Nano-technology Challenges

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Overall Strategy

- CEM has a real interest in nanotechnology as a new approach for enhancing composite performance

- CEM's nanotechnology strategy is based on:
  - Continuously monitoring evolution of nanotechnology science over the whole material property spectrum
  - Identify areas where significant enhancement to material properties becomes conceivable from a technical standpoint. If it doesn't make sense technically, we won't chase it.

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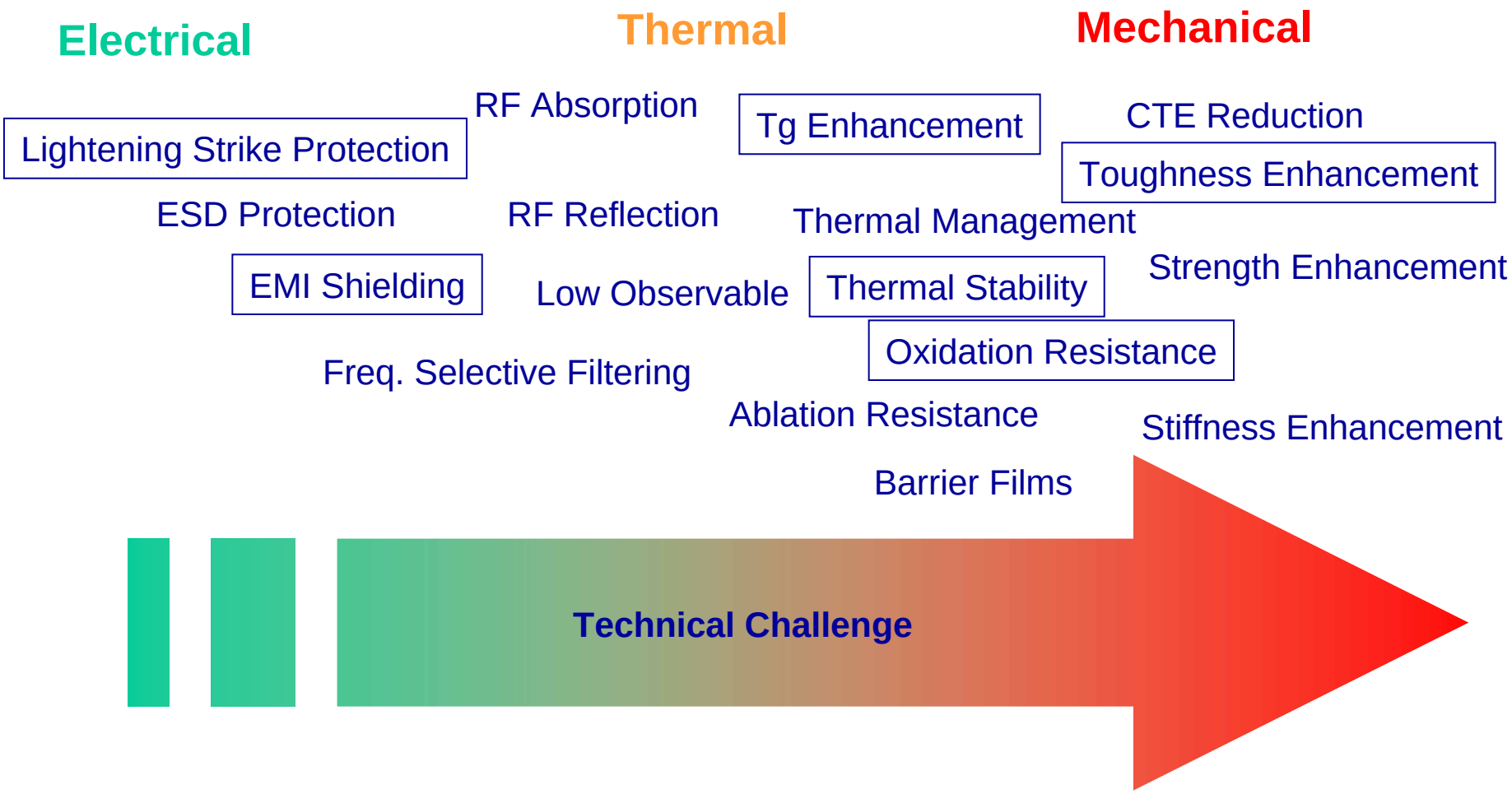
Applications Roadmap



