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Nanoclay/Polymer Composites For Improved Physical Properties

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Outline

- Future soldier requirements
- Nanoclay composites for improved functionality in a lightweight product
- Experimental:
 - Sample Preparation
 - Composite Characterization
 - Physical Properties
 - Flammability
- Conclusions and Future Work

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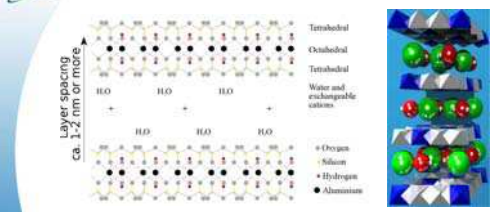
Soldier Systems Requirements

- A system that integrates all that s/he wears/carries.
- Future requirement to:
 - carry more,
 - utilize more technology,
 - withstand more extreme environments.
- Multifunctional materials:
 - lightweight,
 - enhance stealth,
 - ballistic protection,
 - CB resistance,
 - Power,
 - Durability,
 - Comfort.



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Background – Clays



- Sheet-structure interspersed with water and cation layers
 - e.g., $(\frac{1}{2}\text{Na,Ca})_0.7(\text{Al}_{1.3}\text{Mg}_{0.7})(\text{Si}_8\text{O}_{20})(\text{OH})_4 \cdot n\text{H}_2\text{O}$
- Layers swell (Smectite Clays)
 - Water absorption, cation exchange

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Background – Clay Nanocomposites

microcomposite (conventional) **intercalated** **exfoliated (nanocomposite)**

- Conventional composite: 20-50% loading
- Nanocomposite: 2-7% loading

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Commercial Uses – Current

Main areas of use

- Automotive, Packaging

Improved properties

- Mechanical:
 - Dimensional stability
 - Tensile strength, Modulus, Tear strength
- Barrier:
 - Improved O₂, CO₂, VOC, H₂O(g) barrier
- Flame retardancy:
 - Dripping and charring
- Other:
 - Surface – smooth, hard
 - UV-stability
 - Rheology

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Sample Preparation (1)

Polymer	Clay	Conc. (% wt)
Polypropylene (PP) (Profax 1274)	None	0
	Natural	2
	(Cloisite 15A)	4
	Compatibilized Natural (Cloisite + Low MW PP)	2
	4	
Polyamide-6 (PA) (a.k.a. Nylon 6) (PA1015B)	Synthetic (Perkalite F100)	2
	4	
	None	0
	Natural	2
	(Cloisite 15A)	4
	Synthetic (Lucentite SWN)	2
	4	
	Synthetic (Somasis ME100)	2
	4	
	4	

Compare natural vs. compatibilized

Compare aspect ratio 50 vs. 6000

Compatibilization

- To make a clay more oleophilic:
 - Reaction with short chain polypropylenes.

