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Industry Overview

ANTEC 2010 occurs as the plastics industry is trying to rebound from the global financial downturn, and as a financial crisis continues in several parts of the world. In his address during the business session, the incoming *Society of Plastics Engineers* (*SPE*) President Dr. Ken Braney of the UK, predicted the industry will see slow but steady growth in the coming years. He also emphasized the increasingly international face of *SPE* and the organization's inroads into social media to extend its reach and growing participation world-wide. Dr. Braney is the first *SPE* President to live outside the United States. While attendance from the U.S., Spain and Italy was low this year, overall international participation, particularly from Asia, appears to be at or near its highest level.

In his plenary address, John Verity of *Exxon-Mobile* cited *World Bank* projections for economic growth driven primarily by the activity in developing countries in which petrochemical industry demand is expected to grow at rates 2.5% above GDP. This growth will be driven in part by increased plastics demand, which is expected to double over the next 20 years. Demand for bioplastics in particular is expected to grow ten-fold over the same interval. During the presentation on *Failure Analysis* by Vic Barghava, *SPE Fellow* Glenn Beall cited the short-term need for more plastics education to support the recovery and growth of the industry, commenting that in the United States, at the undergraduate level, *there are two hundred and fourteen mechanical engineering degree programs, and only two dozen of them have any classes related to plastics*.

Event Overview

This year's Conference included ninety-three podium sessions, three plenary sessions, a poster session and an exhibition floor featuring 80 booths by publishers, universities, equipment makers, processors, additive suppliers and service providers. Several joint sessions were held to bring emphasis to the new markets and technologies. Among those with the highest interest level was a session on *Hot Melt Extrusion* for creating pharmaceutical dispersions and a forum on non-halogenated flame retardants. Interest also remains high in bioplastics and in nano-composites. Sustainability was a consistent theme through nearly all sessions, and several addressed recent media concerns over the safety and environmental impact of plastics. Two sessions on *Engineering Properties and Structure* focused on energy, primarily discussing polymer applications for solar cells. Wednesday's plenary session by *SPE Fellow* Dr. Donald Baird of the *Virginia Polytechnic Institute* focused on the rheological basis for nanoparticles influencing material properties on a macro scale in exfoliated liquid crystal polymers (LCPs).

Selected Presentation Summaries

Dr. Costas Gogos of the *New Jersey Institute of Technology* gave the introductory presentation for the first of two sessions on pharmaceutical *Hot Melt Extrusion*, in which a solid phase active pharmaceutical ingredient (API) is dispersed into the melt phase of an excipient, typically a water soluble polymer. This technology enhances bioavailability of poorly water soluble APIs, increases their shelf life, and simplifies the drug delivery mechanism. Dr. Gogos surveyed related issues, including the need for some level of chemical bonding between the API and the polymer, and the need to minimize thermal history and maintain a narrow melt age distribution. For these reasons a twin-screw extruder was preferred, in which mixing reaches uniformity within a few screw diameters of travel, and much narrower melt distributions can be achieved.

In the *Color and Appearance Division*, Bruce Mulholland presented *Ticona's* efforts to improve the luster and weld-line appearance of metallic pigments in acetal co-polymers. This project was described in terms of improved sustainability by eliminating the need for metallic painting or plating. *Ticona's* POM was shown to compare favorably to comparable pigmentation in ABS. Areas of research included particle shape, pigment system, gate location and selected process variables. Pigment systems have been developed in several appearance classes, with roughly 40 grades currently available and are targeted mainly at automotive markets. Weatherability data was also presented, with acceptably small delta E values after two years of sunlight/UV exposure in both Florida and Arizona tests.

Ultrasonic energy was the motive force behind plasticizing and transfer molding selected thermoplastics for micro molding applications in research presented by Thomas Kamps of *Aachen University*, Germany. A conventional ultrasonic welder was used in combination with a transfer pot, runner, and attached part cavity. Compressive forces in the range of 300-600 N at amplitudes of 30-50μm were used to achieve fill times in the range of 0.4 to 0.8 seconds. Heating rates of up to 600ºC per second were achieved through a combination of frictional heating and volumetric heating from cyclical compression loading. Standard extruded material pellets were used in the process, which has been demonstrated using PP, POM, PA, PLA, PESU and PPSU. Key benefits of the process are low thermal residence time and retention of properties at a micro molding scale. A 1/16 scale tensile bar was molded for testing purposes.

