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IDEAS THAT WORK
8-9 October 2015 | CSIR ICC

Nanoclay minerals and plastics: tiny particles deliver big impact

Suprakas Sinha Ray

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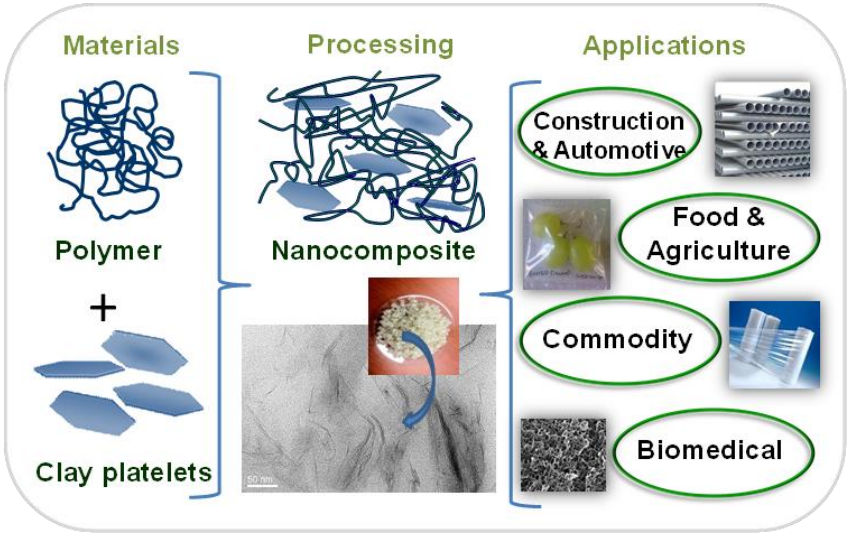
our future through science

CELEBRATING 70 Years
Ideas that work

Outline



- Nanoscience and nanotechnology
- Technology development map
- Markey growth and application
- Nanoclay minerals
- Nanoclay-plastic technology
- Benefits
- Processing and structure
- Advanced plastics
- Advanced cosmetics
- Conclusion

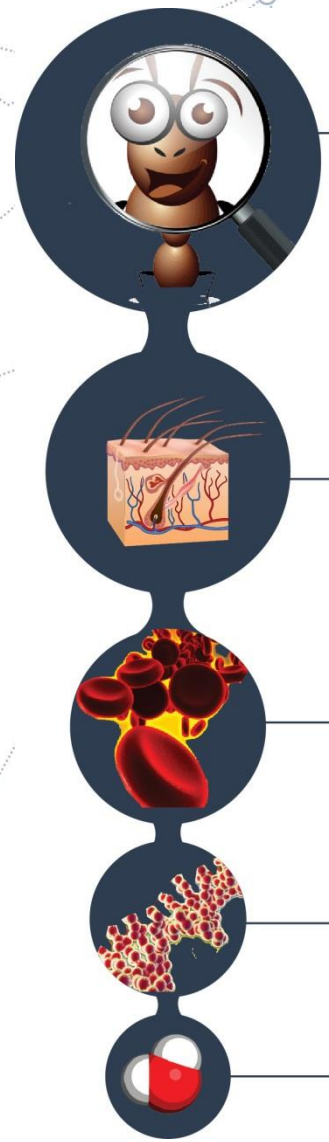
Nanoscience and nanotechnology

Some materials and structures have **special properties** when made in parts smaller than about 100 nm.

