News
The Society of Plastics Engineers
ENGINEERING PROPERTIES
& STRUCTURE DIVISION
November 2010

Chairperson’s Report

EPSDIV Host it’s First Student Webinar

Chairperson Pierre Moulinié

Dear EPSDIV Members,

As I write this, the deadline for submitting a paper to ANTEC 2011 is just around the corner. **Hoang Pham** and **Luyi Sun**, our Technical Program Co-Chairs have already been working hard on EPSDIV’s technical program. We are grateful for the new volunteers who will help them with the program this year – but if you have never volunteered to moderate, or even offered to be among the reviewers for manuscripts, I encourage you to consider it. Though these tasks appear “behind the scenes” they are very important parts of the Technical Program every year…not to mention a great way to get to know your fellow EPSDIV members!

Our Division hosted its first Student Webinar on November 5th and we were very encouraged by the turnout for our first three speakers: **John Lau** from University of Wales, **Sayantan Roy** from University of Akron and **Erik Dunkerley** from University of Massachusetts-Lowell. This was an event whose presenters and participants spanned both borders and oceans! Are we onto something? We already have volunteers for our next session, and we hope to announce our next session soon. We express our gratitude to Bayer MaterialScience who sponsored this first event and provided the Webinar facilities. Interested in presenting, or sponsoring a future Webinar? Email either: pierre.moulinie@bayer.com or zdavid@ces.clemson.edu.

In the spirit of networking, **Dick Bopp** and **John Trent** will now chair our Intra-society efforts and will no-doubt strengthen our collaborations with Local Sections and other Divisions or Special Interest Groups.

Though a year away (and after the next joint NPE-ANTEC in Orlando), our Division will sponsor a session at next-years’ SPE-EUROTEC, which will be held November 14-15, 2011 in Barcelona, Spain. Abstract submission is already open (http://www.4spe.org/spe-eurotec-conference) and this is expected to be a great opportunity for the Global plastics R&D community to meet in Europe.

— *Pierre Moulinié*

Boston, Massachusetts

INSIDE THIS ISSUE

ANTEC 2011 Call for Papers

EPSDIV ANTEC 2011 TPCs
Luyi Sun and Hoang Pham

EPSDIV CALL FOR PAPERS ANTEC 2011, Boston, MA

Proposed Topics:

- Structure & Property Relationships in Engineering Resins and Blends
- Recent Developments in Polyolefins
- Polymer Nanocomposites
- Films and Packaging
- Fracture Mechanics of Polymers
- Biodegradable and Biomass Plastics
- Polymeric Materials from Renewable Resources/
- Medical Device Polymers
- Polymeric Materials for Environmental, Biomedical, and Bioengineering Applications
- Polymers for Energy Related Applications
- Smart Materials
- Nanotechnology in Electronic and Biological Devices
- Sustainable Plastics
- And more……

Abstract/Paper Deadline: **11/19/2010** ***Revision Deadline:*** **2/1/2011**

*Information and Online Submittal at **www.4spe.org…and select Division D26-EPSDIV !***

Contact: **Luyi Sun at luyi.sun@txstate.edu** *-OR-* **Hoang Pham at hoang.pham@dow.com**

SOCIETY OF PLASTICS ENGINEERS
The International Plastics Society

EPSDIV Keynote Speakers – ANTEC 2011

Confirmed Keynote Speakers:

- **Mr. Rob Cotton - Frito-Lay (Plastics packaging)**
- **Prof. Satish Kumar – Georgia Institute of Technology (Nano-structured materials in energy related applications)**
- **Prof. Robert Langer – MIT (Polymers for biomedical applications)**
- **Prof. Yuezhong Meng – Zhongshan University, China (Degradable polymers from carbon dioxide)**
- **Prof. Hung-Jue Sue – Texas A&M University (Scratch behavior of polymers)**
- **Prof. Brian L. Wardle – MIT (Polymer nanocomposites)**
- **Prof. Josh Wong – University of Akron (Adhesion of Polymer Nanofibers)**

More Keynote Speakers to be confirmed!

SOCIETY OF PLASTICS ENGINEERS
The International Plastics Society

2010 SCI Gordon E. Moore Medalist: Emmett Crawford

Emmett Crawford will receive the 2010 SCI Gordon E. Moore Medal for the invention of Eastman Tritan Copolyester and leadership in the development and commercialization of this new family of plastics.

