Feldmann, Hans-Peter Heim, Abdullah Al Mamun</i>	
CARBON NANOTUBES IN BLENDS OF THERMOPLASTIC STARCH/POLYCAPROLACTONE	126
<i>Basil Favis, Ata Taghizadeh</i>	
COMMERCIALIZATION ROADMAP OF BIOPOLYMERS AND BIOCOMPOSITES	132
<i>Sam McCord, Mike Parker</i>	
CROSS-LINKING OF HYDROGEL WITH A NEW WATER-SOLUBLE AGENT, DIISOSORBIDE BISEPOXIDE	135
<i>George Collins, William Hammond, Bhavita Joshi, Eleanor Ojinnaka, Herman Suwardie</i>	
EFFECT OF D-LACTIDE CONTENT ON THERMAL BEHAVIOR OF POLYLACTIDE IN PRESENCE OF CO₂ DISSOLVED GAS	139
<i>Mohammadreza Nofar, Chul Park, Jed Randall, Wenli Zhu</i>	
EFFECT OF EPOXIDIZED SOYBEAN OIL ON MECHANICAL PROPERTIES OF POLYLACTIC ACID BLENDS	144
<i>Yong Qing Zhao, Fu Quan, Zheng Hwan Wu, Gui Zhen Zhang, Jin Ping Qu</i>	
EFFECT OF THE MOLECULAR STRUCTURE OF PLASTICIZER ON THE MORPHOLOGY OF POLYMER BLENDS WITH THERMOPLASTIC STARCH	150
<i>Basil Favis, Ata Taghizadeh</i>	
ELONGATIONAL RHEOLOGY AND MECHANICAL PROPERTIES OF BIODEGRADABLE PLA/PBSA BLENDS	155
<i>Hassan Eslami, Musa Kamal</i>	
FABRRICATION OF HIGHLY TUBULAR POROUS CHITOSAN/POLY (DL LACTIC-CO-GLYCOLIC ACID) (PLGA) NANOCOMPOSITE STRUCTURES INTENDED FOR TISSUE ENGINEERING SCAFFOLD APPLICATIONS	159
<i>Zhixiang Cui, Jian Han, Yiyan Peng, Changyu Shen, Lih-Sheng Turng, Xiaofeng Wang, Haibin Zhao</i>	
IN SITU OBSERVATION OF THE FOAMING PROCESSES OF CELLULOSE NANOFIBER REINFORCED POLYLACTIC ACID BIOCOMPOSITES	164
<i>Weidan Ding, Takashi Kuboki, Chul Park, Mohini Sain, Anson Wong</i>	
LAYER MULTIPLYING COEXTRUSION OF POLYLACTIC ACID AND POLYVINYL ALCOHOL CAST FILMS	170
<i>Sarah Schirmer Cheney, Danielle Froio, Jeanne Lucciarini, Gregory Pigeon, Jo Ann Ratto, Christopher Thellen, Darin Vanderwalker, Scott Winroth, Ron Walling, Greg Geil</i>	
MARKET SITUATION AND POSSIBILITIES FOR INFORMATION PROCUREMENT OF BIOPOLYMERS (BIOPOLYMER DATABASE)	177
<i>Maren Bengs, Hans-Josef Endres, Andrea Siebert-Raths</i>	
MAXIMIZING TALC BENEFITS IN DURABLE PLA APPLICATIONS WITH LUZENAC HAR®	182
<i>Caroline Abler, Jerome Crepin-Leblond, Frederic Jouffret, Saied Kochesfahani</i>	
MELT EXTRUSION AND FILM PROPERTIES OF SOY FLOUR/POLYETHYLENE BLENDS FOR PACKAGING APPLICATIONS	187
<i>Jo Ann Ratto, Christopher Thellen</i>	
MODELLING OF HYGROSCOPIC STRESSES DUE TO NON-UNIFORM LIQUID DISTRIBUTION IN HOMOGENEOUS BIOPLASTICS	192
<i>Syed Masood, Igor Sbarski, Indah Widiastuti</i>	
MODIFICATION OF MECHANICAL PROPERTIES OF POLYBUTYLENE SUCCINATE USING IN-SITU COMPATIBILIZATION BLEND WITH POLY(LACTIC ACID)	198
<i>Nattakarn Hongsrirphan, Benchamas Panyad</i>	
NUMERICAL INVESTIGATION OF BIOMASS MATERIAL TPS (THERMOPLASTIC STARCH) IN INJECTION MOLDING PRODUCTION	204
<i>Chih-Jen Chang, Vivaldi Lee, Sheng-Ju Liao, Shih-Juh Liou</i>	
MORPHOLOGY OF POLY(LACTIC ACID)/POLY(BUTYLENE ADIPATE-CO-TEREPHTHALATE) BLENDS AND ITS COMPOSITE WITH SPHERICAL SILICA PARTICLES	209
<i>Pierre Carreau, Ebrahim Jalili Dil, Basil Favis, Sepehr Ravati</i>	

MULTI-COMPONENT BIO-BASED BLENDS WITH POLYLACTIC ACID AND POLYHYDROXYBUTYRATE: MORPHOLOGY AND PHYSICAL PROPERTIES.....	219
<i>Christine Beaulieu, Viêt Cao, Louise Deschênes, Basil Favis, Sepehr Ravati</i>	
MULTICOMPONENT BIODEGRADABLE BLENDS WITH POLY(BUTYLENE SUCCINATE): PARTIAL AND COMPLETE WETTING PHENOMENA	225
<i>Basil Favis, Sepehr Ravati</i>	
NANOFIBRILLATED CELLULOSE REINFORCED POLYVINYL ALCOHOL: PROPERTIES AND SOLUBILITY OF CARBON DIOXIDE	231
<i>Craig Clemons, Ronald Sabo, Yottha Srithep, Lih Sheng Turng</i>	
DEVELOPMENTS OF NEW NON-HALOGEN FLAME RETARDED POLYMER BLENDS WITH BIO CONTENT	237
<i>Roger Avakian, Patricia Hubbard, Jing Liu, Shixiong Zhu</i>	
SELECTIVE LOCALIZATION OF SPHERICAL SILICA PARTICLES IN HETEROPHASE POLY(LACTIC ACID)/ LOW DENSITY POLYETHYLENE BLENDS	240
<i>Ebrahim Jalili Dil, Basil Favis</i>	
SPECIALTIES OF THE PROCESSING OF PLA THROUGH EXTRUSION AND INJECTION MOLDING, AND RESULTING CHARACTERISTICS.....	247
<i>Hans-Josef Endres, Andrea Siebert-Raths, Sicco De Vos</i>	
THE STRUCTURE AND PROPERTIES OF PLA/PP POROUS FILM	255
<i>C. Chau, P. Koch, T. Powers, S. Solovyov, J. Williams</i>	
A STUDY ON RECYCLING OF POLYHYDROXYBUTYRATE (PHB) COPOLYMER AND ITS EFFECT ON MATERIAL PROPERTIES.	260
<i>Stephen McCarthy, Bhavin Shah, Robert Whitehouse</i>	
POLYMER BLEND FOR BLOW MOLDED BOTTLE WITH LOW GREENHOUSE GAS EMISSIONS	265
<i>Gregory Anderson</i>	

BLOW MOLDING D30

ASSESSMENT OF A NOVEL CO-POLYESTER RESIN THAT EXHIBITS EARLY STRAIN HARDENING BEHAVIOR	271
<i>Mark Barger, William Harris, John Weaver, Robert L. Sammler</i>	
PHA BIODEGRABLE BLOW-MODLED BOTTLES: COMPOUNDING AND PERFORMANCE	278
<i>Joseph Greene</i>	
POLYESTER DEVELOPMENT PROGRESS FOR EXTRUSION BLOW MOLDING APPLICATIONS.....	284
<i>Thomas Pecorini, Mark Treece</i>	
PREDICTING CAPILLARY DIE SWELL OF HIGH MOLECULAR WEIGHT HDPE RESINS FOR BLOW MOLDING APPLICATIONS.....	291
<i>Carmine D'Agostino, Tieqi Li, Tracy Li, Wen Lin, Anna Rajkovic</i>	
A SIMULATION OF INJECTION STRETCH-BLOW MOLDING PROCESS BY USING A VISCO-PLASTIC MODEL	294
<i>Baeg-Soon Cha, Dong Han Kim, Heung-Kyu Kim, Hyung-Pil Park, Byung-Ohk Rhee, Min Jae Song</i>	
SINGLE-STAGE BLOW MOLDING SIMULATION & CONTAINER PERFORMANCE PREDICTION	298
<i>Sumit Mukherjee</i>	
VIRTUAL PROTOTYPING APPLIED TO A BLOW MOLDED CONTAINER.....	308
<i>Frédéric Fradet, Philippe Klein, Thierry Marchal, Hossam Metwally</i>	

COLOR AND APPEARANCE D21

ALUMINUM PIGMENT TROUBLE SHOOTING FOR PLASTICS	313
<i>Robert Schoppe</i>	
CORROSION INHIBITION OF FLAKY ALUMINIUM BY SOL-GEL COATINGS OF MTES AND TEOS	320
<i>Zhiqi Cai, Kun Chen, Jiang Cheng, Pihui Pi, Xiufang Wen, Shouping Xu, Zhuoru Yang, Lianfu Zheng</i>	
DECISION TREE CLASSIFIER FOR ANALYSIS OF PARAMETERS ASSOCIATION CAUSING POLYMER COLOR MISMATCH	330
<i>Jamal Alsadi, Farid Bourennani, Ghaus M. Rizvi, Daniel Ross</i>	
EFFECTS OF PROCESSING PARAMATERS ON COLOUR MISMATCH DURING COMPOUNDING.....	336
<i>Shahid Ahmad, Jamal Alsadi, Ghaus Rizvi, Daniel Ross, Usman Saeed</i>	
EXECUTION OF 3 LEVEL FULL FACTORIAL DESIGN TO EVALUATE THE PROCESS PARAMETRS: POLYMER COLOR.....	341
<i>Shahid Ahmad, Jamal Alsaadi, Richard Clarke, James Price, Ghaus Rizvi, Daniel Ross, Usman Saeed</i>	
THE GOLDEN TRIANGLE: A STRATEGY FOR IMPLEMENTING SUCCESSFUL PRODUCTS FOR THE MASTERBATCH INDUSTRY	346
<i>Doreen Becker</i>	
IMPROVING QUALITY AND REDUCING COSTS BY STATE-OF-THE-ART COLOR AND APPEARANCE SUPPLY CHAIN MANAGEMENT	348
<i>Scott Brewer, Walter Franz</i>	
MULTI-DISCIPLINE PROBLEM SOLVING IN A MULTI-FACETED GLOBAL TECHNICAL STRUCTURE	353
<i>James Rediske</i>	

NEW TECHNOLOGY FOR ANTI-YELLOWING AND WEATHER RESISTANT PEARLESCENT WHITE MICA BASED PIGMENTS	360
<i>Scott Aumann</i>	
NEXT GENERATION UV STABILIZED, IMPACT MODIFIED POLYACETAL COPOLYMER (POM) FOR AUTOMOTIVE INTERIOR APPLICATIONS	363
<i>Bruce Mulholland</i>	
OVERCOMING TECHNOLOGICAL ISSUES ASSOCIATED WITH COLOR ADDITIVES IN POLYMERS VIA SOLID-STATE SHEAR PULVERIZATION	371
<i>Philip Brunner, John Torkelson</i>	
A STUDY ON EFFECT OF SMALL PERTURBATIONS IN COLOUR FORMULATION ON OUTPUT COLOUR OF A PLASTIC GRADE COMPOUNDED WITH A SINGLE POLYCARBONATE RESIN	376
<i>Shahid Ahmed, Jamal Alsadi, Ghaus Rizvi, Daniel Ross, Usman Saeed</i>	

COMPOSITES D39

RECENT DEVELOPMENT ON GREEN COMPOSITES FROM NATURAL FIBER AND POLY(FURFURYL ALCOHOL) BIORESIN	381
<i>Harekrishna Deka, Manjusri Misra, Amar Mohanty</i>	
ANALYSIS OF CFC AS ITER DIVERTOR PROTECTOR	386
<i>Ali Goodarzi, Hailey Taylor</i>	
ANALYSIS OF NANOSTRUCTURES SYNTHESIZED BY USING RESIDUAL SOLIDS FROM WASTED TIRES AS CARBON SOURCE	393
<i>Jesus Arenas-Alatorre, Jose Azamar-Barrios, Ricardo Mis-Fernandez, Carlos Rios-Soberanis</i>	
BARRIER PROPERTIES OF GRAPHENE-BASED POLYMER NANOCOMPOSITES	397
<i>Sushant Agarwal, Rakesh Gupta, Prithu Mukhopadhyay, Matthew Thompson</i>	
CARBON NANOFIBER/POLYETHYLENE NANOCOMPOSITES FOR ESD AND EMI APPLICATIONS	403
<i>Mohammed Al-Saleh, Uttandaraman Sundararaj</i>	
CHANNEL FLOW SIMULATION WITH DELAYED FOLGAR TUCKER FIBER ORIENTATION MODEL	408
<i>Donald Baird, Syed Mazahir, Gregorio Velez-Garcia, Peter Wapperom</i>	
THE CHARACTERISTICS OF IMMISCIBLE POLYMER BLENDS WITH MWNT	414
<i>Tae Yong Hwang, Sang Min Kim, Jae Wook Lee</i>	
COMPARATIVE STUDY OF WOOD-PLASTIC COMPOSITES BASED ON BIODEGRADABLE POLYMERS	418
<i>Nattakarn Hongsriphan</i>	
COMPARISON OF COMMON ELECTRICAL TESTING METHODS FOR THE MEASUREMENT OF INJECTION MOLDED PC/CNT COMPOSITES	424
<i>Jill Kunzelman, Jane Spikowski</i>	
COMPARISON OF WHEAT STRAW AND TALC ON POLYPROPYLENE COMPOSITES	432
<i>Arathi Mohan Sharma, Leonardo C. Simon</i>	
COMPOSITION-OPTIMIZED SYNTHETIC GRAPHITE/POLYMER NANOCOMPOSITES	437
<i>Ehsan Bafekrpour, Bronwyn Fox, Jana Habsuda, Minoo Naebe, George Simon, Chunhui Yang</i>	
COMPOUNDING EXTRUSION OF POLYPROPYLENE CARBON NANOTUBE COMPOSITES: OPTIMISING AND ECONOMIZING PROCESS WITH A COMMERCIAL PERSPECTIVE – A CASE STUDY	442
<i>Jan Diemert, Peter Elsner, Frank Henning, Christof Hübner, Shyam Sathyanarayana, Patrick Weiss, Daniel Berkowitz Zamora</i>	
CREATING MOLECULAR REBAR FROM MULTI-WALL CARBON NANOTUBES	448
<i>Clive Bosnyak, Kurt Swogger</i>	
DEGRADATION MECHANISM OF GFRP AT HOT WATER	452
<i>Yoshimichi Fujii, Tatsuro Morita, Hiroyuki Nishimura, Shun Sato</i>	
DEVELOPMENT AND CHARACTERIZATION OF LOW DENSITY POLYETHYLENE/CELLULOSE MICROFIBRIL COMPOSITES	457
<i>Sherly Paul, B. Harsha, V. Vidya, R. Aswathy</i>	
DIELECTRIC BEHAVIOR OF POLY(VINYLDENE FLUORIDE)/GRAPHENE COMPOSITES WITH LOW PERCOLATION THRESHOLD	463
<i>Feng Chen, Ping Fan, Lei Wang, Jintao Yang, Mingqiang Zhong</i>	
DOSABLE SISAL FIBRES FOR THERMOPLASTIC COMPOSITES	467
<i>Manfred Bachtrodt, Christoph Burgstaller</i>	
EFFECT OF FIBER SURFACE TREATMENT ON THERMAL AND MECHANICAL PROPERTIES OF JUTE MAT REINFORCED POLYCARBONATE COMPOSITES	472
<i>Hiroyuki Hamada, Hiroyuki Nishimura, Smith Thitithanasarn, Kazushi Yamada</i>	
THE EFFECT OF GLASS FIBER LENGTH ON ORIENTATION DISTRIBUTION WITHIN INJECTION MOLDED COMPOSITES	476
<i>Don Baird, John Hofmann, Kevin Meyer, Gregorio Velez-Garcia, Abby Whittington</i>	
EFFECT OF HIGH TEMPERATURE OXIDATION ON MECHANICAL PROPERTIES OF 2D C_F/SIC COMPOSITES	481
<i>Ali Goodarzi, Hailey Taylor</i>	
THE EFFECT OF NANOCCLAY ON THE RHEOLOGICAL PROPERTY AND MELT STRENGTH OF POLYPROPYLENE/POLYAMIDE-6 BLEND	495
<i>Binyi Chen, Jinwei Chen, Jichang Fan, Yongqiang Lin, Xiangfang Peng, Haibin Zhao</i>	

