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# *Multilayer Coextrusion Processing for Micro/Nano-Layered Devices*

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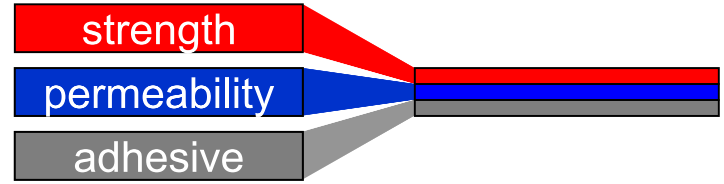
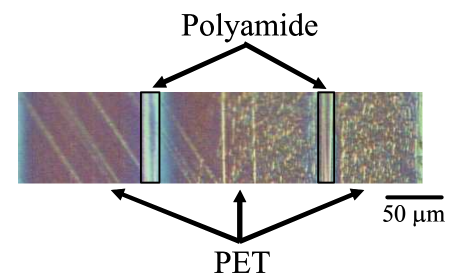
# *Multilayered Materials Applications*

Multilayered coextrusion combines multiple polymers in a layered structure to produce properties not found in a single polymer




**Current Applications**

- Packaging (bottles, bags, etc.)
- Protection coatings
- Barrier properties



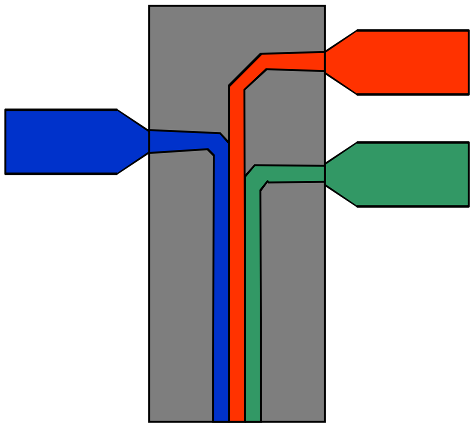

**Emerging Technologies**

- Display devices
- Sensors
- Optical devices
- Barrier materials
- Membranes
- Microcomposites
- Armor applications
- Responsive clothing

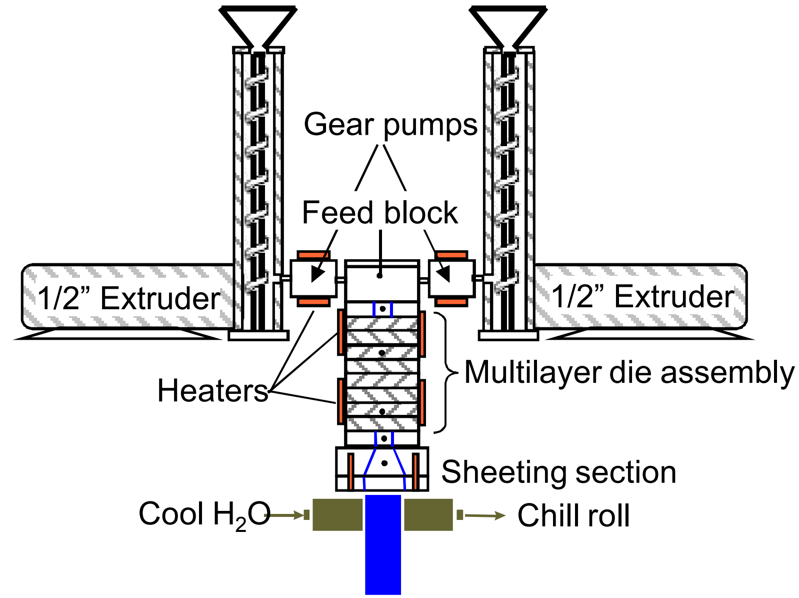
*Cargotech Airliner®*
*maintains temperature during extended transport*

# *Multilayer Coextrusion Processing*

*Multiple Extruders*



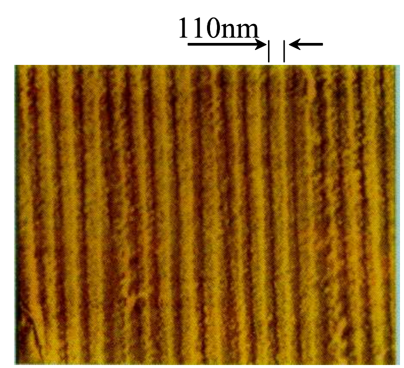
*Multiplication Die*




- Multilayer die assembly increases the number of layers within the same cross-section
  - Decreases layer thickness
- Gear pumps provide precise flow rate control
- Sheeting die creates ~ 1 mm tape

$\delta_{PS} = 23.8 \pm 4.0\ (\mu m)$

$\delta_{PP} = 22.9 \pm 5.1\ (\mu m)$




PC/PMMA multilayer, Dow Chem.