Nanoscience = discovery and study

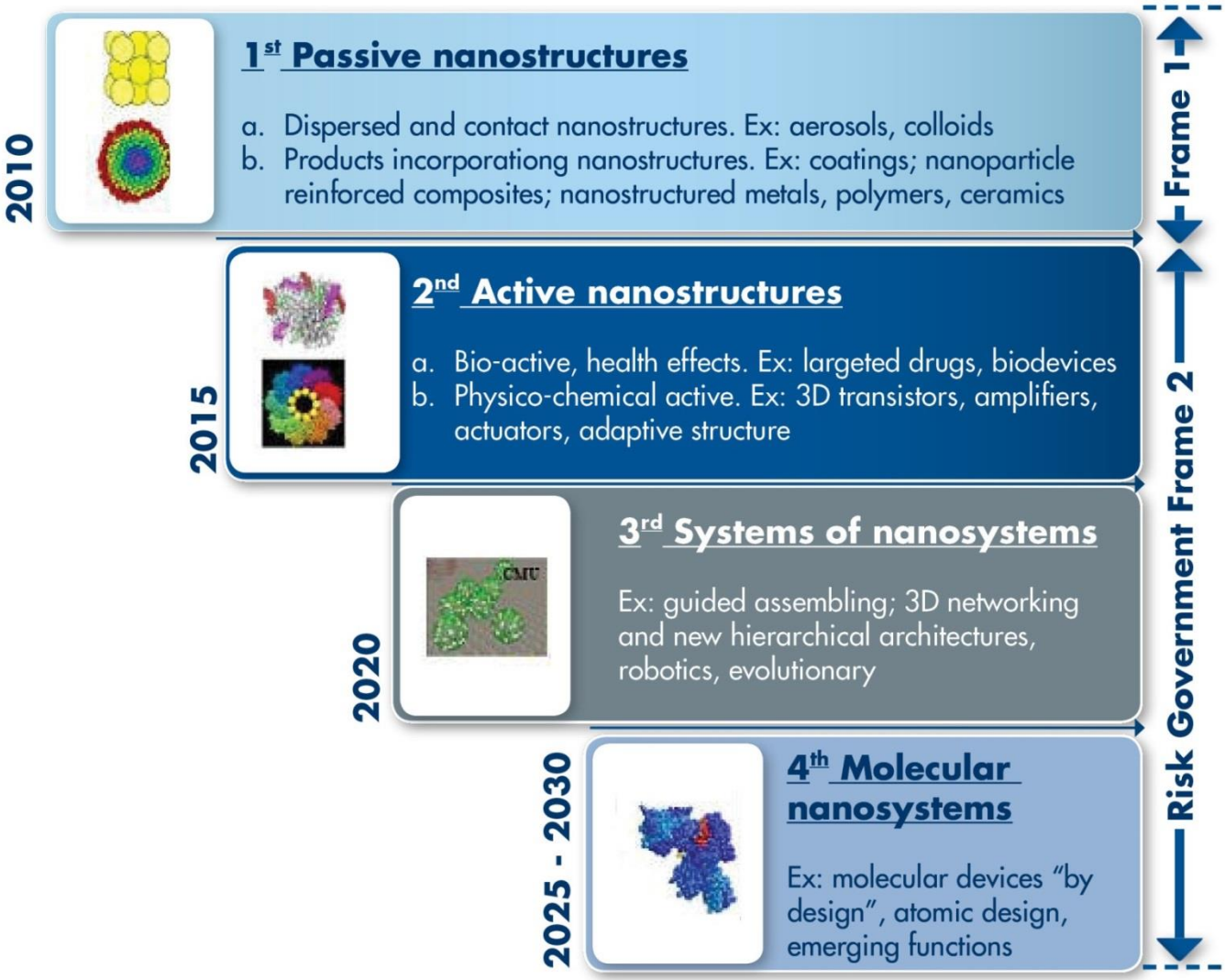
Nanotechnology = use in products and applications

Appreciating the scale



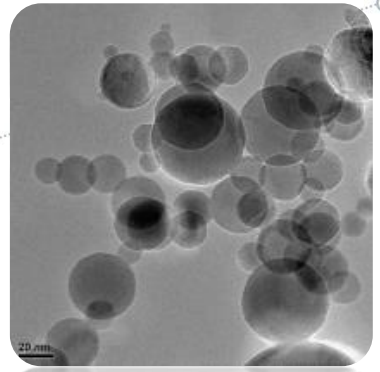
- Ant head 1mm
- Human hair 100μm, 100 000nm
- Red blood cell 10μm, 10 000nm
- DNA 4nm wide
- H_2O molecule 0.2nm