THE EFFECT OF WELL EXFOLIATED AND DISPERSED GRAPHENE OXIDE SHEETS ON THE POLYSTYRENE SUPERCRITICAL CARBON DIOXIDE FOAMING	500
<i>Feng Chen, Lingqi Huang, Jintao Yang, Yuefang Zhang, Mingqiang Zhong</i>	
ENCAPSULATED GRAPHENE WITH POLYSTYRENE BY ULTRASONICALLY INITIATED IN-SITU EMULSION POLYMERIZATION	505
<i>Feng Chen, Ping Fan, Lei Wang, Jintao Yang, Mingqiang Zhong</i>	
GLASS FIBER REINFORCED ENGINEERING PLASTICS SIZING AN ESSENTIAL COMPONENT FOR PERFORMANCE.....	509
<i>Piet Leegstra, Jaap Van Der Woude</i>	
IMPROVED GLASS-FILLED HIGH PERFORMANCE THERMOPLASTIC POLYIMIDE COMPOSITES.....	516
<i>Aditya Narayanan</i>	
INFLUENCE OF FIBER LENGTH ON THE FATIGUE BEHAVIOR OF GLASS FIBER REINFORCED POLYAMIDE	524
<i>Volker Altstaedt, Melanie Rohde, Hannes Welz, Felipe Wolff-Fabris</i>	
INFLUENCE OF PROCESS PARAMETERS OF AN UNDERWATER PELLETIZING SYSTEM ON THE MOISTURE OF WPC (WOOD-PLASTIC-COMPOSITE) PELLETS	532
<i>Nils Böhm, Volker Schöppner, Xiaolan Song</i>	
INVESTIGATION OF CLAY MORPHOLOGY IN HIGH CONCENTRATION POLYPROPYLENE-CLAY NANOCOMPOSITES USING THE SUPERCRITICAL CO₂ AIDED MELT BLENDING METHOD	537
<i>Donald Baird, Chen Chen, John Quigley</i>	
MECHANICAL PROPERTIES OF ABS/SPARKLE ALUMINUM COMPOSITES	542
<i>Xiaoting Xiao, Jingjing Zhang, Haiyan Zhu</i>	
NANOCOMPOSITES CHARACTERIZATION BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)	546
<i>David Norman, Andrew Salamon</i>	
NON-LINEAR STRESS-STRAIN AND DUCTILITY MODELING OF A POLYMER COMPOSITE WITH FILLERS	549
<i>Dev Barpanda, Ha Pham, Sweta Somasi, Nikhil Verghese</i>	
A NOVEL METHOD TO PREPARE PET NANOCOMPOSITES BY WATER-ASSISTED MELT COMPOUNDING.....	563
<i>Pierre Carreau, Maryam Dini, Musa Kamal, Tahereh Mousavand, Minh-Tan Ton-That</i>	
AN OVERVIEW OF SIZING CHEMISTRY AND ITS IMPORTANCE IN COMPOSITE PROCESSING AND PROPERTIES.....	569
<i>Andrew Brink, Yves De Smet</i>	
PAPER.STUDY OF THE INTERFACIAL PROPERTIES OF FIQUE FIBER REINFORCED POLYETHYLENE ALUMINIUM	575
<i>Miguel Hidalgo, José Mina, Mario Muñoz, Tim Osswald</i>	
POLYMERIC HEAT DELIVERY SYSTEM.....	581
<i>Maziyar Bolourchi</i>	
PREDICTION OF ELASTIC MODULUS OF HYBRID INJECTION MOLDED COMPOSITE	588
<i>Hiroyuki Hamada, Hiroyuki Inoya, Manabu Nomura, Tomoko Ota, Putinun Uawongsuwan, Toshikazu Umemura, Yuqiu Yang</i>	
PREPARATION AND PROPERTY STUDY OF TOUGHENED AND REINFORCED NYLON WITH NON-HALOGEN FLAME-RETARDANTS	593
<i>Binyi Chen, Qiang Fu, Xin Jing, Haoyang Mi, Xiangfang Peng</i>	
PREPARATION OF MWCNTS GRAFTED WITH POLYAMIDOAMINE DENDRIMER AND ITS EFFECT ON POLYSTYRENE SCCO₂ FOAMING.....	598
<i>Feng Chen, Honghu Dai, Renhao Hu, Jintao Yang, Mingqiang Zhong, Yunguo Zhou</i>	
PROGRESS ON SIMULATING LONG-GLASS FIBER ORIENTATION IN COMPLEX MOLDING GEOMETRIES.....	602
<i>Donald Baird, Kevin Meyer</i>	
RENDERING WATERPROOF AND MULTIFUNCTIONAL FIBROUS SHEETS OF CELLULOSE: FROM PACKAGING AND ANTICOUNTERFEIT TO CONSTRUCTION APPLICATIONS	607
<i>Athanassia Athanassiou, Agnese Attanasio, Ilker Bayer, Roberto Cingolani, Despina Fragouli</i>	
SOME REASONS FOR THE FRACTURING OF GLASS REINFORCED PLASTIC PIPES	613
<i>Valeriy Makarov, Rakhil Sinelnikova</i>	
STRUCTURE AND PROCESSING DESIGN OF JUTE SPUN YARN/PLA BRAIDED COMPOSITE BY PULTRUSION MOLDING.....	616
<i>Anin Memon, Asami Nakai</i>	
STRUCTURE AND PROPERTIES OF POLYPROPYLENE/MICRONIZED RUBBER POWDER COMPOSITES	622
<i>Ravi Ayyer, Jonathan Colton, Tom Rosenmayer, William Schreiber</i>	
THE STUDY ON MESOPOROUS SILICA IN POLYLACTIDE SUPERCRITICAL CO₂ FOAMING AND THERMAL PROPERTIES.....	628
<i>Feng Chen, Daoxing Dai, Honghu Dai, Jintao Yang, Mingqiang Zhong, Yunguo Zhou</i>	
STUDY ON PREPARATION AND PROPERTIES OF POLYLACTIDE/GRAFTED SILICA NANOCOMPOSITES.....	631
<i>Bin-Yi Chen, Zhi-Gang Hu, Xin Jing, Xiangfang Peng, Haibin Zhao</i>	

A STUDY ON THE PERCOLATION AND DEFORMATION MECHANISM OF POLY(BUTADIENE ADIPATE-CO-TEREPHTHALATE)-LAYERED SILICATE NANOCOMPOSITES.....	636
<i>Sunggyu Lee, Alexandria Niemoeller</i>	
SYNTHESIS OF FUNCTIONAL GRAPHENES FOR HIGH-PERFORMANCE NANOPAPERS	640
<i>Wenyi Huang, L. James Lee</i>	
TEMPERATURE DEPENDENCE OF THE INTERFACIAL SHEAR STRENGTH IN GLASS-FIBER POLYPROPYLENE COMPOSITES INVESTIGATED BY A NOVEL SINGLE FIBER TECHNIQUE	644
<i>James Thomason, Liu Yang</i>	
THERMAL CONDUCTIVITY OF POLYCARBONATE-CARBON NANOTUBE COMPOSITES	649
<i>Jill Kunzelman, Nayandeep Mahanta</i>	
THERMAL PROPERTIES OF LIQUID CRYSTALLINE EPOXY RESIN/ GLASS FIBER-REINFORCED NYLON 66.....	655
<i>Zhi-Qi Cai, Weicheng Wang, Junjie He, Pihui Pi, Huifan Ye, Shouping Xu, Xiufang Wen, Jiang Cheng</i>	

DECORATING AND ASSEMBLY D34

CONTROLLING ADHESION OF DIGITAL UV DECORATING TECHNIQUES	660
<i>Rory Wolf</i>	
DIGITAL PRINTING OF PLASTICS A NEW FRONTIER FOR INDUSTRIAL PRODUCT DECORATION	661
<i>Kasper Nossent</i>	
EMERGING FIBER LASER TECHNOLOGY FOR MARKING PLASTICS.....	662
<i>Scott Sabreen</i>	
HOW TO CONFIRM LIGHT CURE ADHESIVES ARE FULLY CURED	663
<i>Anne Forcum</i>	
IMPROVING PACKAGE TRACEABILITY, MARKETABILITY, AND SUSTAINABILITY WITH DIGITAL DECORATING.....	664
<i>Amy Swab, Chris Demell, Chris Sobaszek</i>	
LATEST UV COATING TRENDS	665
<i>Abdullah Ekin</i>	
NEW ADVANCES IN BONDING POLYOLEFIN-BASED PLASTICS	666
<i>Alex Matassa</i>	
PASSIVE MULTI-SCALE ALIGNMENT AND ASSEMBLY	667
<i>Stephen Johnston, David Kazmer, Mary Moriarty, Christopher Santeufemio</i>	
PHYSICAL VAPOR DEPOSITION AND UV CURABLE COATINGS	674
<i>Jason Eich, Eileen Weber, Phil Abell, Kristy Wagner, Chris Mack</i>	
PVC REPLACEMENT IN RF MEDICAL DEVICE PLASTICS WELDING	682
<i>Tom Ryder</i>	
STRUCTURAL BONDING ALTERNATIVES FOR PLASTICS	683
<i>Rachel Nashett</i>	
TRANSFER EFFICIENCY VERSUS COATING WASTE REDUCTION	684
<i>Ken Eyestone</i>	
WHEN IS IT TIME TO DIGITALLY DECORATE? MAKING THE RIGHT CHOICES.....	685
<i>Darlene Putz</i>	
WIRELESS DEVICES DECORATED USING NON-CONDUCTIVE VACUUM METALLIZATION (NCVM) TECHNIQUES: CONSIDERATIONS AND COMMON FAILURE MODES	686
<i>Dwayne Wasylshyn, B. Varkey, Y. Huang</i>	

ELECTRICAL AND ELECTRONIC D24

COMPATIBLIZED POLYPHENYLENE SULFIDE/LIQUID CRYSTAL POLYMER ALLOY FOR ELECTRICAL & ELECTRONIC APPLICATIONS.....	691
<i>Rong Luo, Xinyu Zhao</i>	
ENHANCED DIELECTRIC LIFETIME OF MULTILAYERED PC/PVDF-HFP FOR CAPACITOR APPLICATIONS.....	696
<i>Eric Baer, Matthew Mackey, Zheng Zhou</i>	
LASER DIRECT STRUCTURING OF THERMALLY CONDUCTIVE POLYMERS: AN INNOVATIVE THERMAL MANAGEMENT APPROACH	701
<i>Dietmar Drummer, Christoph Heinle, Florian Ranft</i>	
MULTIFUNCTIONAL COMPOUNDS USING CARBON NANOSTRUCTURE ENHANCED GLASS REINFORCEMENTS IN ELECTROMAGNETIC COMPATIBILITY APPLICATIONS.....	706
<i>David Hartman, Stephanie Rinne, William Smith, Desmond Vanhouten</i>	
STATIC CHARGE CONTROL FOR PLASTIC WEBS IN ROLL-TO-ROLL MANUFACTURING PROCESSES.....	712
<i>Kelly Robinson</i>	
ULTRA-HIGH THERMALLY TREATED LLDPE NANOCOMPOSITES: TRANSPORT PROPERTIES AND ELECTROMAGNETIC SHIELDING.	718
<i>Todd Hubing, Amod Ogale, Byron Villacorta</i>	

ENGINEERING PROPERTIES AND STRUCTURE D26

ADDITIVE MIGRATION IN POLYMER FILMS	723
<i>Douglas Hirt</i>	
ALKYD RESIN COATING SYNTHESIZED FROM POST-CONSUMER PET BOTTLES FOR WOOD-PLASTIC COMPOSITE	724
<i>Nattakarn Hongsriphan, Sawinee Klinrod</i>	
ANALYSIS OF TERNARY NON-COVALENT FILLER/MATRIX/ UV STABILIZER INTERACTIONS IN CARBON NANOFIBER/ PMMA COMPOSITES VIA TIME-RESOLVED FLUORESCENCE EMISSION SPECTROSCOPY	728
<i>Pavel Anzenbacher, I. Sedat Gunes, Sadhan Jana, Guillermo Jimenez, Fengyu Li, Cesar Perez-Bolivar</i>	
ANALYSIS OF THE PROPERTIES AS CONTENT OF END-GROUP FOR POLYCARBONATE (PC) IN MELT POLYMERIZATION PROCESS	734
<i>Sang-Hyun Park, Su Ran Lee, Byung Hood Lim, Kwan Hwi Park, Byoung Ok Jang</i>	
COPOLYMER POLYOXYMETHYLENE PERFORMANCE IN AGGRESSIVE FUELS	740
<i>Jeremy Klug</i>	
CRYSTALLIZATION BEHAVIOUR OF POST-INDUSTRIAL WASTE NYLON COMPOSITES	748
<i>Philip Bates, Paul Lem, B. Baylis, J. Vanderveen</i>	
DEVELOPMENT OF A METHOD FOR THE LIFE-TIME DIMENSIONING OF SHORT FIBER REINFORCED PLASTICS	756
<i>Christian Hopmann, Hendrik Kremer, Walter Michaeli</i>	
DEVELOPMENT OF LIGNIN-BASED THERMOPLASTICS FOR COMPOSITE APPLICATIONS	760
<i>Amit Naskar</i>	
THE EFFECT OF FEEDING PROFILE IN THE DISTRIBUTION OF CHAINS COMPOSITION AND MECHANICAL PERFORMANCE OF STYRENE/BUTYL ACRYLATE EMULSION COPOLYMERS	761
<i>Francisco Aranda-Garcia, Alvaro Arnez-Prado, Luis González-Ortiz, Carlos Jasso-Gastinel</i>	
EFFECT OF NANOTUBE CHARACTERISTICS ON MULTIWALLED CARBON NANOTUBE/POLYAMIDE 6,6 COMPOSITES PREPARED BY MELT-MIXING	767
<i>Cristina Caamano, Brian Grady, Daniel Resasco</i>	
EFFECT OF PLASTICIZER ON THE PHYSICAL PROPERTIES OF TRI-ACETYL CELLULOSE FILM	773
<i>Ho-Jong Kang, Hongsuk Kim</i>	
EFFECTS OF ANNEALING TIME AND TEMPERATURE ON THE CRYSTALLINITY AND DYNAMIC MECHANICAL BEHAVIOR OF INJECTION MOLDED POLYLACTIC ACID (PLA)	777
<i>Paul Nealey, Yottha Srithep, Lih-Sheng Turng</i>	
EFFECTS OF MOLECULAR ORIENTATIONS AND RESIDUAL STRESSES ON THE ENVIRONMENTAL STRESS CRACKING STRESS CRACKING RESISTANCE OF POLYCARBONATE	783
<i>Nikolai Borchmann, Markus Brinkmann, Christian Hopmann, Andre Potthoff</i>	
ENVIRONMENTAL AGING OF COATED FABRICS COMPOSITES	789
<i>James M. Sloan, D. Flanagan, C. Pergantis, P. Touchet, H. Feuer</i>	
ESTER FUNCTIONALIZATION AND STRUCTURAL MODIFICATION OF POLYPROPYLENE VIA SOLID-STATE SHEAR PULVERIZATION	793
<i>Jeanette Diop, John Torkelson</i>	
EVALUATION OF DEGRADATION OF BACK-SHEET FOR PHOTOVOLTAIC PANELS	797
<i>Hideo Hirabayashi, Akinori Iguchi, Kazushi Yamada, Hiroyuki Nishimura</i>	
EVALUATION OF FRACTURE CHARACTERISTICS OF POLYETHYLENE BLOWN FILMS USING THE ESSENTIAL WORK OF FRACTURE (EWF) WITH VARIABLE FILM ORIENTATIONS	803
<i>Byoung-Ho Choi, Ilhyun Kim</i>	
EVALUATION OF NON-CROSSLINKED POLYETHYLENE PIPES FOR HEATING	809
<i>Hideo Hirabayashi, Akinori Iguchi, Kazushi Yamada, Hiroyuki Nishimura, Kazuhisa Ikawa, Takafumi Kawaguchi</i>	
EXPLOITING CHAOS: SHOULD POLYMERIZATION REACTORS BE CHAOTIC?	814
<i>Sadhan Jana, Chang Do Jung</i>	
FEM MODELING OF SURFACE FRICTION EFFECT ON SCRATCH-INDUCED DEFORMATION IN POLYMERS	818
<i>Mohammad Hossain, Hung-Jue Sue</i>	
FLOW BEHAVIOR OF DIFFERENT POLYETHYLENES IN CAPILLARY FLOW	824
<i>Mahmoud Ansari, Savvas Hatzikiriakos, Evan Mitsoulis, Thanasis Zisis</i>	
FRACTURE TOUGHNESS AND SCRATCH BEHAVIOR OF POLYMERIC THIN FILMS	830
<i>Hung-Jue Sue, Brian Hare, Chinfu Lee</i>	
FUNCTIONALITY IN MULTILAYER FILMS FOR PACKAGING	831
<i>Abdellah Ajji, Abdelghani Housni, Farhad Sadeghi, Richard Silverwood</i>	
HIGHLY GAS PERMEABLE UV CURED, PERFLUORINATED ACRYLATE MODIFIED THIOL-ENE NETWORKS WITH TUNABLE TRANSPORT PROPERTIES	832
<i>James Goetz, Brian Greenhoe, Luke Kwisnek, Sergei Nazarenko</i>	
INTERPENETRATING POLYMER NETWORKS (IPNS)	837
<i>Maria Auad</i>	
INVESTIGATION OF AIR FILTRATION EFFICIENCY FOR NANOFIBER BASED FILTERS IN ULTRAFINE PARTICLE SIZE RANGE	838
<i>Dusan Kimmer, Wannes Sambaer, Martin Zatloukal</i>	
JOURNAL OF PLASTIC FILM AND SHEETING - HOW IT CAME TO BE AND TECHNOLOGY OVERVIEW	N/A
<i>John Wagner</i>	