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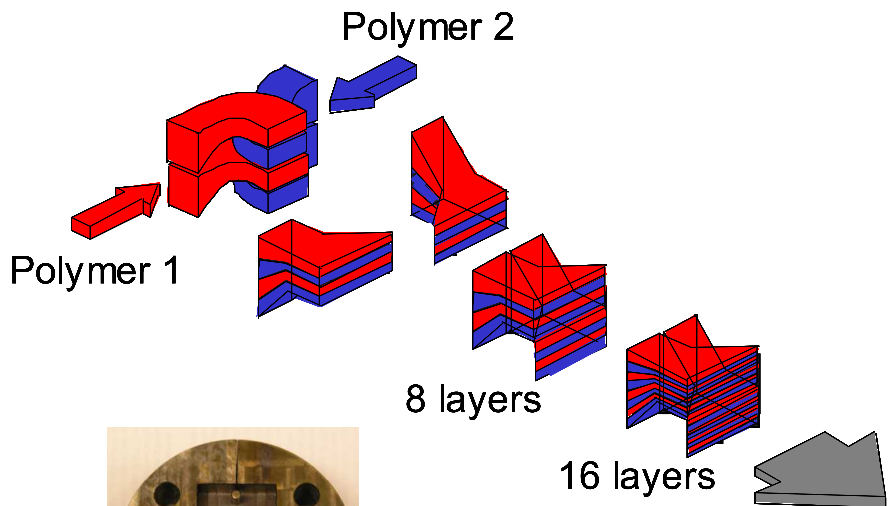
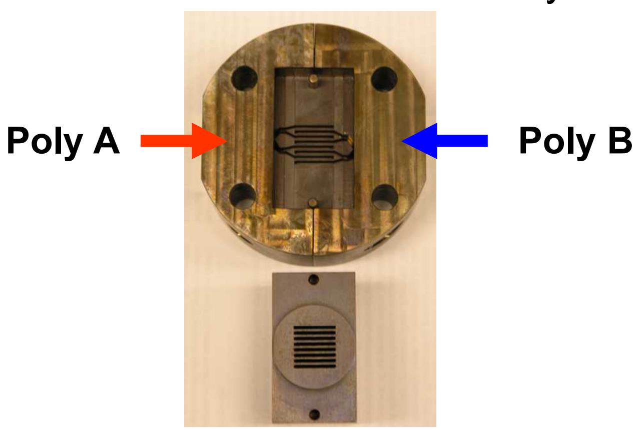
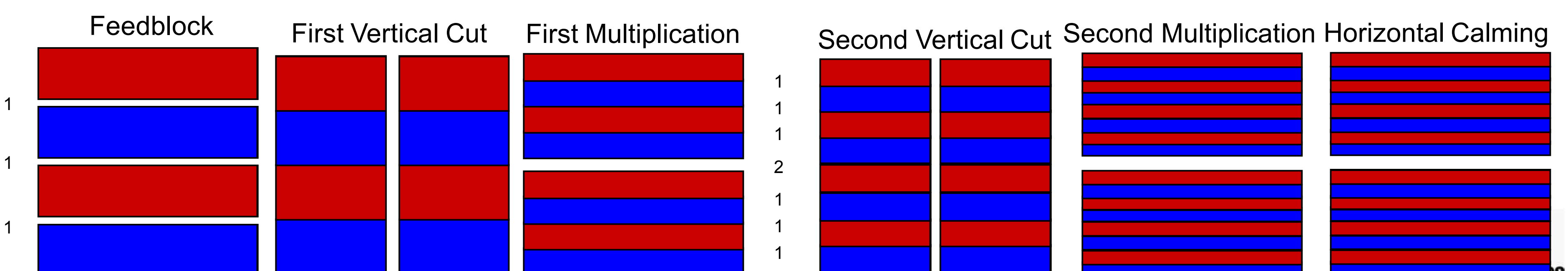
# *Multiplication Scheme*