In the *Natural Fiber Composites* session, Tomoko Ohta of the *Kyoto Institute of Technology* described her research to improve the recyclability of reinforced polypropylene by substituting natural cellulosic fibers in place of glass fiber. The resulting hybrid composite reduced the net percentage of glass and increased the *Green Degree* of the composite. Data was presented on jute, sisal, flax, cotton, hemp, ramie, bamboo and pineapple fibers. Calculations were presented to compare the observed tensile modulus with theoretical predictions based on both a rule of mixtures approach and on Cox's formula. After extensive microscopic studies to statistically assess fiber orientation, a fiber efficiency parameter was calculated to characterize each material. A 20% jute fiber / 10% glass fiber composite was selected as the optimal combination of improved performance and *Green Degree*.

Roland Maesing of *Aachen University*, Germany, described a process that used packing pressures within an injection mold for in-situ pressure forming of metal inserts. Human Factors research indicated a minimum 0.2 mm metal thickness is needed to achieve a metallic *cool touch* perception. A primer was used for adhesion, requiring a 120ºC activation temperature. Studies using PC and PC/ABS blends with filler loadings up to 35% of mineral and glass fiber were used to match the plastic's coefficient of thermal expansion to the behavior of the metal insert. PC with 35% glass fiber provided the lowest warpage. In a series of process

trials with a 180 mm test disk having details in the range of 0.5 – 2.0 mm, surface replication quality was most affected by packing pressure, with some influence from mold temperature. Moderate variations in melt temperature and fill speed had no discernable effect. Process variation was directly proportional to the formed volume. Necking failures observed in the metal inserts occurred in the smallest formed radii for steel, and in the most deeply drawn sidewalls for aluminum.

In an *Engineering Properties and Structure* session, Angela Ries of *Kassel University*, Germany, presented the *Influence of the Compression Molding Process on Impact Behavior of Self-reinforcing HDPE Tapes*. The tapes were created from single-needle-crystal HDPE, with an extended chain crystal axis and radial lamellar structure, formed under high deformation conditions during extrusion. The tapes were compacted, selectively melted, and fixated to retain their process-induced structure. As a self-reinforcing material they show improved strength and dampening properties with excellent recyclability. Sample peaked-roof test pieces were compression molded from the tapes using an infra-red pre-heat station and an 800 kN press. The resulting parts showed up to a 2.5x improvement in impact properties and up to 6x improvement in vibration dampening applications.

Nano-Assembled Biaxially Oriented Polypropylene Films (Nano-BOPP) with High Oxygen Barrier properties were described in a well-attended presentation by Yijian Lin of Case Western University during a joint session of *Flexible Packaging* and *Composites*. Lin combined 33 alternating layers of PP and PEO to achieve internal film layer thickness on the order of 30 nm, or about the estimated thickness of a single crystal. PEO, with good barrier properties and 70% crystallinity, separated by equivalent thickness layers of PP, provides a tortuous path for diffusion of oxygen and carbon dioxide molecules, resulting in higher barrier properties than possible with either material alone. A Nano-BOPP laminate with 10% PEO and a 7x draw ratio in the X and Y axes resulted in a 20x reduction in permeability. Nano-BOPP provides equilibrium respiration properties for highly perishable foods while retaining good clarity and showing improved tear strength.

In an *Engineering Properties and Structure* session, Srinivas Siripurapu presented *Sabic's* overall strategy for extending the performance of polycarbonates into specialty markets, and more specifically, on *Lexan XHT*, aimed at improving long-term ageing performance of high-heat polycarbonates. The *XHT* grades are co-polymers, combining the standard bisphenol-A monomer with a hi-heat co-monomer, having Tg > 200ºC. The resulting co-polymer has a glass transition temperature of 185ºC, and performs well in Relative Thermal Index (RTI) testing, in which four key measures (tensile strength, impact strength, dielectric strength, and flame resistance) are compared to a control – typically *Lexan 141* for polycarbonates. One of the main applications *Sabic* is considering for this material is film for OLED display technologies.