KINETIC MODEL OF GLASS FIBER BREAKUP IN COROTATING TWIN SCREW EXTRUDER	844
<i>Avraam Isayev, Sug Hun Bumm, James L. White</i>	
LIGHT SCATTERING ANALYSIS OF POLYETHYLENE BLOWN FILMS: RELATIONSHIPS BETWEEN INTERNAL HAZE AND MORPHOLOGY	851
<i>Selim Bensason, Xuming Chen, Mehmet Demirors, Teresa Karjala, Lizhi Liu, Jian Wang</i>	
MECHANICAL AND ELECTRICAL PROPERTIES OF MULTI-WALLED CARBON NANOTUBES/SYNDIOTACTIC POLYSTYRENE COMPOSITE AEROGELS	855
<i>Sadhan Jana, Xiao Wang</i>	

VOLUME 2

STUDY OF NANOPARTICLE REINFORCEMENT MECHANISMS IN EPOXY NANOCOMPOSITES	860
<i>Hung-Jue Sue, Kevin White</i>	
MECHANICAL PROPERTIES OF CYCLOALIPHATIC TEREPHTHALATE CO-POLYESTER CLAY NANOCOMPOSITES.....	865
<i>Humza Jafferji, Emmanuelle Reynaud, Daniel Schmidt</i>	
MECHANICAL PROPERTIES OF SULFONATED BLOCK COPOLYMERS	871
<i>Eugene Napadensky, James Sloan, D. Suleiman</i>	
MOLECULAR NETWORK CONNECTIVITY IN EPOXY-AMINE THERMOSETS	875
<i>Sarah Morgan, Christopher Sahagun</i>	
NITRILE RUBBER-BASED NANOCOMPOSITES PREPARED BY LATEX COMPOUNDING OF POSS MODIFIED CLAY	879
<i>Elana C. Lewis, Sarah E. Morgan</i>	
OBSERVATION AND ANALYSIS OF DEFOMATION AND FAILURE MECHANISMS OF ORIENTED POLYMERIC FOAM MATERIALS	884
<i>Byoung-Ho Choi, Alexander Chudnovsky</i>	
OPTIMIZATION OF TEMPLATE PARAMETERS IN TEMPLATE-DIRECTED ELECTROSPINNING OF NANOFIBERS	888
<i>Ali Ashter, Stephen Driscoll</i>	
PARTICLE SIZE AND CONCENTRATION EFFECTS ON MECHANICAL PROPERTIES OF POLYETHER BASED TPU/SILICA NANOCOMPOSITES	896
<i>Cagla Kosak, Ozge Malay, Yusuf Menciloglu, Oguzhan Oguz, Emel Yilgor, Iskender Yilgor</i>	
POLYMER COMPOSITES WITH HOLLOW GLASS MICROSPHERES: PROCESSING, PROPERTIES AND APPLICATIONS.....	897
<i>Steve Amos, Marcel Doering, Stefan Friedrich, I. Sedat Gunes, Troy Ista, Dae-Soon Park, Baris Yalcin, Takijurou Yamabe</i>	
POLYMER PARTICLE INTERACTIONS IN NANOCOLLOIDS	898
<i>Yusuf Menciloglu, Burcu Ozel, Mehmet Yildiz</i>	
POLYMER SCIENCE AND ENGINEERING IN COSTA RICA	899
<i>Guillermo Jimenez</i>	
PRECISION CONTROL OF MORPHOLOGY,ORIENTATION AND FUNCTION WITH FIELD ASSISTED ALIGNMENT TECHNIQUES ON NOVEL ROLL TO ROLL MANUFACTURING PLATFORMS.....	900
<i>Mukerrem Cakmak</i>	
PREPARATION OF INTERCALATED ORGANIC/INORGANIC HYBRIDS VIA IN SITU SYNTHESIS	901
<i>Luyi Sun, Lichen Xiang, Matthew F. Milner, Jarett C. Martin, Cara S. Southworth, Cody A. Gummelt</i>	
PRODUCING NANO AND MICRO FIBERS BY USING JETS OF GAS	905
<i>Rafael Benavides, Sadhan Jana, Darrell Reneker</i>	
REAL-TIME TRACKING OF BIREFRINGENCE, WEIGHT AND THICKNESS DURING DRYING/CURING OF SOLUTION CAST POLYMER COATINGS AND FILMS	913
<i>Mukerrem Cakmak, Jason Drum, Isil Nugay, Emre Unsal, Baris Yalcin, Orcun Yucel</i>	
RECYCLE TECHNOLOGY OF USED PLASTIC MATERIALS.....	914
<i>Nobuyuki Imamura, Masahiro Muto, Tatsuro Ueda, Kazushi Yamada, Hiroyuki Nishimura, Hiroki Sakamoto, Shinichi Kawasaki, Takahiro Nishino</i>	
RELATIONSHIP BETWEEN RESIDUAL STRESS AND FLAME RESISTANCE OF POLYCARBONATE	920
<i>Himanshu Asthana, Jean Francois Morizur</i>	
SELECTING DISPERSING AGENTS FOR THERMOSET/CARBON NANOTUBE MASTERBATCHES	924
<i>Ica Manas-Zloczower, M. R. Loos, J. Yang, D. L. Fek</i>	
SOME ISSUES ARISING IN FINDING THE DETACHMENT POINT IN CALENDERING OF PLASTIC SHEETS.....	925
<i>Evan Mitsoulis</i>	
STRESS-STRAIN BEHAVIOR OF EXPANDED POLYMER COMPOSITES AT ELEVATED TEMPERATURES.....	926
<i>Krishnamurthy Jayaraman, Kevin Nichols, Katherine Shipley, M. Nichols</i>	
STRUCTURE AND PERFORMANCE OF MULTILAYER NANOCOMPOSITES FILMS.....	932
<i>Abdellah Ajji, Maryam Fereydoon, Farhad Sadeghi, Hesam Tabatabaei</i>	
STUDY ON ENVIRONMENTAL STRESS CRACKING BEHAVIOR OF INJECTION MOLDED POLYCARBONATE PARTS UNDER DIFFERENT PROCESSING CONDITIONS	933
<i>Zhixiang Cui, Jian Han, Chuntai Liu, Xiaofeng Wang, Chenguang Yan, Yingguo Zhou</i>	

STUDY ON STRUCTURE FORMATION OF PVA NANOFIBERS SPUN BY FREE SURFACE ELECTROSPINNING	939
<i>Kok Ho Kent Chan, Hiroyuki Itoh, Masaya Kotaki</i>	
SUPRAMOLECULAR IONIC BLOCK COPOLYMERS.....	943
<i>Nicole Brostowitz, Kevin Cavicchi, Robert Weiss, Longhe Zhang</i>	
SURFACE ENERGY EFFECTS OF PC/SAN/MWCNT BLENDS WITH THE ADDITION OF A REACTIVE COMPONENT	948
<i>Vicki Flaris, Cherie Fletcher, Maren Gultner, Petra Potschke</i>	
SYNTHESIS OF POLYHEDRAL OLIGOMERIC SILSESQUIOXANE (POSS) FUNCTIONALIZED CARBON NANOTUBES	953
<i>Xiaonan Kou, Robert Lochhead, Sarah Morgan, Christopher Sahagun</i>	
VISCOELASTIC BEHAVIOR OF HYDROPHOBICALLY MODIFIED HYDROGELS	958
<i>Jinkun Hao, Robert Weiss</i>	

EXTRUSION D22

ADVANCED COMPUTATIONAL TECHNIQUE FOR THE OPTIMIZATION OF SPIRAL MANDREL DIES	959
<i>Marcin Humpa, Uwe Klemme, Peter Köhler, Kenny Saul, Johannes Wortberg</i>	
CHAIN EXTENSION OF LOW VISCOUS PA 66 IN REACTIVE EXTRUSION PROCESS IN ORDER TO EXTRUDE THICK-WALLED PIPES	966
<i>Christian Bonten, Hans-Gerhard Fritz, Dan Zhang</i>	
COMPARISON OF WATER-QUENCH VERSUS AIR-QUENCH BLOWN FILM PROCESSES – PART I: FLAT FILM PROPERTIES	972
<i>Robert Armstrong, I-Hwa Lee, Karen Xiao</i>	
COMPARISON OF WATER-QUENCH VERSUS AIR-QUENCH BLOWN FILM PROCESSES – PART II: THERMOFORMABILITY	978
<i>Robert Armstrong, I-Hwa Lee, Karen Xiao</i>	
COMPUTER SIMULATION OF RUBBER EXTRUSION IN THE CAPILLARY DIE USING VISCOELASTIC MODELS	984
<i>Sung Hyun Choi, Hak Joo Kim, Jin Hyun Kim, Min-Young Lyu</i>	
CO-ROTATING FULLY INTERMESHING TWIN-SCREW COMPOUNDING EXTRUDERS: ADVANCEMENTS FOR IMPROVED PERFORMANCE AND PRODUCTIVITY.....	988
<i>Paul Andersen, Frank Lechner</i>	
DISTRIBUTION OF SPECIFIC ENERGY IN TWIN-SCREW COROTATING EXTRUDERS USING ONE-DIMENSIONAL PROCESS SIMULATION	993
<i>Eduardo Canedo, Adam Dreiblatt</i>	
DROP OF PRESSURE OF POLYMER MELTS IN MICROSCOPIC CHANNELS	999
<i>Franz Irlinger, Tim Lüth, Thomas Ottnad</i>	
AN EASY APPROACH OF MEASURING THE RESIDENCE TIME DISTRIBUTION WITH THE USE OF NIR-SPECTROSCOPY	1004
<i>Clemens Holzer, Stephan Laske, Ramesh Kumar Selvasankar, Andreas Witschnigg</i>	
EFFECT OF MATERIAL VISCOSITIES ON PURGING IN EXTRUSION PROCESSES.....	1008
<i>Christian Hopmann, Walter Michaeli, Janina Overbeck</i>	
EFFECT OF POLYMER VISCOSITY ON POST-DIE EXTRUDATE SHAPE CHANGE IN COEXTRUDED PROFILES	1013
<i>Mahesh Gupta</i>	
EFFECT OF TYPICAL MELT TEMPERATURE NON-UNIFORMITY ON FLOW DISTRIBUTION IN FLAT DIES.....	1020
<i>Olivier Catherine</i>	
EXAMINATION OF THE PERFORMANCE OF A HIGH SPEED SINGLE SCREW EXTRUDER FOR SEVERAL DIFFERENT EXTRUSION APPLICATIONS	1029
<i>John Christiano</i>	
EXPERIMENTAL INVESTIGATIONS ON VANE EXTRUDER FOR POLYMER SHORT THERMO-MECHANICAL HISTORY PROCESSING	1035
<i>Jin-Ping Qu, Gui-Zhen Zhang, Jia-Jia Chen, Xiao-Chun, He-Zhi He</i>	
FLOW INSTABILITY IN MULTI-LAYER CABLE COATING.....	1041
<i>Birane Toure, Jiri Vlcek</i>	
A FULLY THREE DIMENSIONAL NUMERICAL APPROACH SIMULATING THE MELTING ZONE IN A SINGLE-SCREW EXTRUDER	1047
<i>Sebastian Grammel, Christian Hopmann, Walter Michaeli</i>	
GEOMETRY OF TRIPLE SCREW EXTRUDERS TO PROMOTE MIXING	1053
<i>Yingsheng Xing, Nan Jiang, Changwei Zhu, Baorui Yan, Travis Getzie, Jianguo Zhou</i>	
IMPROVED APPROXIMATIONS IN THERMAL PROPERTIES FOR SINGLE SCREW EXTRUSION	1058
<i>Eberhard Gruenschloss, Maria Noriega</i>	
AN IMPROVED FLOW CHANNEL DESIGN FOR FILM AND SHEET EXTRUSION DIES	1065
<i>Makoto Iwamura, Hideki Tomiyama, Masaki Ueda</i>	

IMPROVING FILM DIE FLOW UNIFORMITY USING OPTIMIZATION METHODS COUPLED WITH FINITE ELEMENT CFD ANALYSIS.....	1070
<i>Laura Dietsche, Joseph Dooley, Patrick C. Lee, Sumeet Parashar</i>	
IMPROVING THERMAL EFFICIENCY OF SINGLE SCREW EXTRUSION	1080
<i>Elaine Brown, Phil Coates, Adrian Kelly, Javier Vera Sorroche</i>	
INVESTIGATION OF DIE DROOL PHENOMENON FOR LINEAR HDPE POLYMER MELTS HAVING IDENTICAL POLYDISPERSITY INDEX BUT DIFFERENT M_z AND M_{z+1} AVERAGE MOLECULAR WEIGHTS	1088
<i>Jan Musil, Martin Zatloukal</i>	
INVESTIGATION OF PROCESSING AND RHEOLOGICAL PARAMETERS EFFECT ON FILM BLOWING PROCESS STABILITY BY USING VARIATIONAL PRINCIPLES.....	1094
<i>Roman Kolarik, Martin Zatloukal</i>	
KINETIC, THERMODYNAMIC AND STRUCTURAL FACTORS GOVERNING THE DISPERSION OF NANOCCLAYS IN POLYMER MELTS.....	1103
<i>Mark Wetzel</i>	
LATERAL STRESS AND DENSITY MEASUREMENTS FOR PC, ABS, HIPS, AND PP BULK RESIN FEED STOCK	1113
<i>Stephen Derezinski</i>	
LOOK UPSTREAM TO AVOID ‘GIGO’ PITFALLS IN EXTRUSION	1121
<i>Jaime Gomez</i>	
MELT EXTRUSION OF A PHARMACEUTICAL COMPOUND CONTAINING A POORLY SOLUBLE THERMOLABILE DRUG	1127
<i>Ravindra Dhumal, Tim Gough, Adrian Kelly, Chaitrali Kulkarni, Anant Paradkar</i>	
NEW DEVELOPEMNTS IN CO-ROTATING TWIN-SCREW EXTRUSION ELEMENTS FOR HIGH WEAR APPLICATIONS.....	1132
<i>Tom Kvinge</i>	
NOTES ON THE MICROPELLETIZATION OF POLYMER RESINS	1136
<i>William Aquite, Daniel Kasperek, Tim Osswald, Natalie Rudolph</i>	
ON-LINE SENSORING IN EXTRUSION-BASED PROCESSES: PAST, PRESENT AND FUTURE.....	1141
<i>Joao Maia</i>	
OPTIMIZATION AND SENSETIVITY ANALYSIS OF A FILM DIE.....	1145
<i>Patrick Lee, Hossam Metwally</i>	
A PRACTICAL GUIDE TO SCALE-UP OF NEW PRODUCTS FROM DEVELOPMENT TO MANUFACTURING	1150
<i>Jeffrey Cicerchi</i>	
PRACTICAL HEAT TRANSFER IMPLICATIONS OF SLIP BOUNDARY CONDITIONS.....	1156
<i>Costas Gogos, Estanislao Ortiz-Rodriguez, Herman Suwardie, Linjie Zhu</i>	
PREPERATION AND CHARACTERIZATION OF PP-PET SEA-ISLANDS TYPE BICOMPONENT AS-SPUN FIBERS BY HIGH-SPEED MELT SPINNING	1161
<i>Wan-Gyu Hahm, Joo-Hwan Yoo</i>	
PROCESSING-STRUCTURE-PROPERTY RELATIONSHIPS IN SOLID-STATE SHEAR PULVERIZATION: PARAMETRIC STUDY WITH NEAT POLYPROPYLENE	1165
<i>Philip Brunner, Joshua Clark, John Torkelson, Katsuyuki Wakabayashi</i>	
RHEOLOGY AND MELT FRACTURE OF POLY(LACTIDES)	1170
<i>Savvas Hatzikiriakos, Bashar Jazrawi, Parisa Mehrkhodavandi, Norhayani Othman</i>	
SELF-REINFORCEMENT OF UNIAXIALLY STRETCHED POLYCARBONATE FILM	1175
<i>Miriam Sasse, Volker Schöppner, Andrea Wibbeke</i>	
SIMULATING THE PARISON GEOMETRY IN EXTRUSION BLOW MOLDING WITH VISCOELASTIC MATERIAL MODELS.....	1182
<i>Michael Aulbert, Christian Hopmann, Walter Michaeli, Christian Windeck</i>	
TECHNIQUES FOR TROUBLE SHOOTING AND ANALYSIS OF BLOW FILM RELATIVE TO PROPERTY DEVELOPMENT	1188
<i>Gregory Campbell</i>	
THICKNESS PROFILE EFFECTS ON THE BUILD-UP PROCESS OF FILM-ROLLS IN THE WINDING PROCESS.....	1194
<i>Felix Heinzler, Johannes Wortberg</i>	
TIPS FOR OPTIMIZING TWIN-SCREW EXTRUDER PERFORMANCE	1200
<i>Bert Elliott</i>	
TROUBLESHOOTING COEX FILM PROBLEMS BY CONSIDERING PROCESS-PROPERTY RELATIONSHIPS	1210
<i>Barry Morris</i>	
TROUBLESHOOTING PLASTICS INDUSTRY POWDER STORAGE & HANDLING PROBLEMS USING FLOW PROPERTIES	1216
<i>Brian Pittenger</i>	
TROUBLESHOOTING RATE LIMITATIONS FOR MELT-FED SINGLE-SCREW EXTRUDERS	1221
<i>Gregory Campbell, Mark Spalding</i>	
TROUBLESHOOTING THE CO ROTATING TWIN SCREW EXTRUDER	1226
<i>Rich Kanarski</i>	