Multiplication Scheme

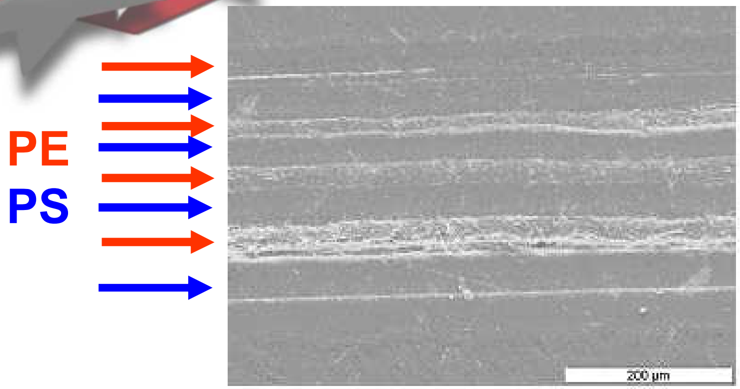


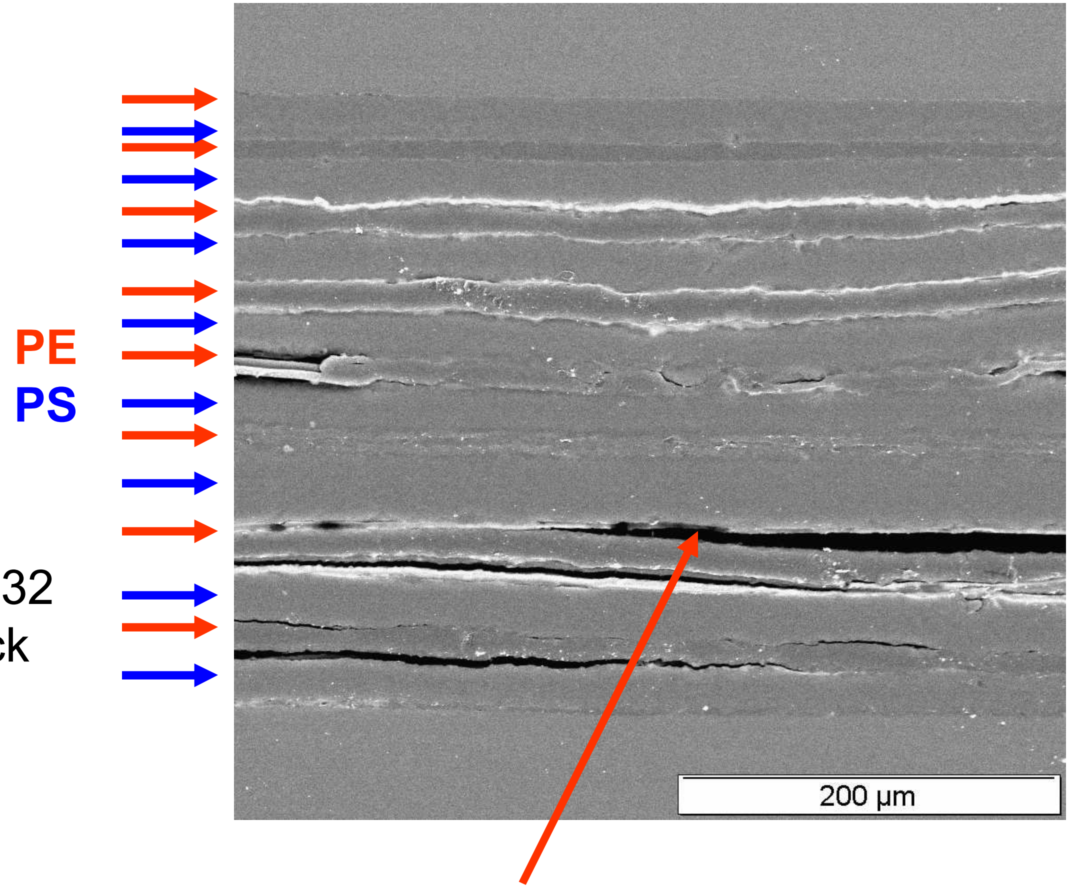




- Feedblock produces initial layered structure
- Each multiplication element doubles the number of layers
- Stacking “n” multiplication dies results in $2^{n+3}$ layers
- Layer stability is largely dependent on uniform laminar flow
- Thin layers (submicron) can easily break-up due to instabilities