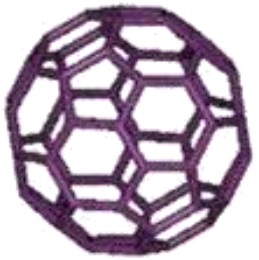
Technology development map

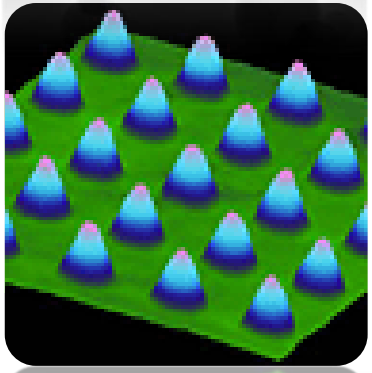


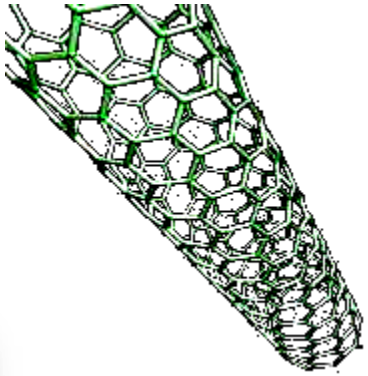
Nano building block

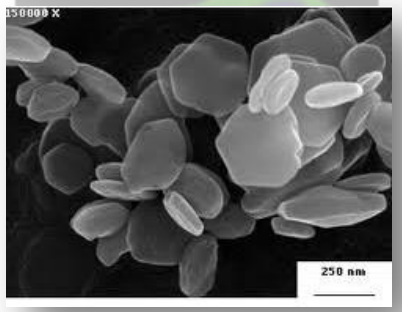
- Nanoclay
- Fullerenes
- Carbon nanotubes
- Graphene
- Nanoparticles
- Quantum dots
- Nanofibres