TROUBLESHOOTING TPU EXTRUSION FOR RATE LIMITATIONS DUE TO SOLIDS IN THE EXTRUDATE	1230
<i>Kun Hyun, Mark Spalding</i>	
VARIABLE STRENGTH STRESS BEAD ANALYSIS IN A TWIN SCREW EXTRUDER.....	1234
<i>Roba Adnew, David Bigio, Harry Brown, Graeme Fukuda, William Pappas</i>	
VISCOELASTIC PROPERTIES OF CNT-PC COMPOUNDS: EFFECT OF COMPOUNDING METHOD, CNT-TYPE AND TESTING PROTOCOL.....	1240
<i>Joseph Golba, E. Ray Harrell, Jill Kunzelman, Jane Spikowski</i>	

FAILURE ANALYSIS AND PREVENTION SIG002

ACCELERATED CHARACTERIZATION OF THE RESISTANCE AGAINST CRACK INITIATION AND SLOW CRACK GROWTH OF POLYETHYLENE FOR GEOMEMBRANE APPLICATION UNDER THE INFLUENCE OF MEDIA.....	1250
<i>Andreas Frank, Gerald Pinter, Anita Redhead</i>	
COMPARATIVE STUDY OF THE EFFECT OF NATURAL AND ARTIFICIAL WEATHERING OF POLYPROPYLENE / ETHYLENE VINYL ACETATE (PP/EVA) BLENDS.....	1256
<i>Rabeh Elleithy, Othman Alothman, Shafaat Salahude, S. M. Al-Zahrani</i>	
CONTINUING STUDIES OF DUCTILE-BRITTLE TRANSITION OF THE SECOND KIND.....	1261
<i>Dane Chang, Alexander Chudnovsky, Mridula Kapur, Kalyan Sehanobish, Haiying Zhang, Zhenwen Zhou</i>	
CREEP FAILURE OF A POLYACETAL HOSE CLAMP.....	1267
<i>Niles Stenmark</i>	
DETERMINATION OF ENVIRONMENTAL STRESS CRACKING FAILURE MODE IN INVESTIGATIONS OF CPVC FIRE-SUPPRESSION SPRINKLER PIPE FAILURES	1273
<i>Dale Edwards, Anand Shah</i>	
DEVELOPMENT OF A RING TENSILE TEST FOR EVALUATING THE CHEMICAL COMPATIBILITY OF PLASTIC PIPES	1281
<i>Michael Hayes</i>	
DURABILITY, RELIABILITY AND SAFETY STUDY OF POLYMERS USED IN PHOTOVOLTAIC MODULES.....	1289
<i>Hsinjin Yang, J. Thomas Chapin, Ethan Wang, Jerry Yen, Carl Wang, Ivan Chou</i>	
ENVIRONMENTAL STRESS CRACKING OF A POLY(ACRYLONITRILE:BUTADIENE:STYRENE) CUP HOLDER.....	1293
<i>Christelle Poquette, Niles Stenmark</i>	
ENVIRONMENTAL STRESS CRACKING OF POLYCARBONATES EXPOSED TO SUNSCREEN AND HAND LOTION	1298
<i>Brian E. Ralston, Suresh Donthu, Paul Ledwith, Adam Kramschuster, Jason McNulty</i>	
EVALUATING FRACTURE TOUGHNESS IN DEGRADED POLYMERIC THIN FILMS	1303
<i>Hanxiao Ge, Susan Mantell</i>	
INVESTIGATIONS OF THE BRITTLE FAILURE CAUSED BY AN ENVIRONMENTAL STRESS CRACKING OF A PLASTIC ENCLOSURE.....	1309
<i>Ahamed Shabeer, Gerard Zamiski</i>	
LIFETIME PREDICTION OF PLASTIC PARTS – A CASE STUDY.....	1313
<i>Javier Cruz, Paul Gramann, Jeffrey Jansen</i>	
WIPER MOTOR DRIVE GEAR FAILURE ANALYSIS AND RESOLUTION	1319
<i>Mark Bennett, Joseph Kelly, Todd Stromer</i>	

FLEXIBLE PACKAGING D44

APPLICATION OF MODELING TO SPEED FLEXIBLE PACKAGE DEVELOPMENT	1327
<i>Barry Morris</i>	
BLOWN FILMS OF NANOCOMPOSITES PREPARED FROM ORGANOCCLAY/COPPER-NANOPARTICLE POLYPROPYLENE.....	1335
<i>Ratanawan Magaraphan, Pitchaya Naneraksa</i>	
COMPARATIVE THERMAL AND RHEOLOGICAL STUDY OF AROMATIC AND ALIPHATIC POLYAMIDE NANOCOMPOSITES AND FILMS.....	1341
<i>Abdellah Aji, Maryam Fereydoon, Seyed H. Tabatabaei</i>	
THE EFFECT OF MACHINE DIRECTION ORIENTATION ON MULTILAYER HIGH BARRIER FILMS	1346
<i>Matthew Burke, Sarah Schirmer, Danielle Froio, Gregory Pigeon, Jo Ann Ratto</i>	
THE EFFECT OF POLYBUTYLENE ON SEAL STRENGTH OF EVA/POLYBUTYLENE SEAL BLENDS IN MEDICAL DEVICE PACKAGING	1352
<i>Melissa Diskin, Theresa Hermel-Davidock, Becton Dickinson</i>	
FAILURE CRITERIA AND CHARACTERISTICS OF HEAT-SEALED ALUMINUM/POLYETHYLENE LAMINATES.....	1357
<i>Hiroyuki Hamada, Yasuo Hashimoto, Reiichi Konishi, Yew Leong, Ichiro Mitani, Ken Miyata, Makoto Nakamura, Kazushi Yamada</i>	
PEEL ABILITY AND MORPHOLOGY OF EASY-PEEL FILMS	1361
<i>Hiroyuki Hamada, Hiromi Matsuura, Ken Miyata, Yoshiaki Oya, Kazushi Yamada</i>	
PURE PERFORMANCE: THIN WALLED FLUOROPOLYMER CONTAINERS.....	1366
<i>Michael Altimore, Cathy Edgington, Kurt Hayden</i>	

STUDY OF THE KINETIC OF SLIP AGENT MIGRATION IN POLYETHYLENE SHEETS	1372
<i>Abdellah Aji, Farhad Sadeghi, Richard Silverwood</i>	
TOWARDS THE UNDERSTANDING OF FIBER TEAR	1378
<i>Theresa Hermel-Davidock, Yusuf Oni, Sridharan</i>	

INJECTION MOLDING D23

ANALYSIS OF THE FLUID ASSISTED INJECTION TECHNIQUE BY USING ULTRASONIC	1383
<i>Sebastian Becker, Christian Hopmann, Walter Michaeli</i>	
ASSEMBLY INJECTION MOLDING AND TESTING OF POLYMER-METAL-HYBRIDS.....	1388
<i>Ines Kuehnert, Torsten Maenz, Konrad Schneider, Jacob Rosner</i>	
CHARACTERISTIC OPTIMIZATION OF ELECTRICALLY CONDUCTIVE INJECTION-MOLDED PARTS USING THE EXAMPLE OF HIGH TEMPERATURE BIPOLAR PLATES.....	1394
<i>Georg Lenze, Marco Lenzen, Johannes Wortberg</i>	
COMPUTER SIMULATION OF FLOW BALANCE IN THE DIE OF SLOT COATER: PART 1: LAND GEOMETRY	1399
<i>Hyun Kim, Yohan Park, Jinsoo Hong, M. Y. Lyu, S. K. Shin, J. K. Seo</i>	
COMPUTER SIMULATION OF FLOW BALANCE IN THE DIE OF SLOT COATER: PART 2: MANIFOLD GEOMETRY	1404
<i>Joa Jin Jeong, Hyun Kim, Min-Young Lyu, Ki Namkung, Yohan Park</i>	
CONTRIBUTION TO THE DEVELOPMENT OF A VARIOTHERMAL PROCESS CONTROL FOR THE TWO-STAGE GITBLOW PROCESS BASED ON THE FINITE ELEMENT METHOD	1409
<i>Elmar Moritzer, Thorsten Plugge, Stefan Seidel</i>	
DEPENDENCE ON MELT VISCOSITY OF FOAM PC/ABS INJECTION MOLDING AND MECHANICAL PROPERTY	1415
<i>Hiroyuki Hamada, Noriaki Kunimune, Takahiro Kunimune, Masuo Murakami, Tsugio Nagasawa, Kazushi Yamada</i>	
DESCRIPTION BY DIMENSIONAL ANALYSIS OF THE WALL THICKNESS DISTRIBUTION IN THE TWO-STAGE GITBLOW PROCESS.....	1420
<i>Johann-Sebastian Lessmann, Elmar Moritzer, Thorsten Plugge</i>	
DESIGN OF INDUCTION HEATING MODULE FOR UNIFORM CAVITY SURFACE HEATING	1427
<i>Deng-Yuan Hwang, Sheng-Jye Hwang, Huei-Huang Lee, Yu-Ting Sung</i>	
DIRECT FABRICATION ON THE POLYMER SURFACES BY USING PRECISION TOOLING MACHINE AND CHARACTERIZATION OF HYDROPHOBICITY AT VARIOUS ROUGH SURFACES	1437
<i>Donghui Chu, Akihiro Nemoto, Hiroshi Ito, Jinwook Ha</i>	
THE EFFECT OF COOLING RATES ON GAS PENETRATION AND FINGERING OF GAS-ASSISTED PLASTIC AND POWDER INJECTION MOLDING	1442
<i>Seokyoung Ahn, Baeg-Soon Cha, Donghan Kim, Kevin Lee, Rajiv Nambiar, Hyung-Pil Park, Byung-Ohk Rhee</i>	
THE EFFECT OF TOOLING ALLOY ON THE PHYSICAL PROPERTIES OF AUTOMOTIVE POLYOLEFINS	1449
<i>David Okonski</i>	
EFFECTS OF PHYSICAL SURFACE TREATMENT ON METAL SURFACE MORPHOLOGY AND MECHANICAL PROPERTIES OF METAL INSERT INJECTION MOLDINGS.....	1456
<i>Hiroyuki Hamada, Tomokazu Sasaki, Toshikazu Umemura, Kazushi Yamada, Yuqiu Yang</i>	
THE EFFICIENCY EVALUATION FOR FRESNEL LENS OF CONCENTRATING SOLAR CELL WITH VARIOUS INJECTION MOLDING PROCESS	1460
<i>Shia-Chung Chen, Wei-Yao Hsu, Sung-Wei Huang, Hsin-Shu Peng</i>	
ELECTRICALLY CONDUCTIVE PLASTICS COMPOUNDS BASED ON SYNERGETIC FILLER COMBINATIONS.....	1465
<i>Jan Fragner, Christian Hopmann, Walter Michaeli</i>	
ELECTROMAGNETIC INDUCTION COIL DESIGN FOR MOLD SURFACE HEATING	1471
<i>Ming-Shyan Huang, Je-Wei Lian, Shih-Chih Nian, Sheng-Wei Tsai</i>	
ESTABLISHMENT OF A GAS-ASSISTED INJECTION MOLDING SYSTEM FOR WAX INJECTION IN INVESTMENT CASTING.....	1477
<i>Shia-Chung Chen, Yi-Chang Lin, Yu-Chun Lin, Chin-Chung Hsu, Venny Yang, Fu-Hung Hsu</i>	
AN EXPERIMENTAL STUDY ON THE DIMENSIONAL CHARACTERISTICS OF 7 INCH LIGHT GUIDE PLATE MANUFACTURED BY INJECTION/COMPRESSION MOLDING WITH RAPID HEATING OF A MOLD.....	1483
<i>Seokkwan Hong, Jeongjin Kang, Yongju Lee, Inki Min, Kyunghwan Yoon</i>	
FIBER LENGTH REDUCTION AND HOMOGENEITY OF INJECTION-MOLDED SHORT FIBER REINFORCED THERMOPLASTICS WITH SPECIAL REGARD TO THE INFLUENCE OF A STATIC MIXING NOZZLE.....	1487
<i>Ellen Albring, Christoper Budde, Elmar Moritzer</i>	
FILM INSERT MOLDING BASED ON POLYOXYMETHYLENE AND POLY(LACTIC ACID): MORPHOLOGY AND MECHANISM OF INTERFACIAL ADHESION.....	1494
<i>Satoshi Nagai, Makiko Sakurazawa, Kunihiro Fujimoto, Masayuki Nagai, Wongsriraksa Patcharat, Kazushi Yamada, Hiroyuki Nishimura</i>	
THE FIVE FACTORS THAT CONTROL TOOL ROOM PERFORMANCE	1498
<i>Steve Johnson</i>	