Crawford’s innovations involved the development of a new monomer-2,2,4,4-tetramethyl-1,3-cyclobutanediol (TMCD). Tritan provides a higher glass-transition temperature than traditional copolyesters, which translates to superior heat resistance. Higher heat resistance allows molded products to withstand dishwasher environments without crazing, cracking, or hazing from continual exposure to high heat, humidity, and aggressive cleaning detergents and sanitizers. Tritan is manufactured without bisphenol-A.

Tritan has enjoyed remarkable early commercial success. Nine companies have chosen to enter into ingredient brand licenses with Eastman. Backed by nearly 100 patent applications filed around the world, two new manufacturing plants have already been built.

Crawford holds a B.S. in chemical engineering from North Carolina State University and a Ph.D. in Polymer Science and Engineering from the University of Massachusetts. He joined Eastman Chemical Company in 1999 as an advanced research scientist.

About the SCI Gordon E. Moore Medal

The Society of Chemical Industry (SCI) has established the SCI Gordon E. Moore Medal to recognize early-career success in innovation, as reflected both in market impact and improvement to quality of life. By highlighting extraordinary individuals and their work, SCI aims to promote public understanding of research and development in modern chemical industries, enhance the interest of students in applied chemistry by providing role models, and emphasize the role of creative research in the global economy. For more information, see SCI Gordon E. Moore Medal on the SCI Web site.

Encourage Others to Join EPSDIV,
By visiting:
www.4spe.org/membership

Financial Report
from July 1, 2010 to October 30, 2010

BALANCE as of July 1, 2010 (cash, checking, savings, investments)	**$**	**36,175.23**
INCOME		**ACTUAL**
Interest	$	244.35
SPE Rebate		355.75
ANTEC Sponsorships		4,473.00
TOTAL INCOME	$	5,073.10
EXPENSES		
Newsletter Production		528.00
Awards		253.00
TOTAL EXPENSES	$	781.00
CASH FLOW	$	4292.10
ENDING BALANCE as of October 30, 2010	**$**	**40,467.33**

-Submitted by Emmett Crawford, EPSDIV Treasurer 2009-2010

ANTEC 2011

May 1-5
Hynes Convention Center and Boston Marriott Copley Center Hotel
Boston, Massachusetts, USA

ANTEC® 2011 Plenary Speakers

Monday, May 2
11:30 a.m. - 12:30 p.m.
Dr. Young H. Kim
Samsung Advanced Institute of Technology,
Samsung Elec. Co., Ltd.

"Polymers and Plastics for the Electronics Industry."

Tuesday, May 3
11:15 a.m. - 12:15 p.m.
Thomas J. Stanley
Vice President,
Technology SABIC
Innovative Plastics

Wednesday, May 4
11:15 a.m. - 12:15 p.m.
Howard Rappaport,
Global Business Director,
Plastics Chemical Market
Associates, Inc.

Industry Dynamics Impacting the Resin Supply Chain

Councilor's Report

Summary Provided by Brian Grady

Council Summary

This summary is condensed highlights of the Council Meeting held in Southbury, CT September 24-25, 2010.

Elections
Council elected the following individuals as Society officers for the 2011-2012 term, which begins at ANTEC 2011:

President-elect – James Griffing

Senior Vice President – Jon Ratzlaff

Vice President – Vijay Boolani

Membership Growth
Membership growth continues to be the Society's single biggest imperative, and has shown modest gain in 2010. This is the first recorded gain in 5 years, and was attributed to modest improvement in the economy and the aggressive new member and membership retention campaigns.

- Overseas new membership is currently the most active segment.
- The most successful campaign has been direct mail & email.
- A Member-Get-A-Member Program has shown only limited success, but will be continued. This is an area that everyone can help with!

Budget
We are on track to have either a zero-balance budget or a net contribution at the end of 2010. Significant budget changes for 2011 include eliminating much of SPEs direct financial support for the Seminar program, and a significantly smaller expected net contribution from ANTEC relative to what was budgeted for 2010 (i.e. ANTEC was not as successful as hoped)

Bylaws & Policies

Two major bylaws were considered; for procedural reasons they will both be considered for final approval at the next Council meeting

- One Bylaw amendment will allow members to affiliate with multiple Sections, in the same way that is currently allowed for multiple Division membership.
- Another bylaw amendment will only allow proxies for Councilors if they are members of the Section/Division

New Associate Management Software

A new software system is desperately needed for SPE society. The old system is antiquated and prohibitively expensive to maintain and upgrade.
A new Avectra System has been

system.