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Target Enhancements

Material Aspect	Development Goals	Target Application
Electrical	Orders of magnitude enhancement in electrical conductivity of composites to eliminate need for conductive metal solutions	- Lightening strike protection for aircrafts -EMI shielding for electronic devices and sensitive satellite comp's. -Piezoelectric sensing and actuation for structural health monitoring
Thermal	> 100 F increase in Tg and/or service temperature of existing epoxy and BMI resin formulations	- Aircraft engine cowlings, exhaust components, wing trailing edges, horizontal control surfaces (flaps, spoilers)
Toughening	30% increase in toughness levels with other resin formulations without compromising structural performance	- Aircraft leading edges, inner flaps, stabilizers, fuselage.

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$$$ of Carbon Materials [Drzal]

	Diameter [um]	*Length [um]*	*Aspect Ratio*	*Tensile Modulus [GPa]*	*Tensile Strength [GPa]*	*Electrical Resistivity [Ω cm]*	*Cost [$/lb]*
Conventional Carbon Black	**0.5-300**	**0.5-300**	**~1**	**3 - 5**	**0.5 - 1**	**10^{-1} - 10^{2}**	**~$0.4**
Highly Structured Carbon Black	**0.01-0.03**	**0.01-0.03**	**~1**			**1 x 10^{-3}**	**~$12**
Chopped CF	**4.3 – 8.4**	**150 - 7500**	**20-1000**	**300-800**	**2.5 - 7**	**1.7 - 6.8 x 10^{-3}**	**$5-6**
VGCF	**0.1 – 10**	**10 – 300**	**10-150**	**250-500**	**3 - 7**	**7 x 10^{-5} - 1 x 10^{-3}**	**$30-40**
SWNT	**0.007 – 0.1**	**1**	**100-1000**	**1000-2000**	**50 - 180**	**4 x 10^{-5}**	**$27,000**
Exfoliated Graphite Nanoplatelets	**0.006-100**	**0.4-2000**	**10-1000**	**1000**	**10 - 20**	**5 x 10^{-5}**	**(~$5)**