FOAM INJECTION MOLDING OF GLASS FIBER REINFORCED POLYPROPYLENE COMPOSITES	1502
<i>Peter Ungeyong Jung, Chul B. Park</i>	
IMPLEMENTATION OF A HIGHLY EFFICIENT MESHLESS METHOD FOR THE THERMAL ANALYSIS OF FOUNTAIN FLOW DURING FILLING IN INJECTION MOLDING	1509
<i>Ivan Lopez, Juliana Restrepo</i>	
IMPROVED MANGEMENT OF PRODUCTION AND CAPACITY THROUGH APPLICATION OF MOLD BASED DATA COLLECTION	1514
<i>Alan Hickok, Shaun Ruck</i>	
IMPROVING SURFACE QUALITY OF FOAMED POLYCARBONATE (PC) PARTS USING WATER AS THE PHYSICAL BLOWING AGENT	1520
<i>Jun Peng, Xiang-Fang Peng, Lih-Sheng Turng</i>	
THE INFLUENCE OF FLOW ENHANCED CRYSTALLIZATION ON SHRINKAGE PREDICTION	1525
<i>Franco Costa, Chitiur Hadinata, Zhongshuang Yuan</i>	
IN-MOLD SURFACE MODIFICATION AND IN-MOLD PRINTING DURING INJECTION MOLDING	1531
<i>Michael Gehde, Thomas Härtig</i>	
INTEGRATED STORAGE ACTUATOR MODULE FOR CONTINUOUS POWER CONSUMPTION IN PERIODIC PROCESSES.....	1534
<i>Marco Lenzen, Johannes Wortberg</i>	
INVESTIGATION OF SUPERCRITICAL FLUID-LADEN PELLET INJECTION MOLDING FOAMING TECHNOLOGY(SIFT)	1539
<i>Xiaofei Sun, Lih-Sheng Turng, Patrick Gorton, Pankaj Nigam, Sezen Buell, Eugene Dougherty Jr.</i>	
IS RTC THE LONG AWAITED PANACEA FOR INJECTION MOLDED PARTS?.....	1544
<i>Kenneth Crow, Raymond Foad, John Pittman</i>	
MICROCELLULAR INJECTION MOLDING OF POLYLACTIDE WITH TALC	1551
<i>Aboutaleb Ameli, Davoud Jahani, Peter Jung, Chul Park</i>	
MOLDING PROCESS AND SCREW MELT PEAK POINTS T-P SENSOR	1556
<i>Frederick Buja</i>	
A MULTIVARIATE IN-MOLD SENSOR DESIGN FOR MEASUREMENT OF MELT PRESSURE, TEMPERATURE, VELOCITY, AND VISCOSITY	1559
<i>Navid Asadiznajani, Zhaoyan Fan, Robert Gao, Guthrie Gordon, Stephen Johnston, David Kazmer</i>	
A NOVEL FOAM INJECTION MOLDING PROCESS USING GAS-LADEN PELLETS.....	1567
<i>Eugene Dougherty, Patrick Gorton, Jungjoo Lee, Lih-Sheng Turng</i>	
NUMERICAL VERIFICATION OF RHEOLOGICAL CHARACTERIZATION OF POLYSTYRENE DURING MICROCELLULAR INJECTION MOLDING	1572
<i>Shia-Chung Chen, Kuan-Hua Lee, Yu-Wan Lin, Tai-Yi Shiu, Chuan-Wei Chang Jimmu C. Chien</i>	
NUMERICAL VISUALIZATION ON COOLING MECHANISM FOR CONFORMAL COOLING SYSTEM IN INJECTION MOLDING	1577
<i>Rong-Yeu Chang, Fu-Hung Hsu, Chao-Tsai Huang, Hung-Chou Wang, Wei-Da Wang</i>	
PART OF FOAMING CONTROL AND MECHANICAL PROPERTIES DURING MICROCELLULAR INJECTION MOLDING PROCESS VIA A SYSTEM OF GAS COUNTER PRESSURE AND DYNAMIC MOLD TEMPERATURE VARIATION	1581
<i>Shia-Chung Chen, Shin-An Lai, Yu-Tseng Lin, Yu-Lun Xiao</i>	
PRECISE INJECTION MOLDING OF BIO-ABSORBABLE HAP/PLA COMPOSITES.....	1586
<i>Hiroshi Ito, Tetsuo Takayama, Kazuyasu Uchiumi</i>	
PREDICTION OF ORIENTATION DISTRIBUTION FOR LONG FIBER REINFORCED THERMOPLASTICS IN CENTER-GATED DISK FLOW	1591
<i>Rong-Yeu Chang, Yuan-Jung Chang, Chia-Hsiang Hsu, Huan-Chang Tseng, Tzu-Chang Wang</i>	
PREDICTION OF THE FLASHING MOMENT BY THE STRUCTURAL ANALYSIS IN CONJUNCTION WITH THE MOLDING ANALYSIS.....	1596
<i>Baeg-Soon Cha, Jae-Hyuk Choi, Hyung-Pil Park, Byung-Ohk Rhee, Joon-Sung Tae</i>	
PROCESSING WINDOW FOR SWIRL-FREE MICROCELLULAR INJECTION MOLDED POLYETHYLENE (LDPE) AND POLYPROPYLENE (PP) PARTS USING SUPERCRITICAL NITROGEN (N₂) AS A BLOWING AGENT	1601
<i>Sezen Buell, Patrick Gorton, Pankaj Nigam, Lih-Sheng Turng, Emily Yu</i>	
RAPID HEATING AND COOLING SIMULATION FOR THE INJECTION MOLDING PROCESS	1606
<i>Lu Chen, Franco Costa, Harold Feng, Clinton Kietzmann</i>	
RELATION BETWEEN WATER PENETRATION BEHAVIOR AND PRODUCT QUALITY IN WATER- ASSISTED INJECTION MOLDING (WAIM) AT DIFFERENT PROCESS PARAMETERS	1612
<i>Jozefien De Keyzer, Peter Van Puyvelde, Sofie Sannen</i>	
SIMULATION OF THE FOUNTAIN FLOW EFFECT BY MEANS OF THE RADIAL FUNCTIONS METHOD (RFM).....	1619
<i>Omar Estrada, Iván López, Tim Osswald, Daniel Ramirez</i>	
THE SKIN/CORE MATERIAL DISTRIBUTION OF A CO-INJECTION MOLDING PROCESS: THE EFFECT OF PROCESSING CONDITIONS AND MATERIAL SELECTION	1624
<i>Chih-Yu Hsu, Chao-Tsai Huang, Kuo-Chou Huang, Shih-Po Sun, Shi-Chang Tseng</i>	
STRESS ANALYSIS FOR POLYMER COMPOSITES	1628
<i>Xiaoshi Jin</i>	
STUDY OF THE INJECTION MOLDING TECHNOLOGY FOR THE NON-CIRCULAR LENS.....	1632
<i>Chung-Chih Lin, Hsin-Shu Peng, Jen-Yu Shie</i>	

A STUDY ON THE SCRATCH RESISTANT CHARACTERISTICS OF INJECTION MOLDED POLYCARBONATE PARTS	1638
<i>Hyuk Kim, M. Y. Lyu, Dong Cheol Shim, Sang Hyun Park, Sung Hwoan Cho, Do Kim</i>	
SUPERCRITICAL FLUID DOSAGE CONTROL USING ARTIFICIAL NEURAL NETWORK (ANN) FOR MICROCELLULAR INJECTION MOLDING	1642
<i>Xiaofei Sun, Lih-Sheng Turng, Patrick J. Gorton, Eugene P. Dougherty Jr.</i>	
TRANSCRYSTALLIZATION OF IN-SITU MICROFIBRILLAR PP/SAN BLEND PARTS MOLDED VIA WATER-ASSISTED INJECTION MOLDING.....	1647
<i>Han-Xiong Huang, Bin Wang</i>	
TRANSIENT PARTICLE FLUX DURING INJECTION OF COMPOSITE POLYMER COMPOUNDS AND THE RELEVANCE OF SUBSEQUENT MANIFESTATIONS IN MULTI-CAVITY TOOLING	1651
<i>Tyler Skiba, John Coulter, Samarth Desai</i>	
TROUBLESHOOTING BLACK SPECKS AND COLOR STREAKS IN INJECTION MOLDED PARTS.....	1656
<i>Gregory Campbell, Mark Spalding</i>	
UNDERSTANDING THE IMPACT OF PIGMENT LOADING LEVEL ON INJECTION MOLDED COMPONENTS.....	1662
<i>Shantanu Shivdekar</i>	
VALVE GATE OPTIMIZATION FOR INJECTION MOLDING OF AN AUTOMOTIVE INSTRUMENT PANEL.....	1666
<i>Sung-Bin Cho, Dong-Hoon Choi, Chang-Hyun Park, Byung-Gi Pyo, Byung-Ohk Rhee</i>	
VERIFICATION OF EXPERIMENT AND NUMERICAL METHOD SIMULATION ON VENTING DESIGN FOR IMPROVING PRODUCT SURFACE QUALITY	1671
<i>Shia-Chung Chen, Shu-Ping Yang, Jen-An Chang, Shih-Po Sun, Hsien-Sen Chiu, Chia-Hsian Hsu</i>	

JOINING OF PLASTICS AND COMPOSITES SIG012

2 UM FIBER LASERS FOR WELDING OF OPTICALLY CLEAR POLYMERS	1675
<i>Tony Hoult</i>	
EFFECTS OF UNSUPPORTED WALL HEIGHT ON LINEAR VIBRATION WELDING OF PMMA TO ABS	1679
<i>Avraham Benatar, Abbass Mokhtarzadeh</i>	
EXPERIMENTS WITH CONVENTIONAL AND HIGH TEMPERATURE HOT PLATE WELDING OF THERMOPLASTICS USING DISPLACEMENT AND PRESSURE CONTROL.....	1684
<i>Avraham Benatar, Abbass Mokhtarzadeh</i>	
FRICRIVETING OF CIVIL ENGINEERING COMPOSITE LAMINATES FOR BRIDGE CONSTRUCTION	1691
<i>Lucian Blaga, Sergio T. Amancio-Filho, Jorge F. Dos Santos, Radu Bancila</i>	
FRICTION SPOT JOINING OF ALUMINUM 6181-T4 AND CARBON FIBER REINFORCED POLY(PHENYLENE SULFIDE).....	1698
<i>Sergio Amancio-Filho, Leonardo Canto, João Esteves, Elias Hage, Jorge Dos Santos</i>	
INFLUENCE OF COMPONENT WARPAGE ONTO PROCESS CONTROL AND COMPONENT PROPERTIES DURING VIBRATION WELDING.....	1705
<i>Sven Friedrich, René Fuhrich, Michael Gehde, Marc Schoss</i>	
LASER TRANSMISSION WELDING OF THERMOPLASTIC TUBES AND PLATES USING LASER REFRACTION	1709
<i>Pascal Hubert, Tahereh Mousavand, Rajaprakash Ramachandramoorthy</i>	
LASER WELDING OF INCOMPATIBLE SEMI-CRYSTALLINE THERMOPLASTICS BE MEANS OF INTERMEDIATE LAYERS	1716
<i>Christian Hopmann, Mathias Weber</i>	

VOLUME 3

REVIEW OF ATMOSPHERIC PRESSURE PLASMA EFFECT ON THE ACTIVATION OF PLASTICS FOR IMPROVED ADHESION	1721
<i>Robert Hicks, Thomas Williams, Hang Yu</i>	
SERVO-DRIVEN ULTRASONIC WELDING OF BIOCOMPOSITES	1727
<i>Sean Flowers</i>	
USING FINITE ELEMENT ANALYSIS TO ADVANCE HEAT STAKE DESIGN	1734
<i>Chin-Jung Chen, Chung Wu</i>	

MARKETING AND MANAGEMENT D37

ADDING VALUE TO PRODUCT DESIGNS: THE CONVERGENCE OF DESIGN PATENTS AND TRADE DRESS	1741
<i>Jennifer Morris</i>	
THE AMERICA INVENTS ACT: SIX KEY CHANGES IN U.S. PATENT LAW	1746
<i>Steven J. Grossman, Beth A. Filip</i>	
ENTREPRENUERSHIP, INNOVATION, AND MANAGEMENT	1751
<i>Bonnie Bachman, Stephen Bozzone</i>	

GLOBALIZED BUSINESS STRATEGIES – THE ANSWER TO WEAK DOMESTIC GROWTH?	1755
<i>Roger Jones</i>	
STRENGTHENING THE MESSAGE OF SUSTAINABLE PLASTICS PACKAGING	1757
<i>Michael Tolinski</i>	
SUSTAINABILITY AND THE PLASTICS INDUSTRY	1764
<i>Bonnie Bachman, Shristy Bashyal, Margaret Baumann</i>	

MEDICAL PLASTICS D36

ADSORPTION AND BARRIER PROPERTIES OF PET/PP BLEND IN INJECTION MOLDING	1770
<i>Hiroyuki Hamada, Ayako Kurosawa, Tadashi Otsuka, Kazushi Yamada</i>	
BENEFITS OF SERVO ULTRASONIC WELDERS TO MEDICAL INDUSTRY- A CASE HISTORY	1774
<i>Kenneth Holt, Miranda Marcus, Antonio Mendes</i>	
BIO COMPATIBLE FLUOROPOLYMERS AND ADVANCES IN INJECTION MOLDING THESE MATERIALS FOR MEDICAL DEVICES, DRUG DELIVERY SYSTEMS AND STORAGE COMPONENTS	1780
<i>Ken Kelly</i>	
INCREASING DRUG RELEASE RATE THROUGH FOAMED STRUCTURES	1784
<i>Niloufar Faridi, Costas Gogos, Graciela Terife</i>	
INJECTION MOLDS IN CLEANROOM ENVIRONMENTS	1791
<i>Peter Röstel, Thomas Seul</i>	
A NEW STERILIZABLE HIGH TEMPERATURE POLYETHERIMIDE BLEND FOR HEALTHCARE APPLICATIONS	1796
<i>Scott Davis, Robert Gallucci, Mark Sanner</i>	
SYNTHESIS OF CROSS-LINKED, PARTIALLY-NEUTRALIZED POLY(ACRYLIC ACID) BY SUSPENSION POLYMERIZATION IN SUPERCRITICAL CARBON DIOXIDE	1802
<i>Joseph Desimone, Yazan Hussain, Tao Liu, George Roberts, Scott Smith</i>	

MOLD MAKING AND MOLD DESIGN D35

FEA SIMULATION STUDY ON DESIGN OPTIMISATION OF MOULD FEEDING SYSTEM FOR PRECISION MICRO MOLDING OF POLYMERIC MICROFLUIDIC CHIP	1808
<i>Ge Chen, Szu Hui Lim, Sin Min Low, Feng Lin Ng, Jianhong Zhao</i>	
INTEGRATION OF INJECTION MOLDING AND STRUCTURE SIMULATION FOR PART LIFECYCLE AND MOLD DEFORMATION ANALYSES	1814
<i>Tzu-Chau Chen, Chao-Tsai Huang, Yu-Chih Liu, Tsung-Min Su</i>	
PORCERAX II, 101 HOW TO PROPERLY MANUFACTURE, USE AND MAINTAIN YOUR PORCERAX INSERTS	1819
<i>Russ Bowen</i>	
TEMPERATURE INVESTIGATION IN REAL HOT RUNNER SYSTEM USING A TRUE 3D NUMERICAL METHOD	1822
<i>Tzu-Chau Chen, Yan-Chen Chiu, Cheng-Li Hsu, Chao-Tsai Huang, Lung-Wen Kao, Chen-Yang Lin, Wei-Da Wang</i>	
USE OF SURFACE ENGINEERING ON MODERN PRE-HARDENED TOOL STEEL	1828
<i>Per Hansson</i>	

NANO/MICRO MOLDING SIG023

ENTRANCE DESIGN OF GAS-ASSISTED MOLD TEMPERATURE CONTROL AND ITS' APPLICATION ON DOUBLE SIDE MICRO MOLDING	1833
<i>Jen-An Chang, Yung-Hsiang Chang, Shia-Chung Chen, Sung-Wei Huang, Wen-Ren Jong</i>	
EXPERIMENTAL STUDY ON RUBBER-ASSISTED EMBOSING OF MICRO FLUIDIC CHIPS	1838
<i>Minjie Wang, Tom Wyatt, Donggang Yao, Allen Yi, Danyang Zhao</i>	
HIGH PRECISION MICRO MOLDING INJECTION OF 2 COMPONENT LIQUID SILICONE	1843
<i>Christian Decker, Bjoern Dormann, Gabor Juettner</i>	
AN INVESTIGATION ON THE EFFECT OF SURFACE CHARACTERISTICS ON ADHESION BETWEEN POLYMER MELTS AND REPLICATION TOOLS	1847
<i>Giuliano Bissacco, Kevin Delaney, David Kennedy, Eric Moore</i>	
MICRO INJECTION MOLDING OF POLYMERS FOR BIOMIMICKRY OF ORGAN TISSUE	1853
<i>Burak Bekisli Bekisli, John Coulter, John Rodgers</i>	
MORPHOLOGICAL ZONES IN MICRO INJECTION MOLDING OF POLYOXYMETHYLENE	1858
<i>Abdesaleem Derdouri, Rabie El-Otmani, Musa Kamal</i>	
NANOSTRUCTURED POLYMER SURFACES TO OPTIMIZE CELL BEHAVIOR	1863
<i>Natascha Andraschek, Werner Balika, Clemens Holzer, Matthias Katschnig, Stephan Laske, Ute Schäfer</i>	
PACKING PARAMETERS EFFECT ON INJECTION MOLDING OF POLYPROPYLENE NANOSTRUCTURED SURFACES	1867
<i>Matteo Calaan, Hans Hansen, Guido Tosello, C. Ravn, A. Islam</i>	

ULTRAPRECISION MOLD MANUFACTURE FOR MICRO INJECTION MOLDED MICRO OPTICS	1873
<i>Ekkard Brinksmeier, Oltmann Riemer, Lars Schönemann</i>	

PLASTIC PIPE AND FITTINGS SIG021

ACCELERATED TESTING AND LIFETIME PREDICTION FOR PLASTIC PIPES	1877
<i>Alexander Chudnovsky, Kalyan Sehanobish, Haiying Zhang, Zhenwen Zhou</i>	
DESIGN INNOVATIONS OF HIGH DENSITY POLYETHYLENE PIPE GRADE RESINS	1884
<i>Sarah Patterson, Mark Spalding</i>	
EVALUATION OF LONG-TERM PERFORMANCE ON COMPOSITE PIPES	1889
<i>Yoshimichi Fujii, Youjiro Minami, Masahiro Muto, Hiroyuki Nishimura, Tatsuro Ueda, Kazushi Yamada</i>	
EVALUATION OF LONG-TERM DURABILITY ON POLYETHYLENE FOR HOT WATER SUPPLY	1894
<i>Masahiro Muto, Hiroyuki Nishimura, Shintaro Tanaka, Tatsuro Ueda, Kazushi Yamada</i>	
THE INFLUENCE OF TEST FREQUENCY AND ECCENTRIC CRACK GROWTH ON CYCLIC CRB TESTS	1899
<i>Andreas Frank, Gerald Pinter, Anita Redhead</i>	
NEW FULL DRY SYSTEM DEVELOPED FOR BI-ORIENTED PIPES BRINGS EXCELLENT OPPORTUNITIES FOR PVC-O	1905
<i>Ignacio Munoz De Juan</i>	
NEW METHOD TO DETECT COLD FUSION JOINTS IN HIGH DENSITY POLYETHYLENE PIPE	1909
<i>Robert Stakenborghs</i>	
POLYBUTYLENE WATER SERVICE PIPE: THE OTHER SIDE OF THE STORY	1914
<i>Donald Duvall, Dale Edwards</i>	
THERMALLY BUTT-FUSED PVC PIPE AND THE EXPANSION OF TRENCHLESS INSTALLATIONS IN THE WATER AND WASTEWATER APPLICATIONS	1920
<i>Bo Botteicher, Tom Marti</i>	

