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MICRO-TEXTURED BORON NITRIDE NANOPLATELET MODIFIED POLYETHYLENE FILMS

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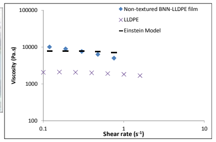
ABSTRACT

Linear low density polyethylene (LLDPE) micro-textured films filled with boron nitride nanoplatelets (BNN) were produced by continuous melt extrusion. Nanoparticles displayed a significant extent of dispersion inside the matrix. The addition of BNN led to more than 10-fold increase of the in-plane thermal conductivity (TC) of the nanocomposite (7.7 W/m.K *vs* 0.3 W/m.K for pure LLDPE), and 1.3-fold increase of through thickness TC. To increase the surface area available for convective heat transfer, micro-textured films (T-BNN) were produced from a micro-patterned die. Nanoplatelets were aligned parallel to the film machine direction. Film stiffness and tensile strength are comparable to the base LLDPE. Textures and BNN lubricant property helped to decrease the coefficient of friction.

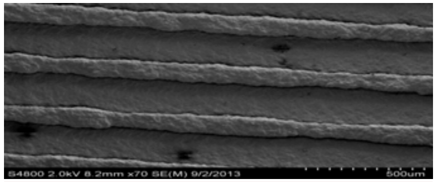
PROCESSING


Twin screw extruder


Cross-section of the micro-textured die



Einstein Model: $\eta_c/\eta_p=1+1.25\phi+A\,\phi^2$



SEM micrograph of lateral surface of microtextured BNN-PE film

- BNN and LLDPE melts can be melt extruded and drawn into thin micro-textured films by a continuous extrusion.

MECHANICAL PROPERTIES

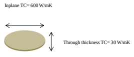
Films	Tensile Modulus (GPa)	Tensile Strength (MPa)	Strain to Failure (%)
Textured-BNN	0.7 ± 0.2	14.7 ± 1.2	2.4 ± 0.6
Non-textured BNN	1.3 ± 0. 2	23.1 ± 4.4	2.6 ± 0.2
Base LLDPE	0.4 ± 0.0	23.4 ± 0.4	687.0 ± 21.6

- Tensile properties of the produced nanocomposite films were still comparable to those of base LLDPE at loading of 30 vol%


Bended textured-BNN film

INTRODUCTION

- There is a dramatic increase in heat generated per unit area as electronic devices become miniaturized
- LLDPE has been attractive due to its light weight, ease of processability, excellent flexibility and low cost; however, it is thermally insulating
- One approach to increase the thermal conductivity of a polymer is to introduce high-thermal-conductivity fillers. Another approach for accelerating heat dissipation is to increase the surface area of the heat exchanger/material
- BNN has a high thermal conductivity and electrical resistivity, low thermal expansion coefficient, and are nontoxic, nonreactive, thermally and chemically stable
- Thus, BNN-based composite materials are of value for thermal management in microelectronics packaging

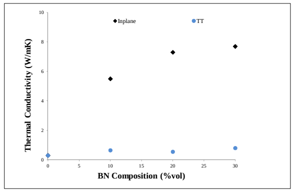


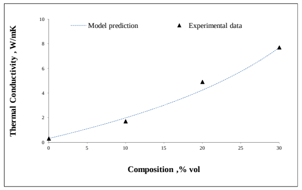
OBJECTIVES

- Continuous melt extrusion of micro-textured LLDPE nanocomposite films
- Enhancement of the transport properties

THERMAL CONDUCTIVITY

Sample	Inplane Thermal Conductivity (W/m.K)	Through thickness Thermal Conductivity (W/m.K)
Textured BNN-LLDPE	11.5±5.2	1.7±0.1
Non-textured BNN-LLDPE	7.7±1.1	0.8±0.1
Base LLDPE	0.3±0.1	0.3±0.1





Lewis-Nielsen Model: $K_c= K_m(1+Ab\phi)/(1-B\psi\phi)$
Where $B= (\lambda-1)/(\lambda+1)$, $\lambda= K_f/K_m$, $\psi =1+ \phi(1-\phi_m)/\phi_m^2$

- The model prediction agreed well with the experimental in-plane results
- BN increased the through-plane and in-plane thermal conductivity of the polymer from 0.3 W/m.K for LLDPE to 0.8 W/m. K and 7.7 W/m.K for the composites containing 30 vol % BN (50 wt%), respectively
- In-plane TC is approximately 8 times higher than through-thickness TC, which is consistent with the in-plane orientation of BNN

TRIBOLOGICAL PROPERTIES

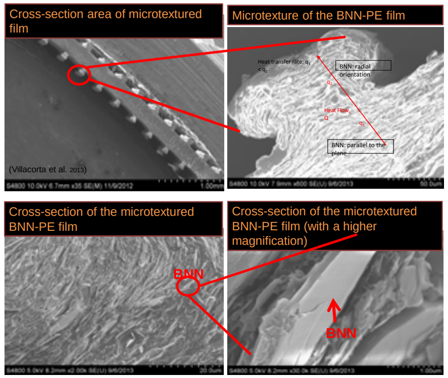
Substrate	COF
LLDPE	0.29±0.01
NBN30	0.15±0.02
TBN30	0.11±0.02

- Adding 30 vol % BNN to the LLDPE resulted in about 50% decrease in coefficient of friction (COF)
- Textures helped to decrease COF

EXPERIMENTAL

- The compounding of BNN into LLDPE matrix and melt-extrusion of composite films was conducted in a DSM micro compounder through a micro-machined trapezoidal textured die (courtesy Hoowaki, LLC) attached to DSM micro-scale twin screw extruder
- The microstructure was studied using S4800 scanning electron microscope
- Tensile and tribological properties of the films were measured on ATS 900 tensile testing machine according to ASTM D882 and modified ASTM D-1894, respectively
- 1 cm x 1 cm square samples were obtained for through-thickness thermal conductivity and 25 mm diameter disks for in-plane measurements. Laser flash analysis were conducted on samples by using Netzch LFA 447

MICROSTRUCTURE



- Micro-textures of the resulting films conformed well to the shape of the die micro-pattern. They displayed a significant extent of dispersion
- BNN aligned parallel to the film direction due to shear and extensional stresses encountered during extrusion and film drawing
- The orientation of nanoplatelets within the fins is in the radial direction due to the shear stress inside the die cavity

FUTURE WORK

- Heat transfer modeling trough micro-textured films
- Investigation the hybrid effect of BNN and GNP on thermal and electrical conductivity of microtextured LLDPE composite films microtextured LLDPE composite films

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