- Initial projected start-up is planned for Oct. 1, 2010
- The initial implementation period will be approximately 60-90 days.
- Final conversion to the new system is planned for 90-120 days.

Expect to see significant changes in the webpage as well as how members and leaders can access data.

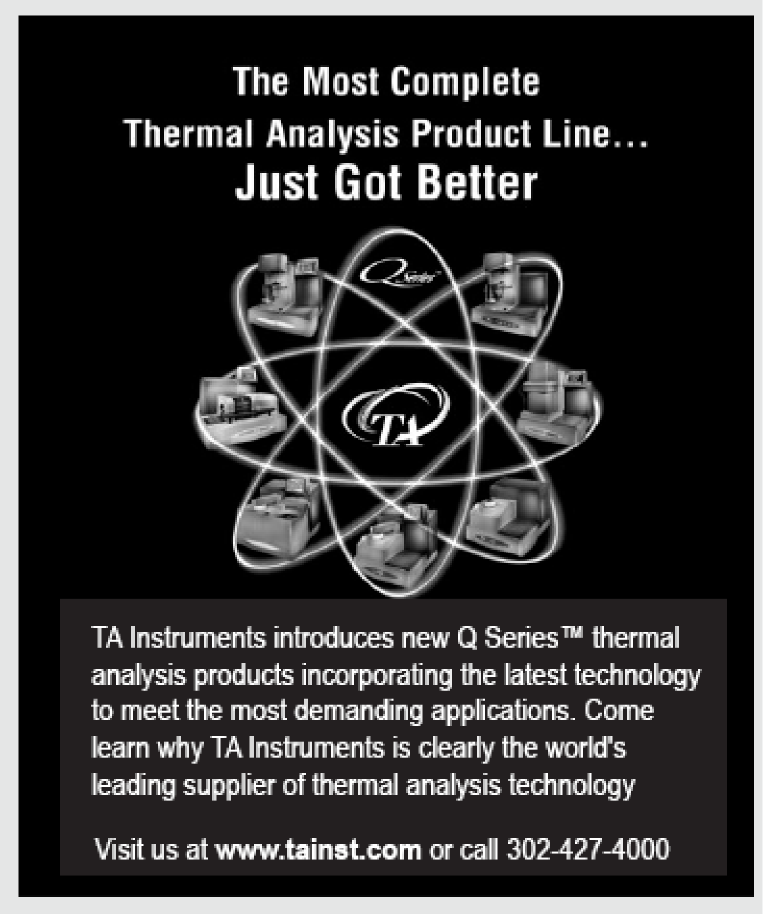
Meeting Schedule and Locations for 2011/2012 and Plans for 2011-2012 Operating Plan

President-elect Russell Broome went through the meeting schedule for 2011-2012 noting that the Fall Council meeting in 2011 will be held in conjunction with EUROTEC in Barcelona. Mr. Broome's 2011-2012 operating plan is focused on continuing the three- year plan created by Past President Andersen and President Braney.

Note: This report was generated starting with a similar report prepared by Tom Morton for the Oklahoma Section.

The John O'Toole Award: Best Student Paper

The John O'Toole Award sponsored by Honeywell Specialty Materials was awarded to **Matthew Bernasconi** (on left in photograph below) from the University of Massachusetts-Lowell. The award was presented by Pierre Moulinié. His paper is featured at the end of our newsletter.



Cleveland SPE Calendar of Events for 2010-2011

September 21, SPE Planning for the Future, Ken Braney, SPE International President, Cleveland, OH.

October 18, Global Plastics Opportunities for Akron and NEO, Sam DeShazior, Akron Mayor's Office, Akron, OH

November 8, Brett Joslyn, Presentation and Tour of Joslyn Themoforming, Macedonia, OH

December 10, Christmas Social, Tour of new Bio Innovation Building, Akron OH

January 24, Global Plastics Overview, Joseph Gingo, CEO A.Schulman, Akron OH

February 21, Tour of Diebold, Canton, OH

March 21, Converting Recycled Polymer to Synthetic Crude Oil and Gas, Jim Garrett, Vadxx Energy LLC, Akron OH

April 11, Fabrication of Air and Fluid Handling Equipment for Automotive Applications, DLH Industries, Canton OH