PLASTICS ENVIRONMENT D40

CHARACTERIZATION OF MICRONIZED RUBBER POWDERS WITH COST EFFECTIVE PERFORMANCE BENEFITS IN RUBBER COMPOUNDS.....	1927
<i>Ravi Ayyer, Frank Papp, Tom Rosenmayer</i>	
DEECOM®: A SUSTAINABLE PROCESS USED IN VARIOUS RECLAMATION PROCESSES	1933
<i>Sue Reynolds, B. Longworth, J. P. Millington, J. Norris, P. Norris, C. Reid</i>	
DEVELOPMENT OF DRYLESS PELLET -APPLICATION OF PELLET ENGINEERING	1937
<i>Megumi Setomoto, Kazuhiko Iyagawa, Hiroyuki Inoya, Kazushi Yamada, Hiroyuki Hamada</i>	
HYDROCARBON FUEL OBTAIN FROM MUNICIPAL WASTE PLASTICS USING STAINLESS STEEL REACTOR	1941
<i>Moinuddin Sarker, Mohammad Mamunor Rashid, Md. Sadikur Rahman</i>	
HYDROLYTIC DEPOLYMERIZATION OF PET DURING EXTRUSION	1946
<i>Pierre Carreau, Maryam Dini, Pascal Hubert, Musa Kamal, Tahereh Mousavand</i>	
IMPROVED UTILIZATION OF CO-PRODUCTS FROM BIOFUEL INDUSTRIES IN NEW MATERIALS USES: A MOVE TOWARDS SUSTAINABLE BIOREFINERY.....	1951
<i>Manjusri Misra, Amar Mohanty, S. Vivekanandhan, Nima Zarrinbakhsh</i>	
INVESTIGATION OF HIGH POWER ULTRASONICS FOR DEPOLYMERIZATION OF POLYLACTIC ACID	1958
<i>David Grewell, Gowrishankar Srinivasan</i>	
RECYCLING OF POLYVINYL BUTYRAL (PVB) FROM LAMINATED SAFETY GLASS.....	1963
<i>Achim Schmiemann</i>	

PLASTICS IN BUILDING & CONSTRUCTION SIG027

DETERRA® BIOBASED POLYMERS-NEXT GENERATION MATERIALS FOR DURABLE APPLICATIONS	1968
<i>Brandon Cernohous, Jeffery Cernohous, Adam Pawloski, Ashley Pinault</i>	
EVALUATION OF LONG-TERM PERFORMANCE OF GFRP FOR HOT WATER APPLICATION BY INJECTION MOLDING	1971
<i>Masahiro Muto, Hiroyuki Nishimura, Kazushi Yamada</i>	
MOISTURE RESISTANT TECHNOLOGIES FOR WOOD COMPOSITES	1977
<i>Jeffrey Cernohous, Adam R. Pawloski, Steven K. Manfred, Neil R. Granlund</i>	
RIGID POLYMERIC FOAM BOARDSTOCK TECHNICAL ASSESSMENT	1982
<i>Inken Beulich, Michelle Hudack, Dan Schroer, Mark Soderquist</i>	

POLYMER ANALYSIS D33

CHARACTERIZATION TECHNOLOGIES FOR PHARMACEUTICAL MELT EXTRUSION	1989
<i>Costas Gogos, Huiju Liu, Peng Wang</i>	

DETECTING POLYMER LONG CHAIN BRANCHING STRUCTURES BY USING ANALYTICAL RHEOLOGY	1994
<i>Xue Chen, Ronald Larson</i>	
DIFFUSION PROPERTIES IN POLYMER MEMBRANES BY FT-IR-ATR	1997
<i>James Sloan</i>	
EFFECT OF NANO - SiO₂ ON THE CRYSTALLINITY AND CRYSTALLIZATION BEHAVIOUR (NON-ISOTHERMAL AND ISOTHERMAL) OF POLYETHYLENE TEREPHTHALATE (PET) NANOCOMPOSITE.....	2001
<i>Rabeh Elleithy, M. E. Ali Mohsin, S. M. Al-Zahrani</i>	
EFFECTS OF HYDROLYTIC DEGRADATION ON THE MECHANICAL PROPERTIES OF RENEWABLE BIOPLASTICS: POLY(TRIMETHYLENE MALONATE) AND POLY(TRIMETHYLENE ITACONATE)	2008
<i>I-Wei Chu, Ersan Eyiler, Mathew Rowe, Keisha Walters</i>	
ISOTHERMAL GROWTH RATES OF NODULAR AND SPHERULITIC STRUCTURES OF ISOTACTIC POLYPROPYLENE	2014
<i>Yousef Mubarak</i>	
MELT MIXED PCL - MWCNT NANOCOMPOSITES PREPARED AT DIFFERENT MIXING SPEEDS.....	2019
<i>Petra Pötschke, Tobias Villmow</i>	
MODELING AND ANALYSIS OF CURE KINETICS OF ALIPHATIC EPOXY RESIN WITH AND WITHOUT DIFFUSION	2025
<i>Juan Hernández-Ortiz, Tim Osswald, Nora Restrepo-Zapata</i>	
OVERVIEW OF THE TESTING PROGRAM ON FIBERS USED IN BALLISTIC APPLICATIONS.....	2030
<i>Joy Dunkers, Amanda Forster, Gale Holmes, Jae Kim, Haruki Kobayashi, Walter McDonough, Kirk Rice, Michael Riley, Scott Wight</i>	
RHEOLOGICAL CHARACTERIZATION OF INJECTION MOULDING GRADE THERMOTROPIC LIQUID CRYSTAL POLYMERS (LCPS)	2035
<i>Sati Bhattacharya, Franco Costa, Rahul Gupta, Ahmed Rahman, Shishir Ray</i>	
TRANSFORMATION OF MEASURED P-V-T DATA INTO MOLFDLOW SOFTWARE	2041
<i>Ruben Schlutter, Thomas Seul</i>	
USING SIMULTANEOUS DSC-RAMAN TECHNOLOGY TO STUDY CRYSTALLIZATION OF NYLON 6	2045
<i>Enrique Lozano Diz, Geert Van Den Poel, Richard Spragg, Lilian Willems, Peng Ye</i>	

POLYMER MODIFIERS AND ADDITIVES D38

ANALYSIS OF THE PROPERTIES AS CONTENT OF END-GROUP FOR POLYCARBONATE (PC)IN MELT POLYMERIZATION PROCESS.....	2049
<i>Sang-Hyun Park, Su Ran Lee, Byung Hoon Lim, Kwan Hwi Park, Byoung Ok Jang</i>	
ANTIMONY TRIOXIDE-FREE FLAME RETARDANT SYSTEMS FOR POLYMERIC MATERIALS.....	2055
<i>Marshall Moore, Subramaniam Narayan</i>	
CALCIUM SULFATE WHISKERS(CSW)REINFORCEMENT OF POLYMERS - A REVIEW	2059
<i>Lisette Akor, George Hawley</i>	
CASE STUDIES OF NEW APPLICATION DEVELOPMENT USING ELECTRON BEAM IRRADIATION	2066
<i>Daniel Yasenchak</i>	
CHAIN EXTENSION OF RECYCLED POLYAMIDES : HOW TO INCREASE THE AMOUNT OF RECYCLED PA IN THE AUTOMOTIVE INDUSTRY	2069
<i>Elodie Gaouyat</i>	
CRYSTALLIZATION OF ACETAMINOPHEN/POLY(ETHYLENE OXIDE) MIXTURES	2074
<i>Costas Gogos, Peng Wang, Min Yang</i>	
ECONOMIC BENEFITS OF CROSSLINKABLE POLYAMIDES – A LOOK AT ELECTRON BEAM IRRADIATED MOLDED PARTS	2080
<i>William Person, Shannon Wayne</i>	
THE EFFECT OF HOST POLYOLEFIN PROPERTIES AND PROCESSING CONDITIONS ON THE ANTISTATIC PERFORMANCE OF K-IONOMER BLENDS	2083
<i>Xiyun Fan</i>	
EFFECT OF STABILIZERS, MOLECULAR WEIGHT AND ENVIRONMENT ON THERMAL STABILITY OF POLYETHYLENE GLYCOL (PEG).....	2088
<i>Abdellah Aji, Pierre J Carreau, Ahmad Rezaei Kolahchi</i>	
SCRATCH RESISTANCE ADDITIVES	2092
<i>Daniel Calimente, Oliver Fuhrmann, Michael Geck</i>	
HIGH TEMPERATURE INTUMESCENT MATERIAL.....	2094
<i>Donald Bigg, Kenneth Heater, Jonathan Macarus, John Price</i>	
IN SITU GENERATED BICONTINUOUS REINFORCEMENTS FOR PEEK	2099
<i>O. Sinan Yordem, Alan J. Lesser</i>	
A METHOD FOR THE EVALUATION OF RESPIRATORS IN A NANORICH ENVIRONMENT	2106
<i>Avraam Isayev, Todd M. Lewis, Ryan Schmidt</i>	
NEW DEVELOPMENTS IN FIRE RETARDANCY OF STYRENIC COPOLYMERS	2111
<i>Pierre Georlette, Yaniv Hirschsohn, Sergei Levchik, Yakov Rachmilevitch</i>	
POLYETHYLENE BLENDS CONTAINING POLYMERIC MICROSPHERES FOR MILITARY PACKAGING APPLICATIONS.....	2115
<i>Sarah Schirmer Cheney, Matthew Burke, Gregory Pigeon, Jo Ann Ratto, Jeanne Lucciarini</i>	

POLYHEDRAL OLIGOMERIC SILSESQUIOXANE SURFACE MODIFICATION AND NANODISPERSION	2121
<i>Sarah Morgan</i>	
A REACTION-DIFFUSION MODEL DESCRIBING ANTIOXIDANT DEPLETION IN PE-CLAY NANOCOMPOSITES UNDER THERMAL AGING.....	2122
<i>Iftekhar Ahmad, Richard Cairncross, Shan Cheng, Grace Hsuan, Christopher Li</i>	
RHEOLOGICAL AND MECHANICAL PROPERTIES OF POLYMER BLENDS, RADIOPAQUE FILLERS AND COUPLING AGENT.....	2130
<i>Breanna Boyden, Brian Labrec, Vijay Wani</i>	
SIMULTANEOUS MILLING, COATING AND COAT-CURING OF PARTICULATES IN A FLUID ENERGY MILL VIA PHOTO-POLYMERIZATION	2137
<i>Peter Bonnett, Costas Gogos, Huiju Liu, Chunmeng Lu, Subhash Patel, Ming-Wan Young, Linjie Zhu</i>	
SOLVENTLESS POLYMERIC PARTICLE COATING IN A FLUIDIZED BED VIA UV LED INITIATED POLYMERIZATION	2142
<i>Costas Gogos, Huiju Liu, Chunmeng Lu, Yong Lu, Ming-Wan Young, Linjie Zhu</i>	
SUREFLO®: A NEW AND HIGHLY EFFECTIVE PROCESS ADDITIVE FOR THERMOPLASTICS	2147
<i>John Jungjohann, Xiaofan Luo, Aaron Puhala, Brian Sarvas</i>	
THE SYNERGISTIC EFFECT OF SiO₂ ON THE FLAMMABILITY PROPERTIES OF INTUMESCENT FLAME RETARDED POLY(EHTENE-CO-OCTENE) ELASTOMER (POE)/ POLYPROPYLENE(PP) BLENDS	2151
<i>Jinping Qu, Jinsong Wen, Zhenghuan Wu, Yonqing Zhao</i>	

PROCESS MONITORING AND CONTROL SIG016

INJECTION VELOCITY CONTROL USING 2D MODEL PREDICTIVE ITERATIVE LEARNING ALGORITHM	2155
<i>Yi Yang, J. Shi, F. Gao</i>	
IN-LINE MEASUREMENT APPARATUS FOR RESIDENCE TIME DISTRIBUTION IN TWIN-SCREW EXTRUDER AND ITS APPLICATION IN POLYMER PROCESSING.....	2161
<i>Lianfang Feng, Xueping Gu, Guohua Hu, Jiajun Wang, Cailiang Zhang</i>	
MODELING AND SIMULATION OF THERMALLY AND FLOW INDUCED CRYSTALLIZATION OF SEMI-CRYSTALLINE POLYMERS	2167
<i>Yue Mu, Guoqun Zhao, Xianghong Wu</i>	
MONITORING OF THERMAL HOMOGENEITY IN SINGLE SCREW EXTRUSION USING INFRARED TEMPERATURE SENSORS.....	2172
<i>Elaine Brown, Phil Coates, Adrian Kelly, Javier Vera Sorroche</i>	
MULTIVARIATE MODELLING, FAULT DETECTION, AND VALIDATION FOR THE EXTRUSION PROCESS.....	2179
<i>Louay Abou-Shady, Chris Ambrozic, Daniel Hazen, Stephen Johnston, David Kazmer</i>	
POLYMER EXTRUSION CONTROL SYSTEM DESIGN	2187
<i>Yi Yan, Z. Jiang, F. Gao</i>	
QUALITY OPTIMIZATION OF INJECTION-MOLDED PLASTIC LENSES VIA MODEL FREE OPTIMIZATION METHOD	2197
<i>Xi Chen, Xiangsong Kong, Zhijiang Shao, Yi Yang, Lingyu Zhu, Shengqiang Zhu</i>	
RAPID PERMEATION MEASUREMENT SYSTEM FOR THE GAS PERMEABILITY OF FILMS	2203
<i>Martin Bastian, Julia Botos, Peter Heidemeyer, Thomas Hochrein, Karsten Kretschmer, Kajetan Müller</i>	
A SINGLE MACHINE SCHEDULING STRATEGY FOR ENERGY SAVING IN INJECTION MOLDING PROCESS.....	2209
<i>Guixia Gong, Jianhua Lu, Ningyun Lu, Yi Yang</i>	
ULTRASONIC MEASUREMENT OF FILLER CONCENTRATION	2214
<i>Charles Fry, Zhigang Sun</i>	

PRODUCT DESIGN AND DEVELOPMENT D41

CHARACTERIZATION OF TENSILE PROPERTIES OF FUSED DEPOSITION MODELLING PROCESSED ABS MATERIAL	2221
<i>Prabin Chaudhary, S. Masood</i>	
A CONTRIBUTION FOR QUALITATIVELY MODELING OF FRICTION AND WEAR BEHAVIOR OF THERMOPLASTICS	2226
<i>Dietmar Drummer, Michael Kobes, Daniel Merken</i>	
DESIGN AND DEVELOPMENT OF THERMOPLASTIC HAND HOLDS FOR PASSENGER SAFETY IN MASS TRANSPORT SYSTEM.....	2233
<i>Venkatesha Narayanaswamy</i>	
INVESTIGATION OF DYNAMIC MECHANICAL PROPERTIES OF METAL-POLYMER FILAMENT FOR FUSED DEPOSITION MODELLING	2238
<i>Syed Hussain, Syed Masood, Mostafa Nikzad</i>	
A NEW IMPROVED FLOW HIGH STRENGTH POM COPOLYMER	2242
<i>Robert Gronner, Ram Narayanan</i>	
USE OF X-RAY TOMOGRAPHY FOR EFFICIENT PACKAGE DESIGN	2248
<i>Sudheer Bandla, Jay Hanan</i>	

VERIFYING AND IMPROVING THE PLASTIC DEFORMATION OF AUTOMOTIVE INTERIOR PARTS AT EARLY DESIGN STAGE	2253
<i>Li Qi, Kaushlendra Singh, Jeff Webb</i>	

ROTATIONAL MOLDING D42

ANALYSIS OF WOOD PARTICLE DRYING FOR ROTOMOLDING APPLICATION	2259
<i>Denis Rodrigue, Nicolas Ward-Perron</i>	
NATURAL FIBER REINFORCED THERMOPLASTICS (NFRTP) PROCESSED BY ROTOMOLDING.....	2263
<i>Denis Rodrigue, Nicolas Ward-Perron</i>	
STUDIES OF DEGRADATION EFFECTS DURING ROTATIONAL MOLDING	2268
<i>Nick Henwood, Graham Lees, Chris Liauw, Payman Sharifi</i>	