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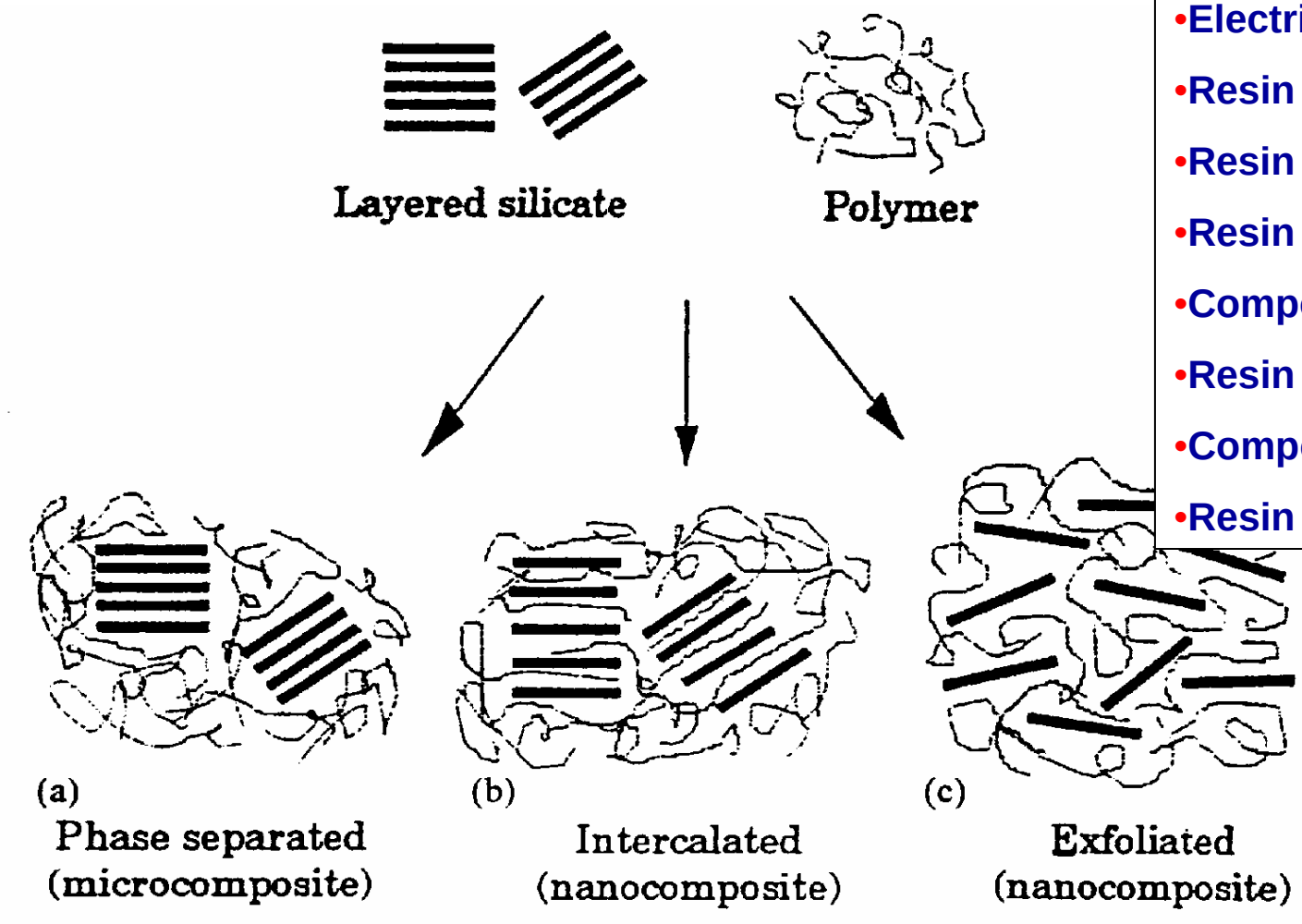
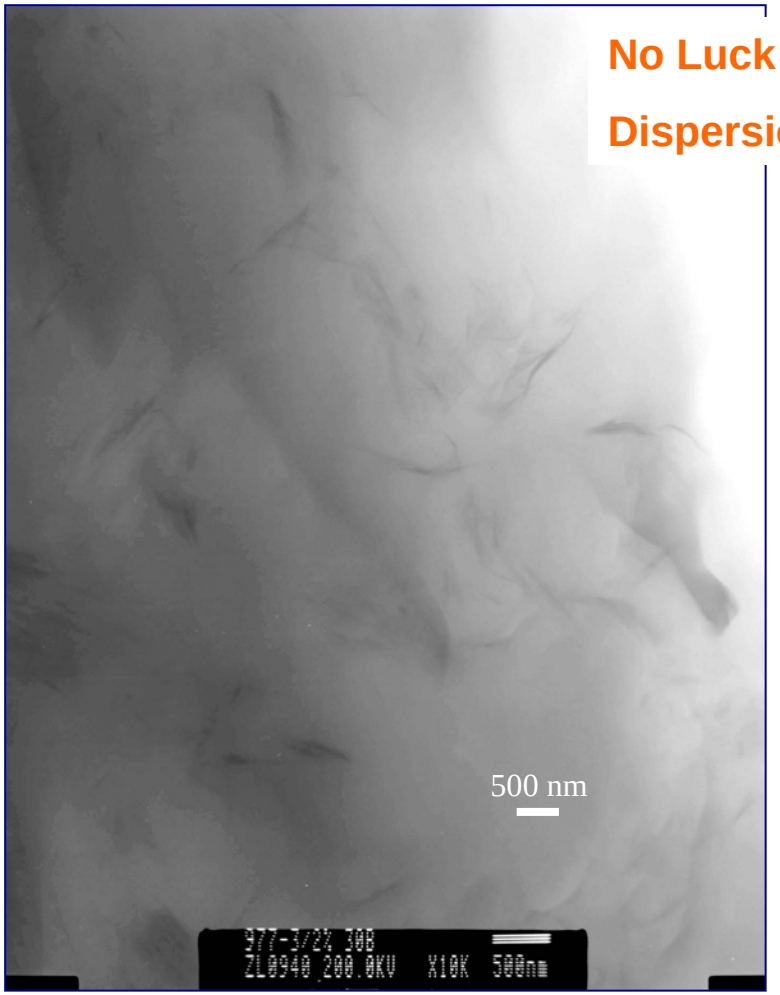
What's achievable ?