May 9, Awards Night, Cleveland OH

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Barrier Properties of Amorphous and Semi-Crystalline Polyamide Nanocomposite Films

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Abstract

This study investigates the effect of crystallinity and nanoclay content on the barrier properties of polyamides of similar polarity, one amorphous the other semi-crystalline. The polyamide resins were compounded with commercial alkylammonium montmorillonite nanoclay to achieve volume percent inorganic contents of 0.125%, 0.25%, 0.5%, and 1%, as confirmed by thermogravimetric analysis (TGA). All formulations were then extruded through a 6 inch cast film die to yield transparent sheets which were then tested for oxygen and water vapor permeability, with the crystallinity of the semi-crystalline materials measured via differential scanning calorimetry (DSC).

Introduction

Nanocomposites are a relatively new class of composites that are particle-filled polymers for which at least one dimension of the dispersed particles is less than 100 nm [1]. There are three types of nanocomposites, each depending on how many dimensions of the dispersed nanoparticles are in the nanometer range [1]. When all three dimensions of a nanoparticle are on the order of nanometers, it may be classified as a 3-D or spherical nanofiller (e.g. carbon black, fumed silica). When two dimensions are on the nanometer scale, it may be classified as a 2-D or rod-like nanofiller (e.g. carbon nanotubes, cellulose nanowhiskers). When only one dimension is in the nanometer scale, it may be classified as a 1-D or plate-like nanofiller (e.g. nanoclays, exfoliated graphite).

Focusing on the nanoclay systems and considering the miscibility of the layered silicate nanoclay and a polymer matrix, three basic dispersion states may be obtained [1]. A phase separated composite is obtained when the polymer chains are unable to intercalate between the silicate sheets and the nanoclay layers exist in stacks measuring greater than 100 nm, giving rise to properties typical of traditional microcomposites [1]. An intercalated structure in which single or multiple polymer chains are intercalated (sandwiched) between the silicate layers gives a well ordered multilayer morphology of alternating polymeric and inorganic layers [1]. When the silicate layers are completely and uniformly dispersed in a polymer matrix, an exfoliated structure is obtained [1]. There are various methods to producing a well dispersed nanocomposite but melt blending has been proven to be one of the more attractive and preferred methods to produce nanocomposites for commercial use [2]. The chemical compatibility between the polymer and the modified nanoparticle is the primary driver when attempting to prepare an optimized (i.e. dispersed) nanocomposite. The mechanical work provided by processing will accelerate the realization of thermodynamically favorable dispersion, but it will not make up for a potential lack of compatibility [2].

Layered silicate nanocomposites provide substantial improvements to thermo-mechanical properties at very low filler content (5 wt% or less) compared to conventional composites [1,2]. These improvements may allow polymers that otherwise lack in thermal, mechanical, or barrier properties to be used in new roles, for instance in the automotive or food packaging industry. Likewise, the incineration of polymer nanoclay composites produces minimal ash and the limited filler content makes them compatible with the recycling process [1].

This study concentrates on the barrier properties of an amorphous polyamide (Grilamid® TR90) and a semi-crystalline polyamide (Grilamid® L20G), both of which were compounded with an organically modified montmorillonite clay. These two polyamides were chosen for this study because they both have similar polarity and the amide linkages present in both interact favorably with the individual nanoclay layers (~1 nm thick, ~75-150 nm across) and encourage dispersion.

One objective of this project was to achieve similar levels of nanoclay dispersion in both polyamide matrices and to compare changes in barrier properties resulting from the presence of the nanoclay. A second objective was to deconvolute the effects of changes in crystalline morphology and the presence of the nanoclay itself in determining these properties.

Experimental

Materials

The two polyamide resins used in this study were Grilamid® TR90 (amorphous) and Grilamid® L20G (semi-crystalline), both manufactured by EMS-Grivory.

TR90 was a polyamide-12 based cycloaliphatic copolyamide (structure shown in Figure 1) with a glass transition temperature of ~155°C, a density of 1.00 g/cm^3, and was dried to a moisture content of less than 0.08% before processing [5]. L20G was a general purpose polyamide-12, with a glass transition temperature of ~43°C, a melting point of 178°C, a density of 1.01 g/cm^3, and was dried to a moisture content of less than 0.10% before processing [6]. The nanoclay used was a commercial bis(2-hydroxyethyl) methyl tallow ammonium modified montmorillonite (Cloisite® 30B) provided by Southern Clay with a density of 1.98 g/cm^3 and an organic content of ~30 wt% based on weight loss on ignition [7]. One individual layer of the nanoclay measures about 1 nm thick and 75-150 nm across (high aspect ratio) but in natural form it exists in clusters (low aspect ratio).