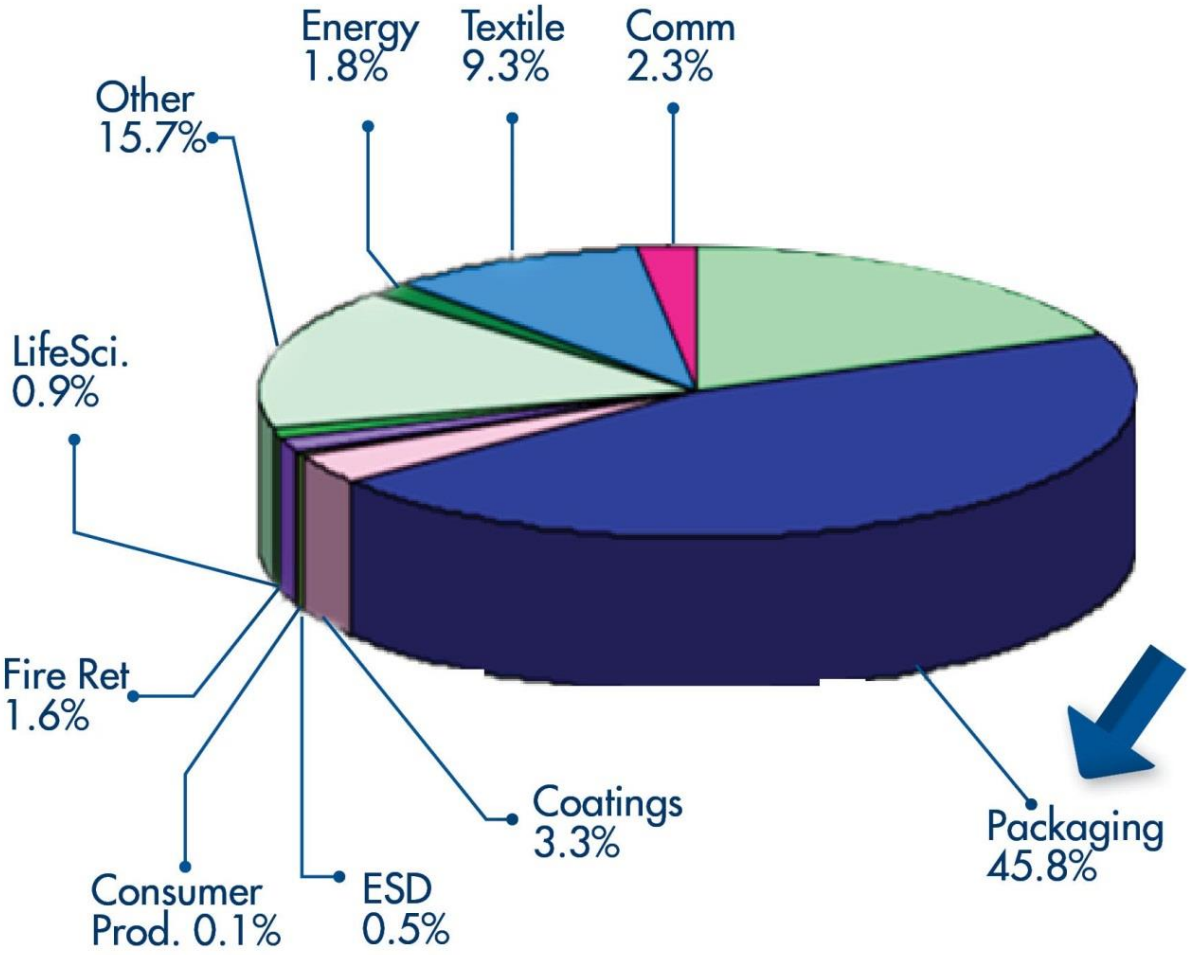
Growth rate of nanostructured materials

	2002 $ Mil	2007 $ Mil	2012 $ Mil	2020 $ Mil	Annual growth (%) 2002-2020
Minerals	140	675	2,100	11,500	28
Metals	45	150	500	3,000	26
Polymers [a]	5	175	1,400	15,500	56
New materials[b]	10	100	500	5,000	41

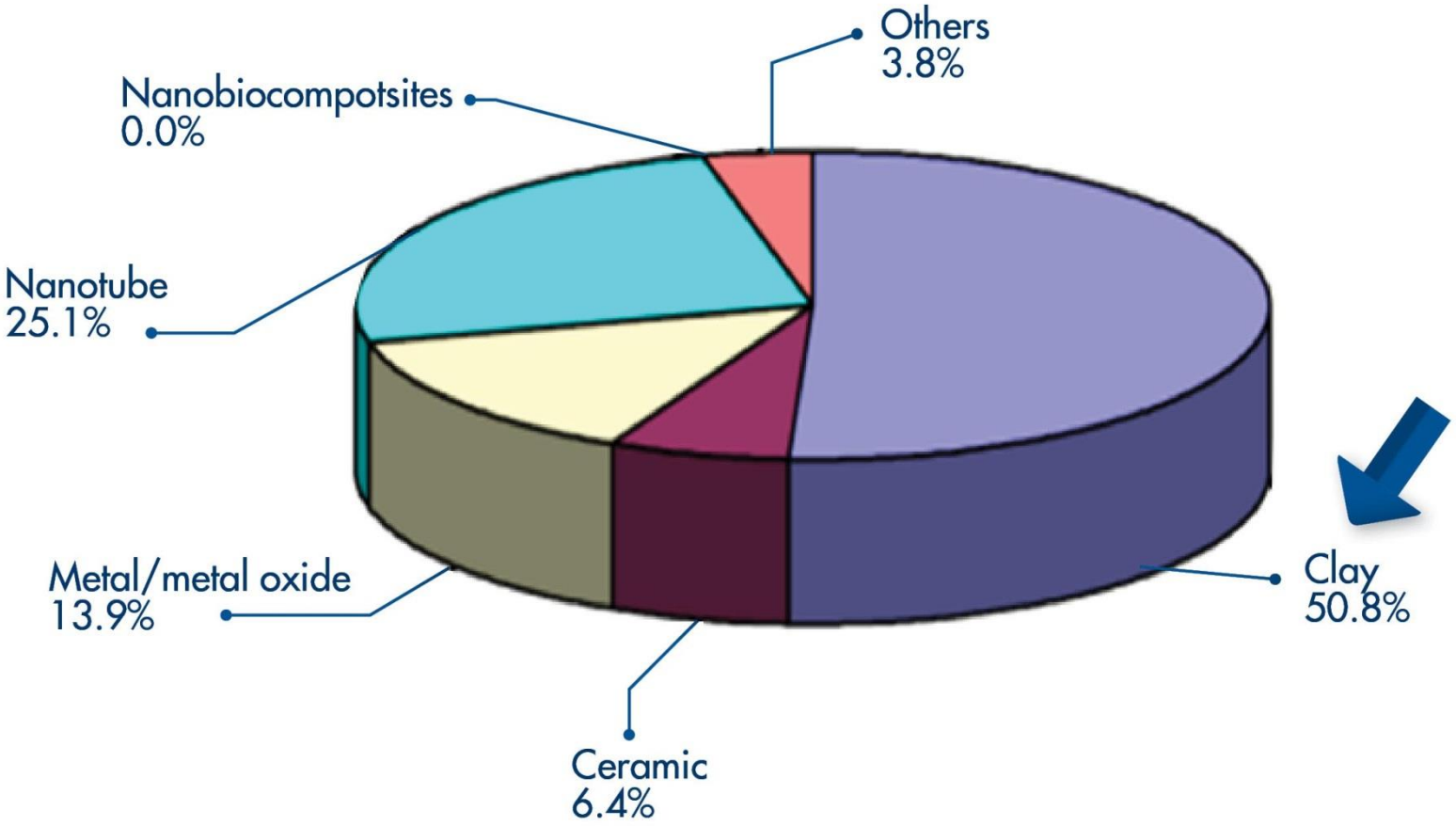
[a] Mainly polymer nanocomposites. [b]New materials include carbon nanotubes, inorganic nanowires, quantum dots, and other nanoparticles. **Source**: Freedonia Group (2012).