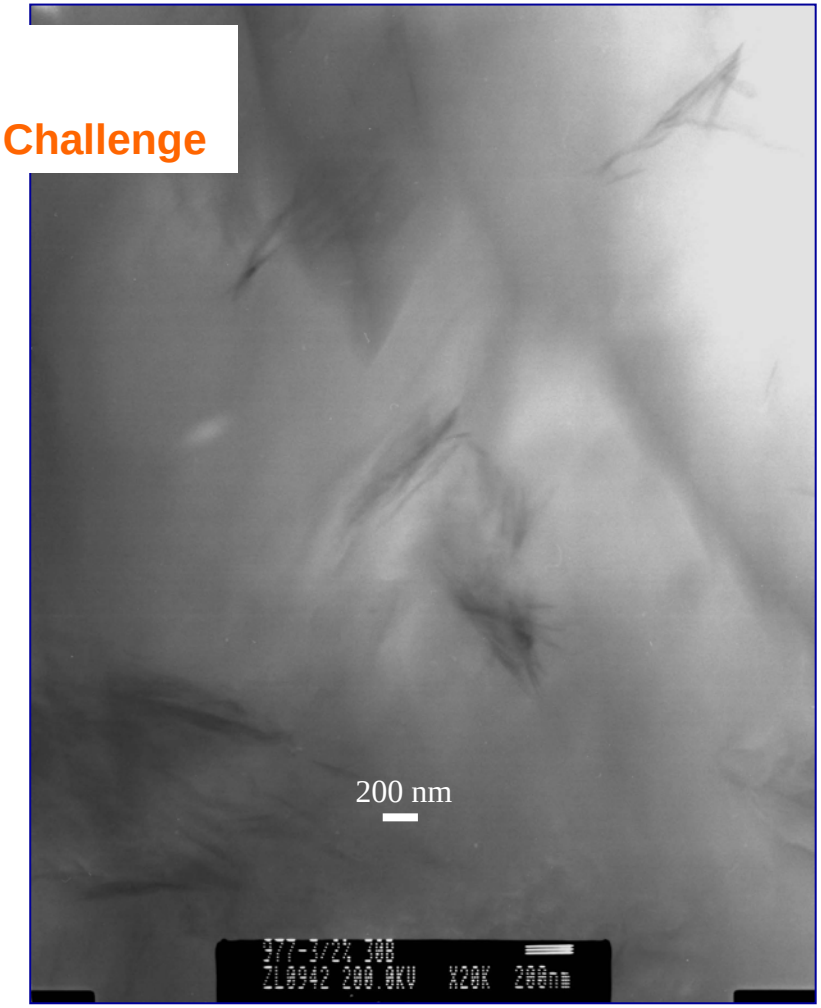
- Tg Enhancement
- Electrical Conductivity
- Resin Modulus
- Resin CTE
- Resin Toughness
- Composite Toughness
- Resin Strength
- Composite Strength
- Resin Ultimate Strain