Processing

The nanocomposite resins were compounded using a high-shear profile intermeshing 27 mm co-rotating twin screw extruder (Leistritz, Model No: ZSE 27HP-40D) with a L/D ratio of 40:1 to achieve volume percent inorganic content of 0.125%, 0.25%, 0.5%, and 1% [4]. First, the dry blends were made by vigorously shaking the required amounts of resin and nanoclay in large sealed bags [4]. A volumetric feeder was used to feed the dry blend to the twin screw extruder [4]. Since polyamide is a very moisture sensitive material, a vent zone was present at the center of the extruder barrel to release any moisture or gas [4]. A vacuum assisted vent zone (200 mbar below atmospheric pressure) at the end of the extruder barrel was used for the same purpose [4]. A water bath at room temperature was used for cooling the hot melt strands exiting the die, which was pelletized using a pelletizer (Reduction Engineering, Model No: 604) [4]. The processing conditions for melt blending are given in Table 1.

Resin drying was performed in an IMS oven (Model No. 133394) with a Novotec dessicant drier (Model No. MD-15) and a Dri Air hopper drier (Hopper Model No. RH15, Drier Model No. ARID-X 10B). The TR90 virgin and nanocomposite resins were dried for 16-25 hours at an oven temperature of 175°F and a dessicant temperature of 180°F. The L20G virgin and nanocomposite resins were dried for 15-26 hours at the same settings. Moisture analysis was done on the resins before sealing in an aluminum bag using a Mitsubishi Karl Fischer Moisture Meter (CA-100) with vaporizer (VA-100) to ensure moisture content was within allowable limits.

Cast film samples were produced with a single screw ThermoHaake Polylab System (RC300P) with Rheomax 254, a Dri Air Industries hopper drier, a Thermo Neslab RTE 7 feed throat cooler, a 6 inch cast film die, a ThermoHaake TPI Tape Postex chill roll set up, and a ThermoHaake cooler for the chill rolls (C35P). The chill roll temperature was increased from 30 °C to 60°C when processing the L20G nanocomposites to ensure good film quality. The processing conditions for cast film extrusion are given in Table 2.

Characterization Methods

Thermogravimetric analysis (TGA) was performed using a TA Instruments Q50-TGA with a ramp of 20°C/min in a platinum pan up to 850°C in air. Oxygen transmission rates were measured using an Illinios Instruments Oxygen Permeation Analyzer (OPA) Model 8001 at 23.0°C and 0% RH in accordance with ASTM D3985-05. Water vapor transmission rates were measured using a Mocon Permatran 3/31 at 37.8°C and 90% RH in accordance with ASTM F 1249-06. An average thickness of each sample was calculated using five measurements made with a digital micrometer to convert transmission rates to permeation rates (cc·mil/m^2·day). Prior to testing, oxygen permeation samples were conditioned in a 0% RH chamber and water vapor permeation samples were conditioned in a 90% RH chamber for seven days and then sealed in zip lock bags. Two samples were tested for each formulation.

Results

Table 3 summarizes the samples studied here, as well as the results of nanoclay content measurements made via TGA [4]. The actual nanoclay concentrations are within ~10% of the desired values in all cases.

The TR90/clay nanocomposite was previously reported to display partial exfoliation and partial intercalation by small angle x-ray scattering (SAXS) and wide angle x-ray scattering (WAXS) [4]. Hocine et al. reported similar states of dispersion in their polyamide-12 / Cloisite 30B nanocomposites, where a low screw speed (N=32 rpm) yielded an intercalated state and a high screw speed (N=100 rpm) yielded a partially exfoliated state [8], supporting the realization of significant dispersion in our systems as well (processed at 150 rpm).

Figure 2 shows the oxygen permeation rates for each set of materials. Samples based on the semi-crystalline polyamide (L20G) display ~60% lower oxygen permeability across the board versus the amorphous polyamide (TR90) samples due to the presence of crystallinity in the former. The oxygen permeation rate also decreased with increasing amounts of the nanoclay in both sets of nanocomposites. The L20G/1%-C30B samples showed a 42% decrease in oxygen permeation compared to the virgin L20G. The TR90/1%-C30B samples showed a 32% decrease in oxygen permeation compared to the virgin TR90.