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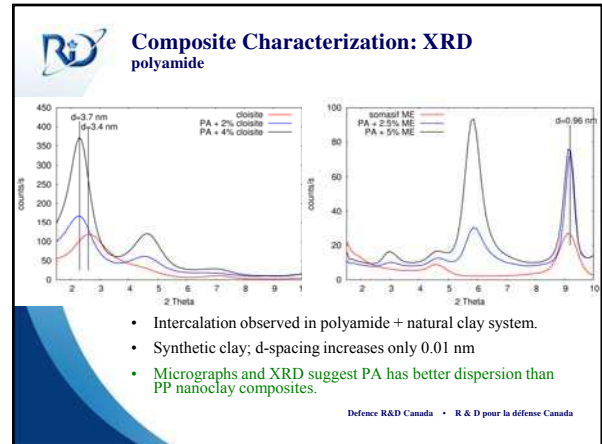
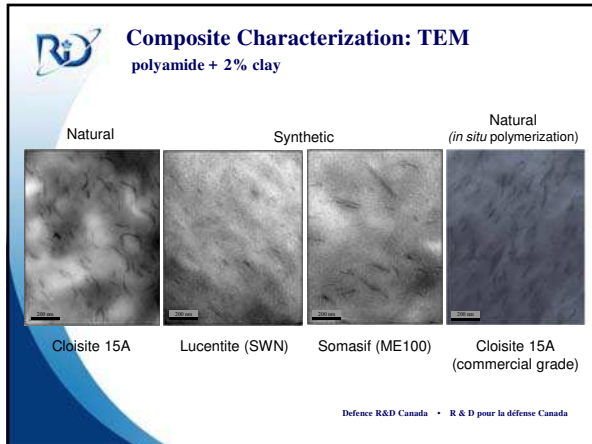
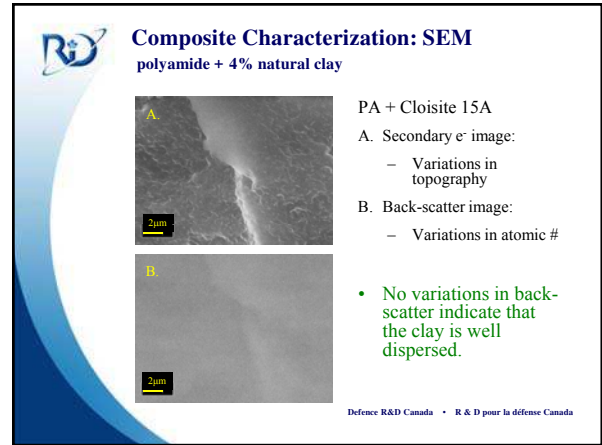
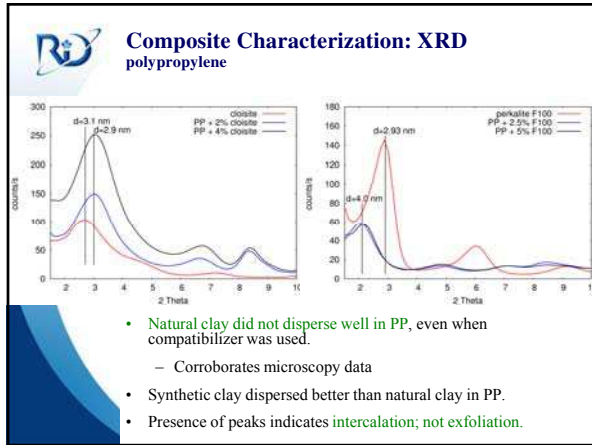
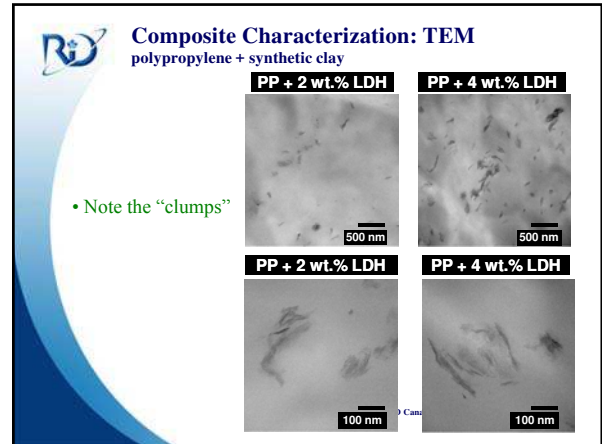
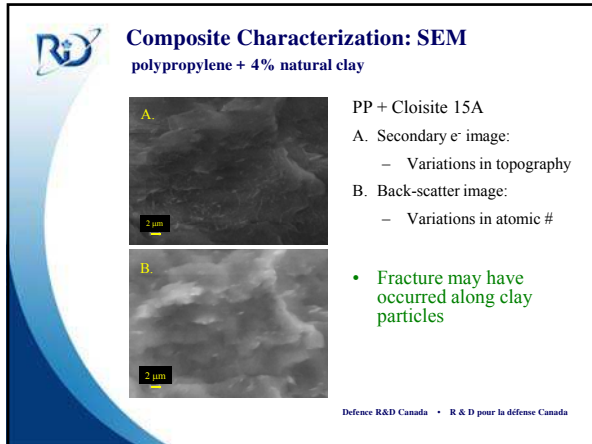
Sample Preparation (2)

- Sheets were extrusion cast.
- Dogbones were injection molded.

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Nanoclay Composite Characterization

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Nanoclay Composite Physical Properties

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Composite Physical Properties: Thermal Gravimetric Analysis

- decomposition temperature:
 - PP1 (neat) = 456°C
 - PP + clay = 465°C } +9°C
 - PP2 (neat) = 463°C
 - PP + syn. clay = 460°C } -3°C
 - PA (plain) = 441°C
 - PA + clay = 410°C } -31°C

Composite Physical Properties: Differential Scanning Calorimetry

- PP:
 - No significant change when the amount of uncom. nat. clay was varied in the composites.
 - When 4% comp. nat. clay was added, crystallinity decreased and crystallization temperature (Tc) decreased 6°C.
 - When synthetic clay was added, crystallinity didn't change, but Tc increased 7°C.
- PA
 - No significant change in melt or crystallization temperatures with the addition of clay.

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Composite Physical Properties: DMA

- General trend is an increase in modulus with an increase in clay loading.
- PP + comp. nat. clay composites tend to be stiffer than their uncom. counterparts.