Tg Enhancement of 977-3 with Nano-clay
Cloisite 10A, Cloisite 30B



No Luck

Dispersion Challenge



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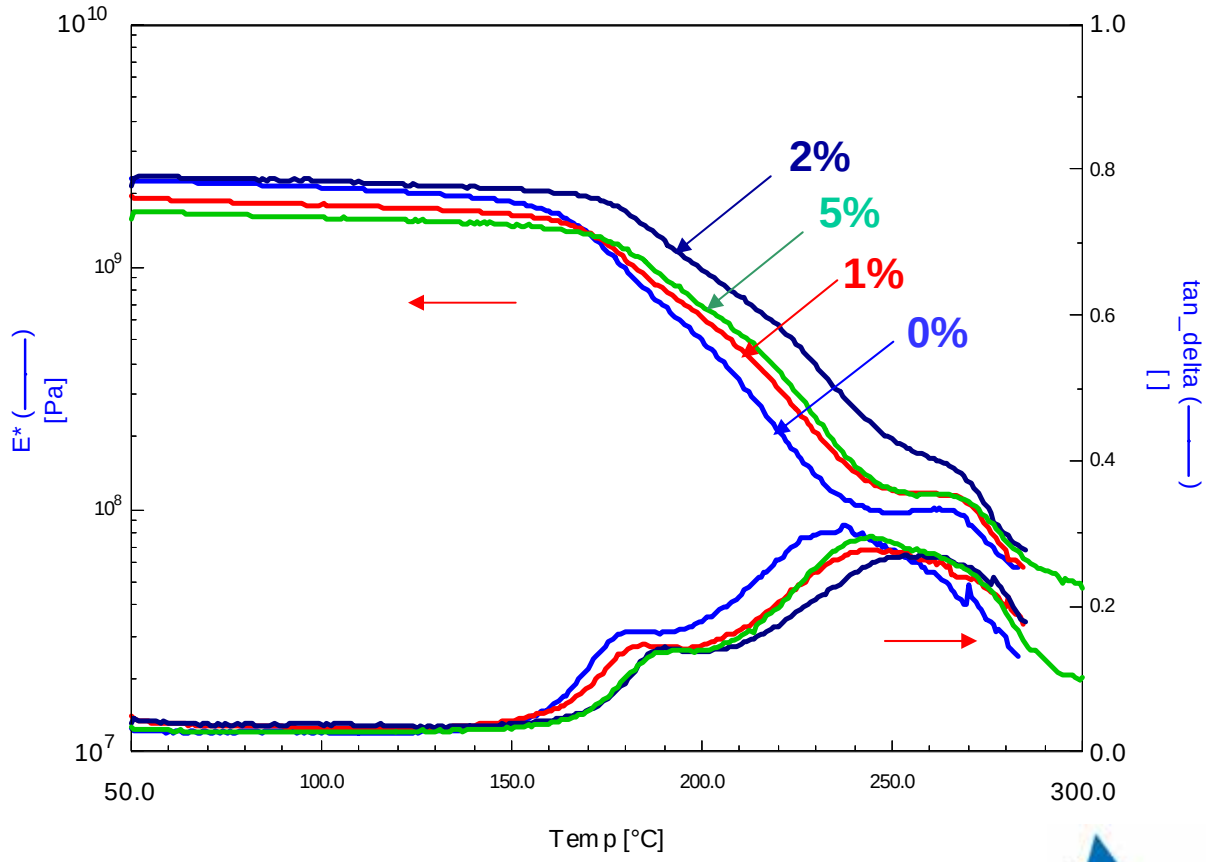
Tg Enhancement of 977-3 with Nano-silica
0%, 1%, 2%, 5%



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Conclusions

- Significant increase (~50 ^{0}F) in Tg is achievable using the nano route.
- No measurable increase in compressive strength of the composite with any of the nano-additives used.
- 2-3 orders of magnitude in conductivity is achievable with conductive nano-additives but that is still below what's achieved from current solutions for EMI and lightning strike protection solutions.
- Some indications of toughness enhancement using specific types of nano-additives.
- In general, the current "mix it and find out" approach may not lead to nano breakthrough's. Fundamental understanding of enhancement mechanisms with nano-additives is still needed especially for mechanical properties.

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