The water vapor permeation rate of the TR90 samples shows the expected decreasing trend with increasing amounts of nanoclay, as shown in Figure 3. The amorphous TR90/1%-C30B samples showed a decrease in water vapor permeation rate by 27% compared to the TR90 virgin samples. In comparison, the L20G samples showed the same trend up to 0.25% nanoclay loading, with a decrease in water vapor permeation of 39% compared to the L20G virgin samples. Beyond this point, however, the water vapor permeability of the L20G samples increased at nanoclay loadings of 0.5% and 1%.

Discussion

It is well known that crystalline polymers have a higher resistance to permeation of gasses and liquids than amorphous polymers due to the reduction in free volume from the tightly packed crystal structures. With that in mind, the fact that the L20G samples display better oxygen barrier than the TR90 sample across the board is to be expected. Likewise, the addition of nanoclay is expected to further improve barrier properties in general, as it is observed to do in the case of oxygen permeation and to at least some extent in the case of water vapor permeation as well. However, the more complex trend in the water vapor permeation data of the semi-crystalline nanocomposites in particular points to additional complications beyond these simple expectations, and makes it necessary to consider the effects of the nanoparticles on the semi-crystalline morphology.

Nanoparticles are known to act as nucleating agents, increasing the number of crystallites while decreasing their average size. At the same time, sufficient quantities of nanoparticles can actually inhibit crystallite growth. The water vapor permeation trend observed in Figure 3 may be consistent with this argument, given that the L20G barrier properties degrade above a critical nanoclay concentration of 0.25 vol% inorganic. That said, the fact that such a trend was not observed in the oxygen permeation results indicates that this cannot be the sole explanation for the data.

The most likely complicating factor here is the specific interaction between water and the nanoclay. Even in its modified state, Cloisite 30B is indicated by its manufacturer to contain up to 2% moisture by weight prior to drying [7], indicating definite potential for interactions with water. The permeation path of a molecule through a polymer / nanoclay nanocomposite increases in length with increasing amounts of nanoclay due to increasing tortuosity. With that said, if the nanoclay has some hydrophilicity and is therefore capable of preferential interactions with water molecules, at higher nanoclay loadings of 0.5 and 1 vol% inorganic it may be that the semi-crystalline polyamide, being less prone to moisture uptake in the first place, is more detrimentally affected by the presence of water at the nanoclay interface, contributing to the observed decrease in water vapor barrier.

Conclusions

The importance of crystallinity in enhancing barrier properties is well-known, and is reaffirmed here, with the semi-crystalline polyamide-12 displaying superior barrier propreties to the amorphous polyamide-12 based cycloaliphatic copolymer. The addition of nanoclay significantly reduces oxygen permeation in both systems in a more or less linear fashion. The water vapor permeation data is more complicated. In the amorphous polyamide a decreasing trend is observed, but in the semi-crystalline system this trend was seen only up to 0.25% nanoclay, beyond which water vapor barrier was actually degraded with increasing nanoclay content. This may be a result of nanoclay-induced changes in morphology of the crystalline phase, but specific interactions with water must play a role as well, or it is not possible to explain the differences between the oxygen and water vapor permeation results. It is posited that at higher nanoclay concentrations the hydrophilicity of the nanoclay may eventually compromise the tendency of the semi-crystalline polyamide to show reduced moisture uptake versus the amorphous polyamide. These findings may have important implications for the design of high-barrier nanocomposites for packaging applications.

Acknowledgements

We are indebted to Dr. Jo Ann Ratto, Chris Thellen, Sarah Schirmer, Scott Winroth, and the AMET team at the U.S. Army Natick Soldier Research Development and Engineering Center for access to the equipment used to process the films, for expert assistance and advice in polymer processing, and for water vapor permeation measurements. We would also like to thank Dr. Earl Ada for his support with oxygen permeation testing and the faculty and staff of the Plastics Engineering Department for their general support.