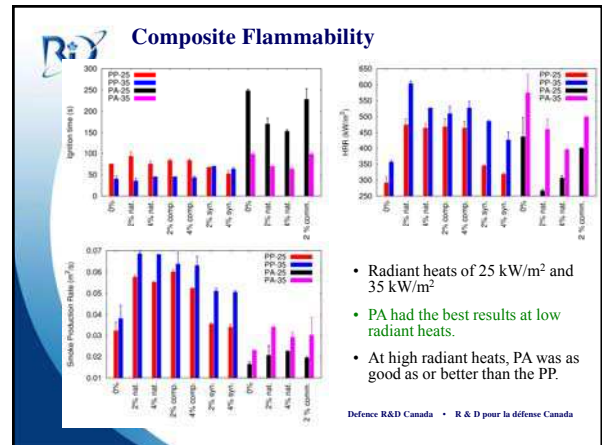
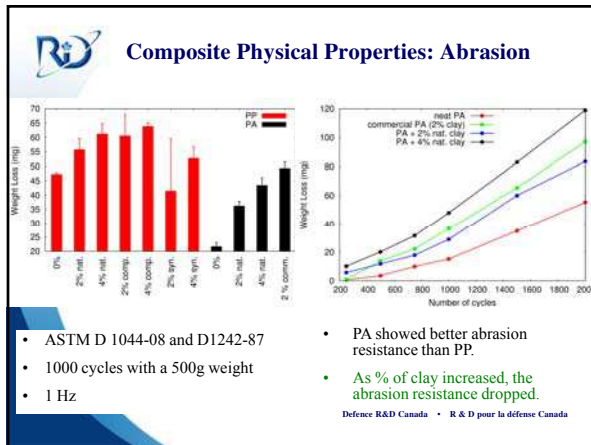
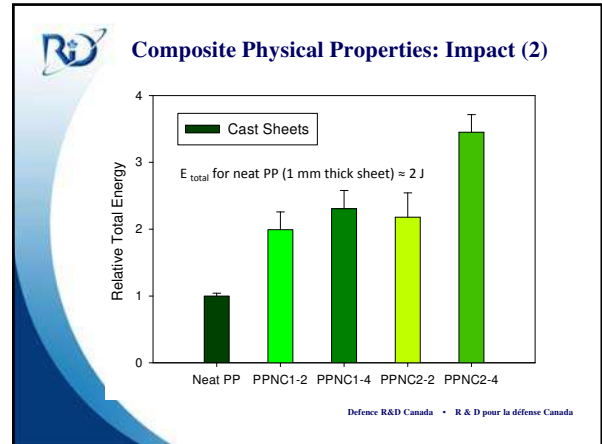
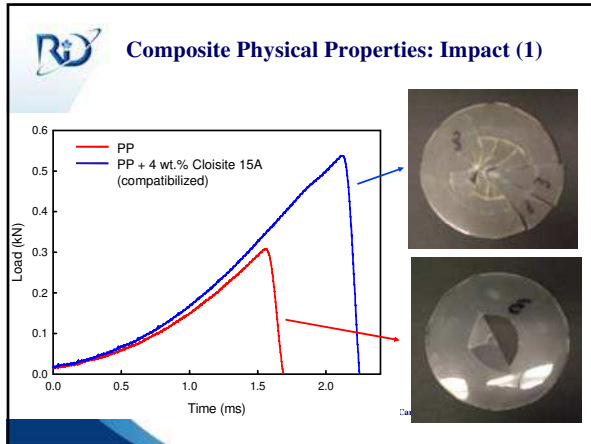
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Composite Physical Properties: Tensile

- Addition of clay increased both the max tensile stress and the necking strength.
- Clay reduced ductility.
- There was a strain rate dependence.

Composite Physical Properties: Tensile(2)

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Conclusions – Nanoclay Composites

- Nanocomposites using natural and synthetic clays in polypropylene and polyamide-6 matrices were synthesized.
 - Polyamide dispersed the clays best.
 - Ideally polyamide nanoclay composites are made by intercalating the caprolactam monomer into the clay and polymerizing *in situ*.
- The physical properties of the nanocomposites showed minor improvements over the parent polymers.
 - Dispersion played a role.

Conclusions – Military Applications

- What do these results mean for potential textiles?
 - Processing plays an important role in realizing the improved properties of nanoclay composites.
 - Polyamides (a.k.a., nylon) appear to be the better matrix for nanoclay composites.
 - More basic research is needed before these composites can be transitioned to viable technology for military applications.
 - Nanoclay composites TRL = 2-3

R&D Future Work

- Move forward with polyamide
 - Investigate *in situ* polymerization
- Durability testing (UV, humidity, temperature)
- CB resistance
- Microfibre and nanofibre formation/testing
 - Textile testing, comparison with “bulk” nanocomposite properties.

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