



# Polymer Blends and Nanocomposites For Real-World Applications

## Professor Wakabayashi's Research Interest

P. J. Hubert and Kat Wakabayashi ([kw025@bucknell.edu](mailto:kw025@bucknell.edu)), Chemical Engineering

### Polymer Hybrids on the Nanoscale

#### Nanotechnology Applied to Material Improvements:

Dispersing nanometer ( $10^{-9}$  m) scale particles in a polymer matrix can improve:

- Mechanical Properties (tensile strength, stiffness, toughness)
- Thermal Properties (expansion, conductivity, stability)
- Electrical Conductivity
- Chemical Resistance / Gas barrier
- Flame Retardance
- ... and many others!



#### Applications

##### Transportation



##### Sports Equipment



##### Packaging



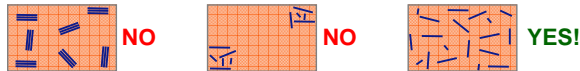
##### Specialized Apparel



##### Electrical



### Challenges



#### Ideal Morphology of Blends and Nanocomposites

To achieve enhanced material properties, the nanofillers must be:

- Well-separated ("exfoliated", "intercalated") from each other
- Well-dispersed throughout the polymer matrix
- The above morphology must be stable at molding conditions (*i.e.* high temperature)

#### Fabrication Techniques and Methods:

Currently, there are not well-established techniques to effectively fabricate:

- a wide range of polymer blends and nanocomposites (it's just *that hard!*)
- polymer hybrids on an industrial/ commercial scale (not *grams*, but *tons*)

### Materials

#### Polymer Matrix

- Polyethylene (LDPE, HDPE, LLDPE, UHMWPE) [PE] [Lehigh Valley]
- Polypropylene (PP) [PP] [Lehigh Valley]
- Polystyrene (PS) [PS] [Ferro]
- Polyethylene Terephthalate (PETE) [PETE] [Coca-Cola]
- PolyLactic Acid (PLA)
- PolyCaprolactone (PCL)

#### Nanofiller

- Nanosilica [LCE, Finland] [Furukawa]
- Gold Nanoparticles [NRL] [Toyota]
- Graphite [Wikimedia] [Asbury]
- Carbon Nanotubes [Wikimedia] [Theodore Gray]
- Montmorillonite (Clay) [Chevron] [Southern Clay] [Triganic]

### Fabrication/ Processing Tools

(Blue indicates in-house facilities)

#### Laboratory Scale (Scientific)

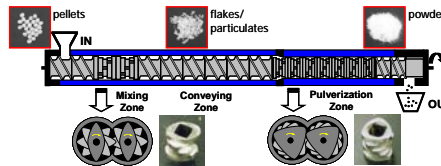
- Batch Mixer (melt-compounding) *Mixing of materials in the molten state*
- Ball-Mill / Cryo-Mill (solid-state compounding) *Processing of materials below melting temperatures*

#### Industrially Applicable Scale (Commercial)

- Single-Screw Extruder (melt-extrusion) *Continuous melting and mixing of polymer hybrids*
- Twin-Screw Extruder (melt-extrusion, high shear) *More intense mixing action than single-screw*

#### Solid-State Shear Pulverization (solid-state pulverization)

High compressive & shear forces in the solid state (below  $T_{melt}$ ,  $T_{glass}$ )



Lead to:

- exfoliation
- chain scission
- intimate mixing
- ultimate dispersion

### Characterization Methods

(Blue indicates in-house facilities)

#### Structural Characterization

- Gel Permeation Chromatography (*molecular weight*)
- Optical Microscope (*macrostructure*)
- Scanning Electron Microscope (*micron-scale*)
- Transmission Electron Microscope (*submicron-scale*)
- X-Ray Diffraction (*nano- and Angstrom-scale*)
- 2-D Small- and Wide-Angle X-ray Scattering (*filler orientation*)

#### Thermal Behavior Probing

- Differential Scanning Calorimetry ( $T_{melt}$ ,  $T_{glass}$ ,  $T_{crystallization}$ )
- Thermogravimetric Analysis ( $T_{degradation}$ , *filler content*)

#### Mechanical Property Measurement

- Uniaxial Tensile and Compression Test (*modulus*)
- Three-point Bend Test (*flexural modulus*)
- Impact Testing (*impact strength*)
- Hardness Test (*hardness*)
- Dynamic Mechanical Analysis (*rubbery/ glassy*)

#### Other Physical Property Characterization

- Impedance Spectroscopy (*electrical conductivity*)
- Gas/ Liquid Permeation (*barrier properties*)
- Compost Testing (*biodegradability*)
- Scuff Test (*filler permanence*)

### References

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