THERMOFORMING D25

THE DESIGN OF A PROTOTYPE VACUUM THERMOFORMING MACHINE.....	2275
<i>Soren Maloney, Nigel Williams, Stefan Wilson</i>	
INFLUENCING THERMOFORMING PROPERTIES OF POLYPROPYLENE FILMS WITH ADDITIVES	2281
<i>Maren Begemann, Christian Hopmann, Walter Michaeli</i>	
PLUG ASSIST MATERIALS FOR IMPROVED TRANSPARENCY WHEN FORMING POLYPROPYLENE	2286
<i>Kathleen Boivin, Hubert Kittelmann, Noel Tessier, Corey Williams</i>	
RECENT INSIGHTS ON THE USE OF BETA NUCLEATION TO IMPROVE THE THERMFORMING CHARACTERISTICS OF POLYPROPYLENE	2292
<i>Philip Jacoby</i>	
THERMOFORMABLE LIQUID CRYSTAL POLYMER (LCP)	2297
<i>Achim Hofmann, Bing Lu, Paul Yung</i>	

THERMOPLASTIC ELASTOMERS SIG006

EFFECT OF BLEND COMPOSITION OF EPOXIDIZED NATURAL RUBBER AND FLUOROPLASTIC VIA DYNAMIC VULCANIZATION.....	2303
<i>Rathanawan Magaraphan, Tharinee Thamronglerdrit</i>	
FOAMING BEHAVIOR OF MELT COMPOUNDED THERMOPLASTIC POLYURETHANE IN PRESENCE OF BUTANE	2307
<i>Nemat Hossieny, M. Nofar, R. Barzegari, C. B. Park</i>	
LOW FREQUENCY SOUND ABSORPTION AND ATTENUATION OF THERMOPLASTIC ELASTOMERS.....	2312
<i>Feng Chen, Jiangming Jin, Huancai Lu, Jianjiang Yang, Mingqiang Zhong</i>	
THE SCIENCE OF FORMULATING OLEFIN BLOCK COPOLYMERS	2317
<i>Lisa Madenjian, Jeff Munro, Jose Rego, Kim Walton</i>	
SUBSTITUTING F-PVC WITH THERMOPLASTIC POLYOLEFIN ELASTOMERS	2321
<i>Jeff Liu, Lisa Madenjian, Jeff Munro</i>	

THERMOPLASTIC MATERIALS & FOAMS D29

BATCH FOAMING BEHAVIOR OF TPU MATERIAL	2325
<i>Chia-Hsun Chen, Chen-Feng Kuan, Hsu-Chiang Kuan, Kun-Chang Lin, Hsin-Chih Peng</i>	
BIOMASS MATERIALS, SHAPE MEMORY POLYURETHANE	2330
<i>Jia Hong Li</i>	
COMPARATIVE STUDIES ON THE CRYSTALLIZATION BEHAVIOR OF POLY ETHER KETONE (PEK).....	2334
<i>Mathew Abraham, Veena Choudhary, Sandeep Kumar</i>	
COMPARISON OF MASS TRANSIT MATERIAL FLAMMABILITY REQUIREMENTS AND TRENDS FOR AIRCRAFT AND TRAIN APPLICATIONS IN EUROPE AND NORTH AMERICA	2342
<i>Ralph Buoniconti, Torben Kempers, Steven Maclean</i>	
DEVELOPMENT OF BEAD FOAMING TECHNOLOGY FOR HIGH PERFORMANCE PEEK. 1.THERMAL ANALYSIS	2355
<i>H. Wang, S. L. Zhang, M. Nofar, R. Barzegari, C. B. Park, Z. H. Jiang</i>	
DYNAMIC BEHAVIOR AND EXPERIMENTAL VALIDATION OF CELL NUCLEATION AND GROWING MECHANISM IN MICROCELLULAR INJECTION MOLDING PROCESS.....	2360
<i>Rong-Yu Chang, Yuan-Jung Chang, David Hsu, Chao-Tsai Huang, Tai-Yi Shiu</i>	
DYNAMIC PROPERTIES OF CROSSLINKED POLYOLEFIN FOAMS	2366
<i>Kyle Kummer, Jose Rego, Shaofu Wu</i>	
THE EFFECT OF POLYHYDROXYBUTYRATE-CO-VALERATE (PHBV) CONTENT ON THERMAL, RHEOLOGICAL, MECHANICAL PROPERTIES AND FOAMING BEHAVIOR OF POLYLACTIC ACID (PLA).....	2372
<i>Qi Guan, Hani Naguib, Reza Rizvi</i>	

EFFECT OF PROCESS VARIABLES ON THE PROPERTIES OF SUPERCRITICAL CO₂ FOAMED PS/GRAPHITE NANOCOMPOSITE FOAM	2379
<i>Kuo-Chung Cheng, Tsu-Huang Chuang, Wen-Jeng Guo, Chien-Hsiung Huang, Shu-Kai Yeh</i>	
EFFECT OF VARIOUS ADDITIVES (TALC, NANOCCLAY, AND NANOSILICA) ON EXTRUSION FOAMING OF PLA THROUGH CRYSTALLIZATION	2384
<i>Mohammad Reza Barzegari, Mehdi Keshtkar, Mohammadreza Nofar, Chul Park, Alireza Tabatabaei</i>	
EXTRUSION FOAMING BEHAVIOR OF PET	2389
<i>Mohamad Reza Barzegari, Nathali Chapleau, Nemat Hossieny, Mehdi Keshtkar, Chul Park</i>	
EXTRUSION-CALENDERING OF FOAMED AND UNFOAMED WOOD/PLASTIC COMPOSITES	2394
<i>Nathalie Benoit, Denis Rodrigue</i>	
FALLING DART IMPACT BEHAVIOUR OF POLYCARBONATE AND MICROCELLULAR POLYCARBONATE FOAMS	2399
<i>Andrzej Bledzki, Hans-Peter Heim, Martin Rohleder, Sebastian Schaub</i>	
FEASIBILITY OF DOUBLE CRYSTAL MELTING PEAK GENERATION IN PLA FOR EXPANDED PLA BEAD FOAMS	2405
<i>Mohammadreza Nofar, Chul Park</i>	
FOAMING OF POLY(ETHYLENE-CO-OCTENE) WITH SUPERCRITICAL CARBON DIOXIDE ACROSS ITS MELTING RANGE	2410
<i>Raymond Chu, Yanting Guo, Chul Park, Nanqiao Zhou, Jin Ho Zong</i>	
GAS PERMEABILITY OF POLY (4-METHYLPENTENE-1) IN A CONFINED NANOLAYERED FILM SYSTEM	2416
<i>Guojun Zhang, A. Hiltner, E. Baer</i>	
GLASS FILLED POLYBUTYLENE TEREPHTHALATE WITH ENHANCED SURFACE AESTHETICS	2421
<i>Kaushal Gandhi, Kumar Parimal, Robert Galluci, Rama Konduri</i>	
HIGH FLOW THERMOPLASTIC POLYESTERS	2425
<i>Robert Gallucci</i>	
HIGH PERFORMANCE METALLOCENE POLYETHYLENE BASED ON SK INNOVATION'S NEXLENETTM TECHNOLOGY	2432
<i>Sungseok Chae, Hyeongtaek Ham, Seungbum Kwon, Sewon Oh</i>	
THE INFLUENCES OF PROCESSING TEMPERATURES AND NUCLEATING AGENT IN FOAMING OF A THIN-WALLED INJECTION MOLDED PART	2437
<i>Amir Ameli, Davoud Jahani, Peter Jung, Hani Naguib, Cull Park, Mehdi Saniei</i>	
ISOTHERMAL CRYSTALLIZATION-INDUCED FOAMING OF POLYPROPYLENE UNDER HIGH PRESSURE CARBON DIOXIDE	2443
<i>Yanting Guo, Chul B. Park, Anson Wong, Nanqiao Zhou</i>	
MELT FRACTURE BEHAVIOR OF PLA FOAMED USING DIFFERENT DIE ENTRY ANGLES	2450
<i>Lun Howe Mark, Chul Park, Mo Xu</i>	
NEW POLYCARBONATE COMPOSITIONS WITH LOW OSU HEAT RELEASE & SMOKE VALUES FOR AIRCRAFT APPLICATIONS	2455
<i>James Hoover, Laura Schultz Hume, Paul Sybert</i>	
ONE- AND THREE- DIMENSIONAL ALIGNMENT OF GRAPHENE USING NEW FABRICATION STRATEGIES FOR THERMALLY CONDUCTIVE LLDPE-GRAPHENE COMPOSITE	2460
<i>Vincent Adinkrah, Francis Dawson, Muhammad Omer Khan, Siu Leung, Hani Naguib</i>	
POLYMER NANOCELLULAR FIBERS VIA SUPERCRITICAL CARBON DIOXIDE BASED EXTRUSION FOAMING	2467
<i>Kimi Chang, Chenglong Dai, Wenyi Huang, L. James Lee, Cailiang Zhang, Shuai Zhang</i>	
POLYMER NANOCOMPOSITE FOAM FOR TEXTILE APPLICATIONS	2472
<i>Wen-Jeng Guo, Yu-Che Liu, Sea-Fue Wang, Wei-Zhe Wu, Shu-Kai Yeh, Kuang-Chin Zhang</i>	
PULL AND FOAM - INJECTION MOULDING METHOD: FOAMED RIBS FOR STIFFENING PLANE COMPONENTS	2477
<i>Stefan Gövert, Hans-Peter Heim, Stefan Jarka, Mike Tromm, Joachim Schnieders</i>	
RHEOLOGICAL PROPERTIES AND FOAMING BEHAVIOR OF COAGENT-MODIFIED POLYPROPYLENE	2481
<i>Savvas Hatzikiriakos, Marianna Kontopoulou, Scott Parent, Chul Park, Ying Zhang</i>	
SOLUBILITY AND DIFFUSIVITY OF CARBON DIOXIDE IN POLYPROPYLENE/MICRO-CALCIUM CARBONATE COMPOSITES	2486
<i>Jie Chen, Tao Liu, Ling Zhao, Wei-Kang Yuan</i>	
STRATEGIES FOR ACHIEVING HIGH EXPANSION FOAMS OF CROSSLINKED ETHYLENE-VINYL ACETATE (EVA) USING A CHEMICAL BLOWING AGENT	2491
<i>Nan Chen, Chul Park</i>	
STUDY OF PRODUCING MICROCELLULAR INJECTION MOLDED PARTS WITH IMPROVED SURFACE QUALITY	2498
<i>Eugene Dougherty, Patrick Gorton, Jungjoo Lee, Lih-Sheng Turng</i>	
A STUDY ON THE ACOUSTIC PERFORMANCE OF BIO-BASED COMPOSITE FOAMS OF PLA AND PHBV	2503
<i>Noureddine Atalla, Shahrzad Ghaffari Mosanenzadeh, Hani E. Naguib, Chul B. Park</i>	
SWELLING OF PLA MELT DUE TO CO₂ DISSOLUTION	2510
<i>Syed Mahmood, Chul Park</i>	

THERMAL AND THERMOMECHANICAL BEHAVIOUR OF INJECTION MOLDED SOLID AND MICROCELLULAR POLYLACTIC ACID (PLA)/POLYHYDROXYBUTYRATE-VALERATE (PHBV) BLENDS	2513
<i>Zhixiang Cui, Xiangfang Peng, Xiaofei Sun, Lih-Sheng Turng, Haibin Zhao</i>	

THERMOSET D28

DETERMINATION OF KINETIC CURE PARAMETERS CONSIDERING SPECIFIC HEAT TEMPERATURE DEPENDENCE.....	2518
<i>Evaristo Biscoia, Veronica Calado, Rogerio Pagano, Frederico Tavares</i>	
DEVELOPMENT OF A METHOD FOR MEASURING THE THERMAL CONTACT RESISTANCE AND THERMAL CONDUCTIVITY OF ELECTRONIC MOLDING COMPOUNDS	2523
<i>Tamas Deak, David Kazmer, Norbert Kovacs</i>	
DISPERSION OF SINGLE-WALLED AND MULTI-WALLED CARBON NANOTUBES IN UNSATURATED POLYESTER RESIN	2529
<i>Virginia Davis, Matthew Kayatin, Esteban Urena-Benavides</i>	
PRESTRESSED DOUBLE NETWORK GLASSES.....	2533
<i>Andrew Detwiler, Alan Lesser, Zhan Yang</i>	
REINFORCING THERMOSETS USING CRYSTALLINE DESOXYANISOIN STRUCTURES.....	2538
<i>Todd Emrick, Alan Lesser, Polina Razina, Beom-Young Ryu</i>	
THE THREE DIMENSIONAL NUMERICAL ANALYSIS AND VALIDATION OF COMPRESSION MOLDING PROCESS.....	2543
<i>Roy Bendickson, Franco Costa, Sejin Han, Xiaoshi Jin, Jin Wang</i>	

VINYL PLASTICS D27

DIBENZOATE PLASTICIZER PLATFORM DEVELOPMENT FOR PVC APPLICATIONS	2549
<i>William Arendt, Rebecca Brewer, Emily McBride</i>	
OSHA'S COMBUSTIBLE DUST NATIONAL EMPHASIS PROGRAM AND COMBUSTIBILITY CHARACTERISTICS TESTING OF PVC RESINS AND PVC DUSTS	2558
<i>Peter De La Cruz, Lawrence Halprin, Richard Krock</i>	
PRIMARY PARTICLE DELAMINATION AS THE IMPACT MECHANISM FOR PVC	2569
<i>Donald Witenhafer</i>	
SCREEN PRINTING PVC FILM WITH UV INK	2572
<i>George Paleos</i>	
Author Index	

Computer Simulation of Flow Balance in the Die of Slot Coater: Part 1: Land Geometry

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Abstract

Coating operations such as spin coating, curtain coating, role coating, slide coating, slot coating, and etc. are dated from long time ago and still considered very important processing. Slot coating is considered very important specially for the manufacturing of liquid crystal display parts. Photo resistant is coated on the glass and is sent to next process to make TFT board. Coating quality such as uniformity of coating thickness can be divided into two categories, which are machine direction quality and transverse direction quality. Machine direction quality is related to die lip design and operation conditions whereas the transverse direction quality is related to flow uniformity inside of the die. The flow uniformity is governed by flow balance in the die. The most important design factors for the inside die geometry are manifold and land. Through this study the flow balance according to the land design has been examined by computer simulation. The parameters for land design are length and shape. Exit velocity at the outlet of die is different from land designs. The best land design has been investigated in this study.

Introduction

The carbonated bottles had consisted in two pieces, Demand of photo-resist (PR) coating has been increased as liquid crystal displays for monitor, TV, and other display screen increase. There are many kinds of coating operations such as curtain coating, roll coating, slide coating, spin coating, slot coating, and so on in coating industry (1-9). There are two kinds of coating uniformity in slot coating. One is a uniformity along the machine direction which is a coating direction. This uniformity depends upon not only die geometry but operational conditions. The other is a uniformity in the transverse direction of coater moving. This uniformity depends upon flow uniformity at the exit of the die. The shape and volume of manifold, and geometry of die land strongly affect the flow uniformity at the exit of the die. Exit velocity has been examined according to the die land designs. Die land design contains land length and its shape. Consequently the best land design has been investigated through flow balance simulations in the die.

Computer Simulation

1 Material and Model

Viscosity and density of photo resistant used in this study were 0.038 poise and 1.003 g/cm³ respectively. Fig.1 shows a die for slot coater. The region of inside of die divided into manifold and land as shown in Fig. 2. The land geometry is a variable in this simulation. The shapes of land for study are summarized in Table 1.

2 Modeling for FEA and Boundary Conditions

Fig. 3 shows a modeling for finite element analysis. It contains four boundaries. Boundary 1 is an inlet of PR and pressure was imposed in this inlet. Boundary 2 is a symmetric plane. Boundary 3 is a wall and no slip condition was imposed on this boundary. Boundary 4 is an exit and outlet condition was imposed on this boundary.

The hexahedron mesh was used for computation and commercial code, Fluent, was used for simulation.

Results and Discussions

1 Various Die Land Length

Velocity Distributions

Fig. 4 shows velocity distributions at the cross sections along the die width direction. The maximum velocity occurred at the center of manifold (Fig. 4(a)). Velocity profiles became uniform as PR flows through die land (Fig. 4(b) and (c)).

Velocity Vector and Path Line

Fig. 5(a) shows velocity vectors in the manifold. Circulation flow was expected at the entrance in the manifold. Circulation flow was clearly observed shown in path line in Fig. 5(b). Circulation flow could intake air and it may make bubble during the coating operation.

Velocities in the Die Land and Die Exit

Fig. 6 shows velocities in the die land and at the die exit. The edge velocity in the region of land beginning was smaller than the velocity at the center region. However as PR flowed through tapered die land the flow area decreased. Thus the velocity at the edge of die land increased when the PR approached to die exit. Finally edge velocity became bigger than center velocity. Exit velocity should be uniform to get uniform coating thickness along the die width. Fig. 7 shows standard deviations of exit velocity according to the die land length. Standard

deviation decreased as PR flowed down to the die land and it showed minimum and it increased as PR flowed out through die exit. Long land length gave low standard deviation of velocity.