Zhiyong Xia of *BP Solar* presented *Polymer Packaging Solution to Increase Photovoltaic (PV) Solar Module Power Output* in the *Advanced Energy* session. The goal was to improve performance or reduce costs wile still meeting the required 25-year warranty life. Current efficiencies provide a cost per kWh of about $0.20, which is already competitive in some parts of the U.S. and Europe. PV energy conversion world-wide currently provides about 7.3 GW of power annually, the equivalent of roughly seven nuclear power plants, up from 175 MW ten years ago. Within each solar array, the Silicon cells are laminated in sheets of EVA, which are heated and compressed to provide encapsulation. A back sheet made of layered PET and PVF is also part of each array. Development efforts are focused on maximizing the lifetime performance of the EVA. New, high clarity grades combined with anti-reflective coatings have improved efficiency by 7%. In addition, the reduction in heat absorption by the back sheet gains 0.5% efficiency in energy conversion for each 1ºC of temperature reduction.

Perhaps the best attended technical session was the keynote presentation by Dr. Michael Kessler of *Iowa State University* on *Polymers and Composites from Agricultural Oils*. Dr. Kessler reviewed free radical, cationic, and ring-opening polymerization reactions for soybean, linseed, tung, peanut and sesame oils to make thermoset polymers, composites and coatings. He noted that soybean-based polymers made with cationic polymerization could be used to create effective shape-memory materials. He also commented that the high reactivity of the unsaturated linoleic and linolenic acids that constitute 62% of soybean oils create materials with good strength and stiffness. Composites are possible with inorganic and organic fillers. Addition of 1% soy-organomodified clay nanocomposite filler can double the strength and stiffness. Possible organic fillers include spent germ, corn stover, wheat straw and switchgrass.

In the *Electrical and Electronic* session, Gregory Pawlikowski of *Tyco Electronics Corp.* presented his research on *The Effects of Moisture and Temperature on the High Frequency Dielectric Properties of Engineering Thermoplastics*. He commented that dielectric properties vary (i) lot-to-lot, (ii) with molding process settings and (iii) with environmental exposure to heat and moisture. The environmental effects were evaluated using several test vehicles for a range of materials, including PA, PPA, PBT, PCT, LCP SPS and RTV silicones at temperatures from 25ºC to 125ºC and frequencies up to 10GHz. Pawlikowski found that the dielectric constant for most tested polymers remained constant with temperature except for polyamides. Dielectric constant varied with all materials that absorb moisture, as did the dielectric loss tangent. Both values increased with moisture content – in a linear function for polyamides and in a non-linear function for most other materials.

Brian Simpson of the *Georgia Institute of Technology* presented a paper on *Manufacturing and Characterization of Nanocomposite Linear Strain Sensors* in the Composites session. Simpson dispersed inexpensive vapor-grown nano carbon fibers (VGCF) in polydimethyl siloxane to create a piezoelectric elastomeric composite. He then constructed a positioning fixture enabling characterization of impedance as a function of applied strain. Samples were created and tested across a range of 0 to 4% VGCF by weight at catalyst/monomer concentrations ranging from 1/10 to 2/10. The optimum observed performance was at 4% VGCF and a 1.5:10 formulation. While calculations suggested the range of testing was within the elastic limit of the material, some hysteresis was observed in surface resistivity. In discussion, this was attributed to fiber re-location due possibly to a lack of sizing chemistry.

Mark Lebel of *FRX Polymers* presented his paper, *Polyphosphonates – A New Family of Polymeric Flame Retardants* in the *New Technology Forum*. The new materials are inherently flame retardant – even in thin sections or films, and are available in both homo- and co-polymer forms as thermoplastics, and as a reactive oligomer for thermoset systems. The thermoplastic forms are stable to 400ºC, inherently clear, and have a very high limiting oxygen index of up to 65%. The molecule is similar to PC, with a phosphonate group replacing the carbonate; the precursor oligomer is 11% phosphorus by weight. The material is melt processable, spinnable, blowable, and hydrolytically stable. *FRX* is looking at blending the polymer into polyesters for connectors and TPUs for wire and cable. In PC or PC/ABS blends it can increase HDT by 30º to 40ºC. Its high melt strength makes it attractive as an additive for polyester fiber applications.

Complete papers from *ANTEC 2010* are available from *SPE* on a USB memory drive (www.4spe.org). *ANTEC 2011* is scheduled for May 1-5 in Boston, Massachusetts.