# *Initial Layered Structures*




- Successfully extruded 8, 16, and 32 layered structures ~ 0.35 mm thick
- 10 micron layers with reasonable uniformity
- Next step: produce layered structures of filled polymers
- Investigate impact of filler shape, size, size distribution on layer quality and stability

Delamination from potting in epoxy and polishing for SEM not due to poor extrusion

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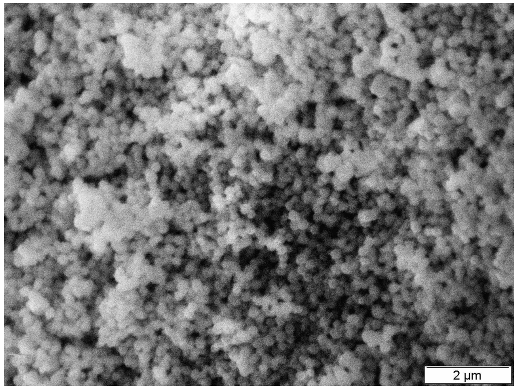
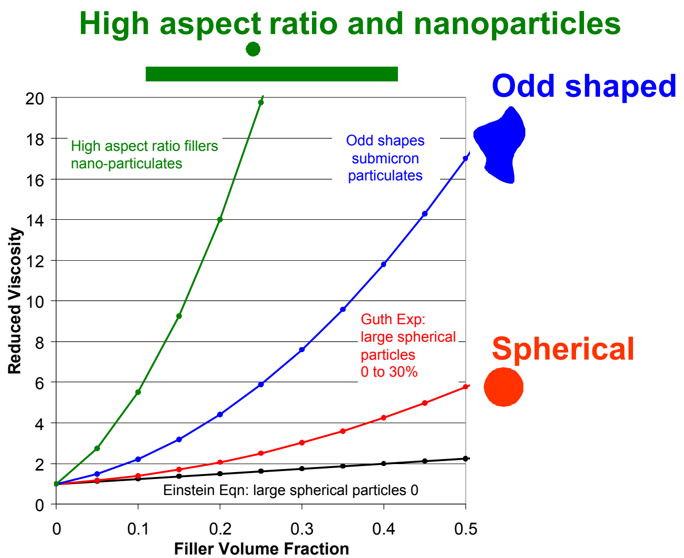
# *Incorporating Fillers*

- Coextrusion of composites can increase the versatility and applicability of the technique
- Incorporation of fillers can enhance material properties
  - Mechanical properties, permeability, thermal stability, flame retardancy, chemical resistance, electrical conductivity, etc.
- Sub-micron layers require nanoscale fillers
- Several processing issues associated with nanoparticle fillers
  - As with all fillers, property enhancement can require high loadings
  - Limited commercial availability in large quantities and small size and shape distributions
  - Difficult to disperse (aggregate at high loadings)
  - Can have a dramatic impact on viscosity even at low loadings
    - Viscosity mismatch between materials in coextrusion leads to layer instability

**Nickel Nanoparticles**

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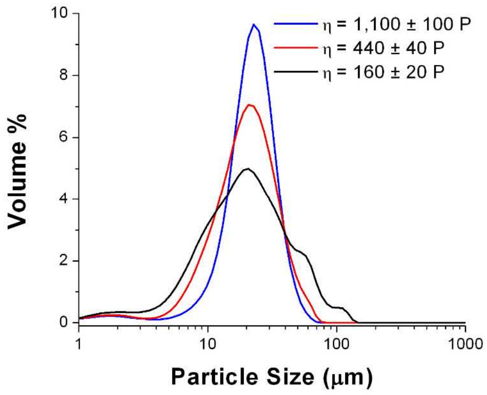
# *Focus of Mitigation Strategies*

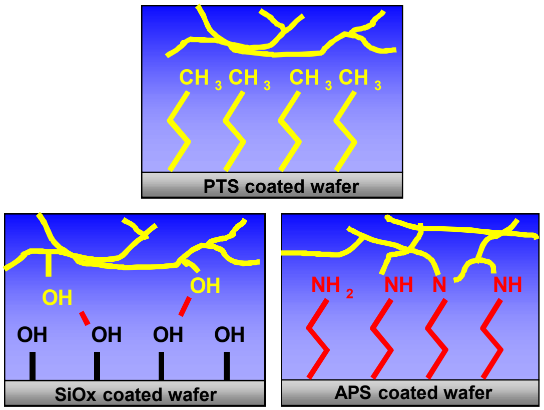
1) Particle size, shape, and size distribution