2 Various Land Shape

Velocities in the Die Land and Die Exit

Velocity vectors along the straight die land are shown in Fig. 8. Velocities along the die width direction at the cross section of the die land were quite uniform. Straight die land had more uniform exit velocity compared with tapered die land shown in Fig. 6. Velocity vectors in the hybrid die land are shown in Fig. 9. The die land was tapered in the beginning region and it made increasing the edge velocity as flows went on. After the tapered region land became straight. Thus the increasing of edge velocity stopped and velocities along the die length direction became uniform.

Exit Velocity

Fig. 10 shows standard deviations of exit velocity along the die width for tapered, straight and hybrid land shapes. Standard deviation for straight land showed low and steady. Standard deviation for hybrid land decreased from the beginning region of die land and showed steady low value at the exit region. However, it showed jumping of standard deviation after just passed the straight land in the hybrid land. Standard deviation decreased and then increased in the tapered land. The flows met the straight die while the standard deviation increased thus the standard deviation dropped and showed low and steady value. This implies there exists optimum position for beginning of straight land in the hybrid land to achieve steady low standard deviation of velocity. Standard deviations for straight and hybrid lands were smaller than tapered land.

Conclusions

Flow balance in the coater die has been investigated through computer simulation. Circulation flows were observed at the entrance region of manifold. Flow balance can be influenced by die inside geometry, such as manifold shape, manifold volume, die land length, and land shape. Flow balance according to the land length and land shape in the die has been studied in this paper. Flows inside of the die were more stable as land length increased. Standard deviation of exit velocity along the die length decreased as flow went down to the middle of the die land and then increased as flow approached to the exit. The longest die land showed the lowest standard deviation of exit velocity in the tapered die land. Hybrid type of land shape showed the most uniform velocity among the tested land shapes, tapered, straight, and hybrid of tapered and straight lands. Computational results can be utilized to die design for slot coater. There were three design factors, clearance, foot length and valley width that affect the crack in petaloid

bottom of bottle. The crack resistance of bottom of carbonated bottle can be improved by the modification of the petaloid shape considering the design factors. Through these modifications, maximum principal stress was reduced and the location was moved to the safe region, near sidewall. The improvement of crack resistance of new designed petaloid shape was verified by cracking test

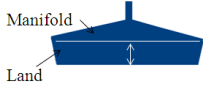
Acknowledgements

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Table 1 Geometry of land in a die for flow balance simulation

Land Geometry		
Land Shape and Length	Tapered, 68mm	
	Tapered, 58mm	
	Tapered, 48mm	
	Tapered, 38mm	
	Tapered, 28mm	
Land Shape and Length	Straight, 58mm	
	Hybrid(Tapered and Straight), 58mm	

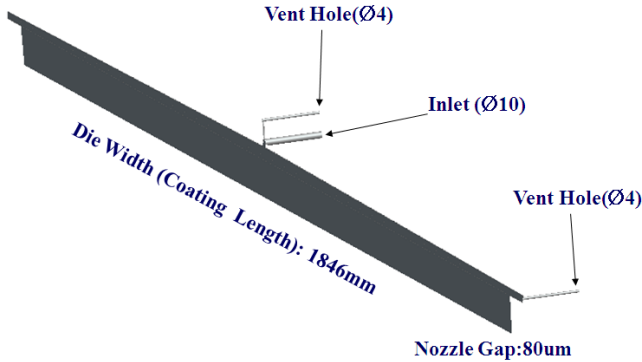


Fig. 1 Schematic drawings of slot coater

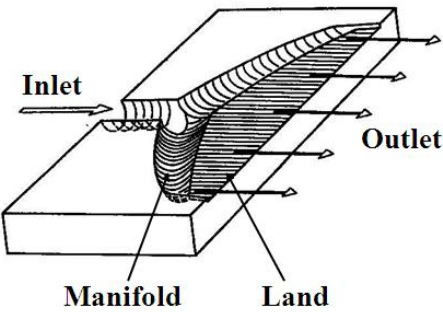


Fig. 2 Schematic drawing of inside die geometry in the slot coater

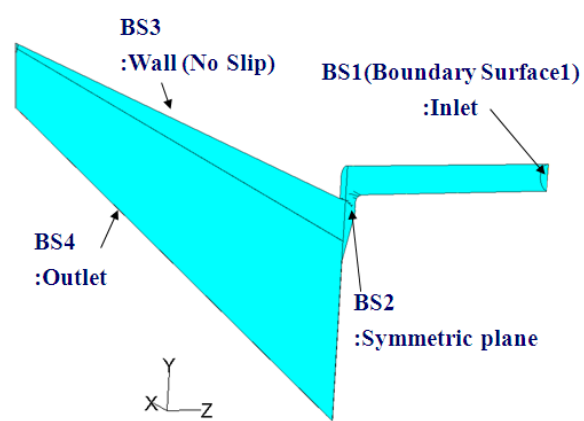
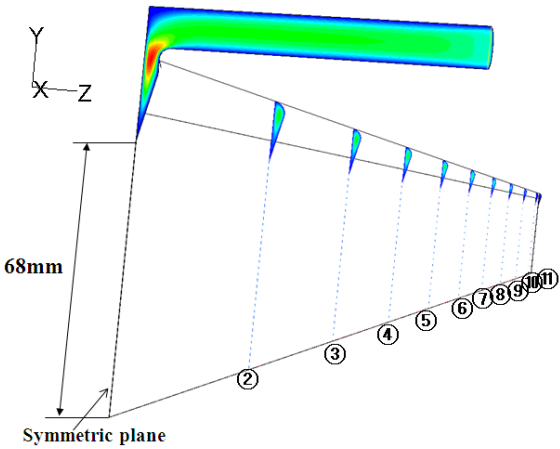
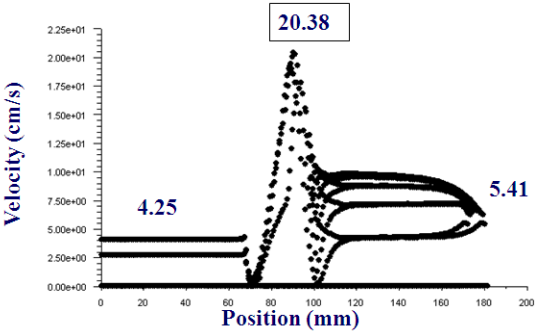


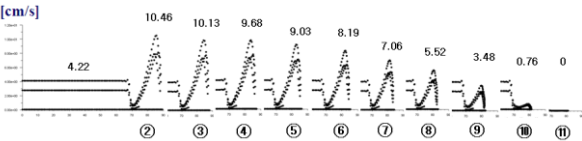
Fig. 3 Die modeling of slot coater for simulation



(a) Velocity distribution

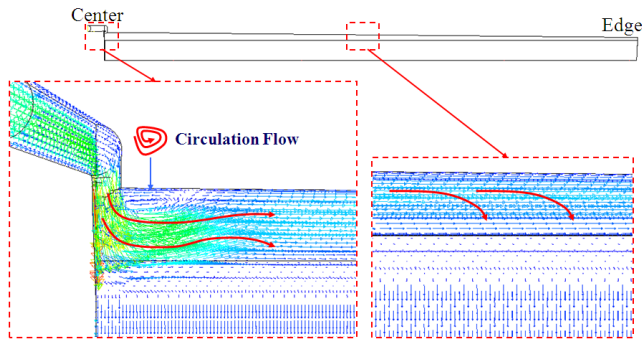


(b) Velocity profile at symmetric plane

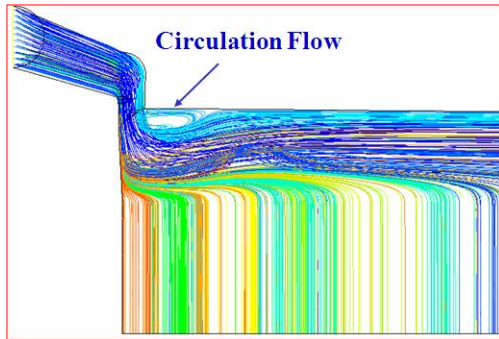


(c) Velocity profiles at cross sections along the die width

Fig. 4 Velocity at the cross section along the die width for tapered land with 68mm long



(a) Velocity vector



(b) Path line

Fig. 5 Velocity vector and path line at the entrance region of manifold

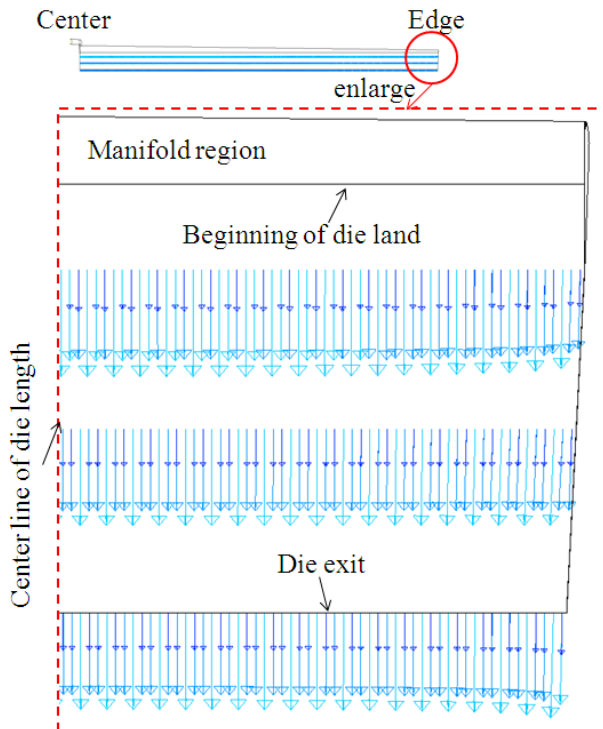


Fig. 6 Velocity vectors of die inside for tapered die land with 28mm long

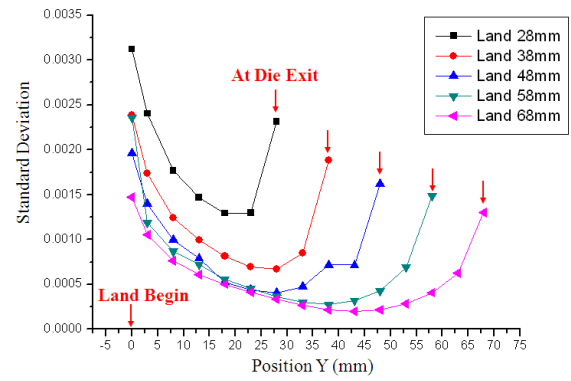


Fig. 7 Standard deviation of velocities along the die width according to die land length for tapered land

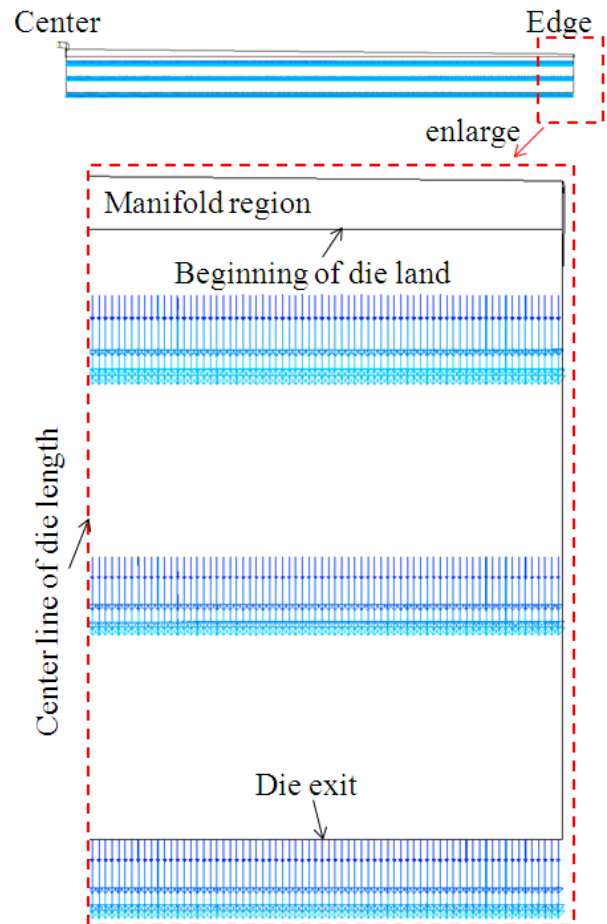


Fig. 8 Velocity vector of die inside for straight die land

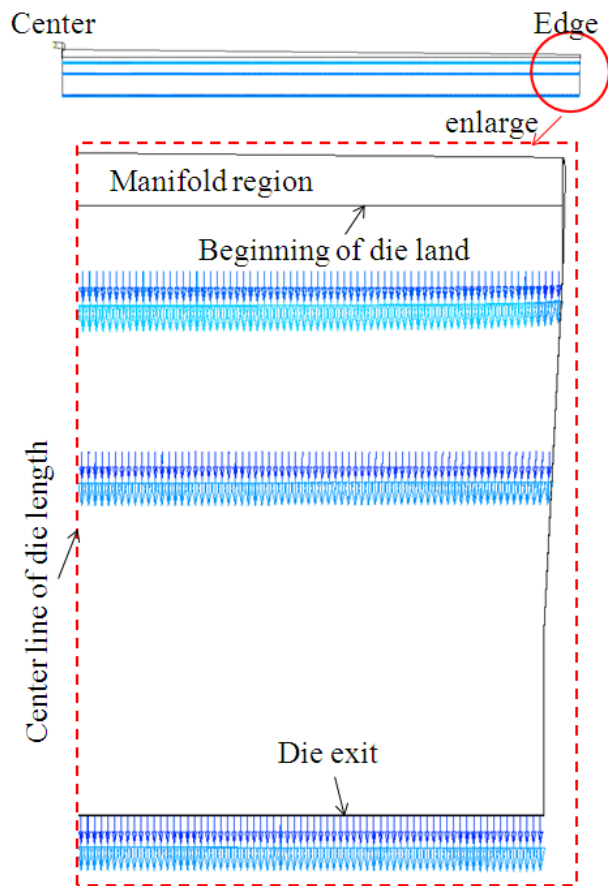


Fig. 9 Velocity vector of die inside for hybrid die land

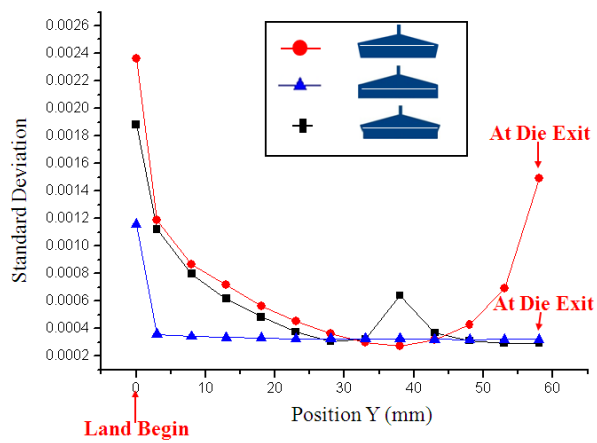


Fig. 10 Standard deviation of velocities along the die width according to die land shapes



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United States; 2 April 2012 through 4 April 2012; Code 92358

Computer simulation of flow balance in the die of slot coater: Part 1: Land geometry (Conference Paper)

Kim, H.^a, Park, Y.^a, Hong, J.^a, Lyu, M.-Y.^a, Shin, S.K.^c, Seo, J.K.^b ^a Seoul National Univ. of Science and Technology, Seoul, South Korea^b Soonhan Engineering Corp., Kyunggi-do, South Korea

Abstract

Coating operations such as spin coating, curtain coating, roll coating, slide coating, slot coating, and etc. are dated from long time ago and still considered very important processing. Slot coating is considered

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Tsuda, T.
Coating flows of power-law non-newtonian fluids in slot



Abstract

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Coating operations such as spin coating, curtain coating, role coating, slide coating, **slot** coating, and etc. are dated from long time ago and still considered very important processing. **Slot** coating is considered very important specially for the manufacturing of liquid crystal display **parts**. Photo resistant is coated on the glass and is sent to next process to make TFT board. Coating quality such as uniformity of coating thickness can be divided into two categories, which are machine direction quality and transverse direction quality. Machine direction quality is related to **die** lip design and operation conditions whereas the transverse direction quality is related to **flow** uniformity inside of the **die**. The **flow** uniformity is governed by **flow balance** in the **die**. The most important design factors for the inside **die geometry** are manifold and **land**. Through this study the **flow balance** according to the **land** design has been examined by **computer simulation**. The parameters for **land** design are length and shape. Exit velocity at the outlet of **die** is different from **land** designs. The best **land** design has been investigated in this study.

Indexed keywords

Coating quality; Coating thickness; Curtain coating; Design and operations; Design factors; **Die geometry**; Exit velocity; **Flow balance**; **Flow** uniformity; Machine directions; Transverse directions

Engineering controlled terms: Computational methods; **Computer simulation**; Design; Dies; Liquid crystal displays; Plastic products; Thickness measurement

Engineering main heading: Coatings

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