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Table 1. Processing conditions for melt blending

Extruder Parameters	Grilamid TR90	Grilamid L20G
Zone 1 (feed)	200 °C	165 °C
Zone 2	240 °C	180 °C
Zone 3	240 °C	210 °C
Zone 4 (vent zone)	241 °C	220 °C
Zone 5	240 °C	220 °C
Zone 6	245 °C	220 °C
Zone 7	245 °C	220 °C
Zone 8	260 °C	220 °C
Zone 9 (vacuum assisted vent)	260 °C	220 °C
Zone 10	260 °C	220 °C
Zone 11 (die)	260 °C	220 °C
Melt Temp	255-257 °C	220 °C
Melt Pressure	6.8-7.6 MPa	5.1-5.7 MPa
Screw Speed	151-152 rpm	150 rpm
Torque	72.5-77.2 Nm	54.6-68.9 Nm

Table 2. Processing conditions for cast film extrusion

Extruder Parameters	Grilamid TR90	Grilamid L20G
Zone 1 (feed)	30 °C	30 °C
Zone 2	240 °C	180 °C
Zone 3	245 °C	210 °C
Zone 4	270 °C	230 °C
Zone 5 (die)	260 °C	220 °C
Melt Temp (die)	262-263 °C	223-224 °C
Melt Temp (exit)	239-240 °C	204-205 °C
Melt Pressure	1.6-2 MPa	0.2-0.8 MPa
Screw Speed	20 rpm	20 rpm
Torque	40-62 Nm	74-93 Nm
Chill Roll Temp	30 °C	60 °C (30 °C for virgin polymer)

Table 3. TGA data of TR90 and L20G Nanocomposite formulations, pure Cloisite 30B, and virgin resins

Material	Actual Inorganic Content (vol%)	Actual Organoclay Content (wt%)	Material	Actual Inorganic Content (vol%)	Actual Organoclay Content (wt%)
TR90	0.17 ± 0.04	-	L20G	0.27 ± 0.02	-
Cloisite 30B	69.72	-	Cloisite 30B	69.72	-
TR90/C30B-0.125	0.10 ± 0.02	0.40 ± 0.07	L20G/C30B-0.125	0.11 ± 0.01	0.41 ± 0.06
TR90/C30B-0.25	0.22 ± 0.01	0.86 ± 0.04	L20G/C30B-0.25	0.23 ± 0.01	0.87 ± 0.06
TR90/C30B-0.5	0.50 ± 0.02	1.90 ± 0.08	L20G/C30B-0.5	0.48 ± 0.02	1.82 ± 0.04
TR90/C30B-1	0.91 ± 0.02	3.44 ± 0.07	L20G/C30B-1	0.96 ± 0.01	3.60 ± 0.01

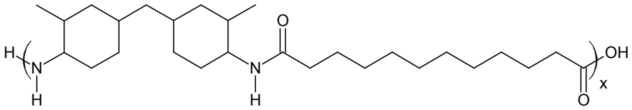

Figure 1. Structure of Grilamid TR90, an amorphous polyamide-12 based cycloaliphatic copolyamide

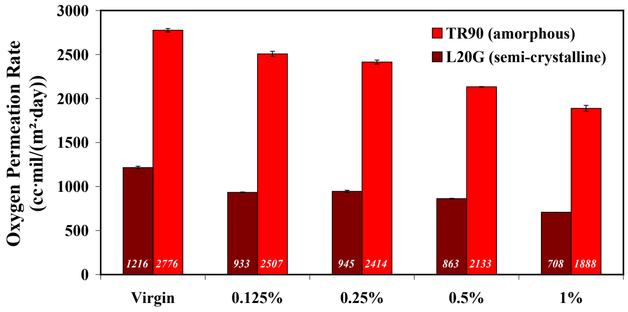

Figure 2. Oxygen permeation rate data for amorphous (TR90) and semi-crystalline (L20G) polyamide nanocomposites

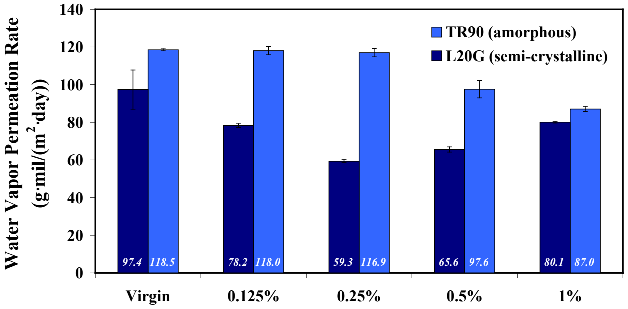

Figure 3. Water vapor permeation rate data for amorphous (TR90) and semi-crystalline (L20G) polyamide nanocomposites