- we have observed a decrease in the composite viscosity by broadening the particle size distribution at a set loading of micron sized fillers



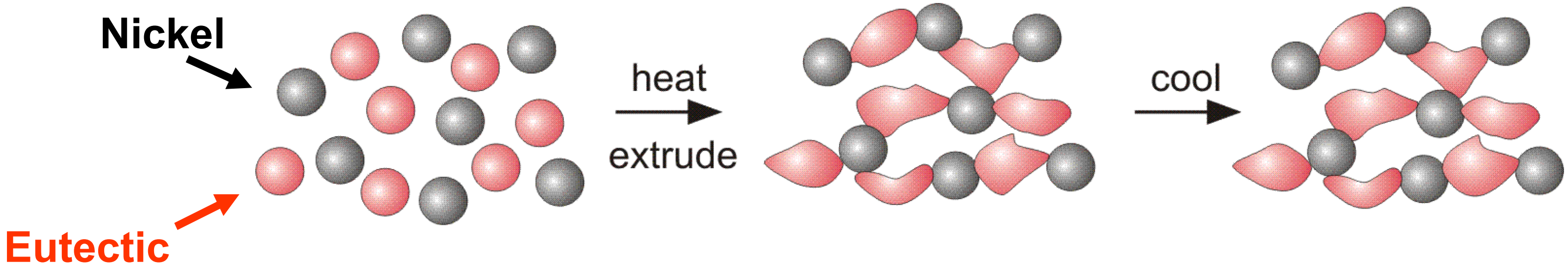

2) Filler surface chemistry

- Control interparticle and particle – polymer interactions by altering the surface chemistry




3) Incoporation of a low melting eutectic metal

- Dispersed eutectic metal will be molten at the extrusion temperature and should not increase the viscosity until cooled below the melting point

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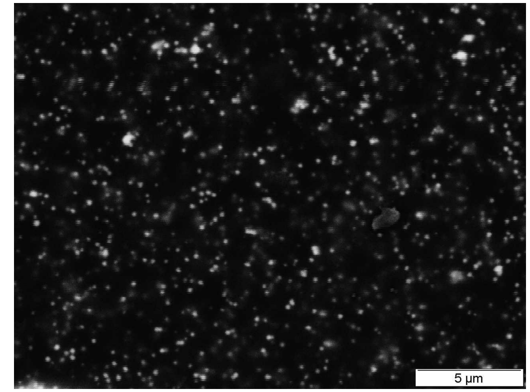
# *Current Work*

- Investigate influence of particle size, shape, and size distribution on viscosity

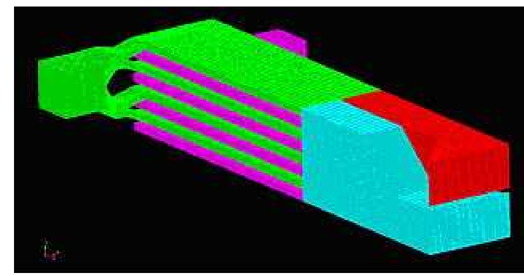
- Determine processability window for coextruded nanocomposites
  - How big of a viscosity mismatch can be tolerated?
  - How do the nanoparticles influence the flow field?

- Elongated vs. spherical fillers
  - Elongated fillers can enhance the properties at lower loadings than spherical fillers but typically have a larger influence on the viscosity

- Produce layered structures with layer thicknesses < 10 μm composed of nanocomposites

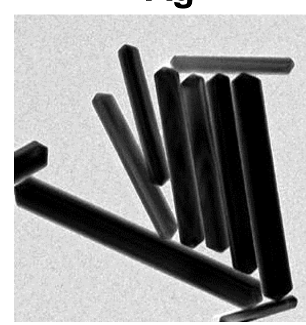



*200 nm Ni in polystyrene*



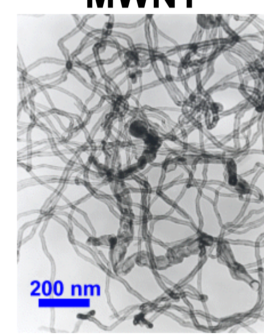
*modeled flow field*

**Ag**



**Seashell Technologies**
Diameter = 75 nm
a.r. ranges from 10 - 1000

**MWNT**




**NanoAmor**
Diameter = 20 - 30 nm
Aspect Ratio = 15 - 100