(BCC Market Research Report 2012 – NAN021E)

Nanostructured materials applications



Global nanostructured materials consumption

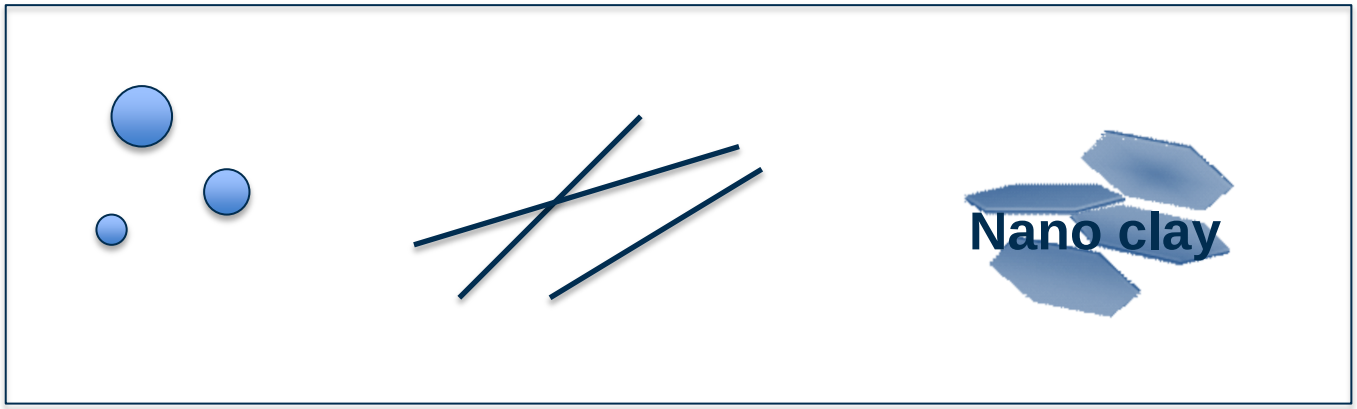


Polymer nanotechnology: nanocomposite

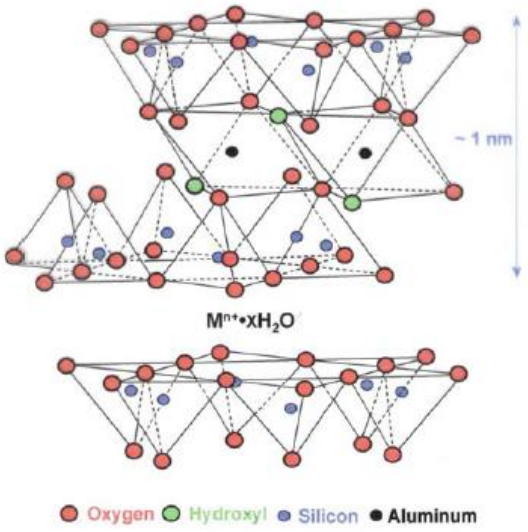
From composite to nanocomposite

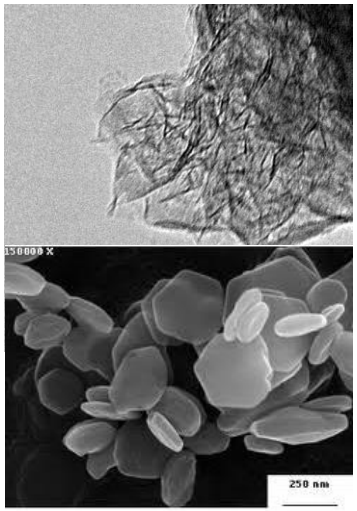
One continuous phase and at least one discontinuous phase

- At least one dimension in 100-nm scale



Nano-clay mineral





BENTONITE:

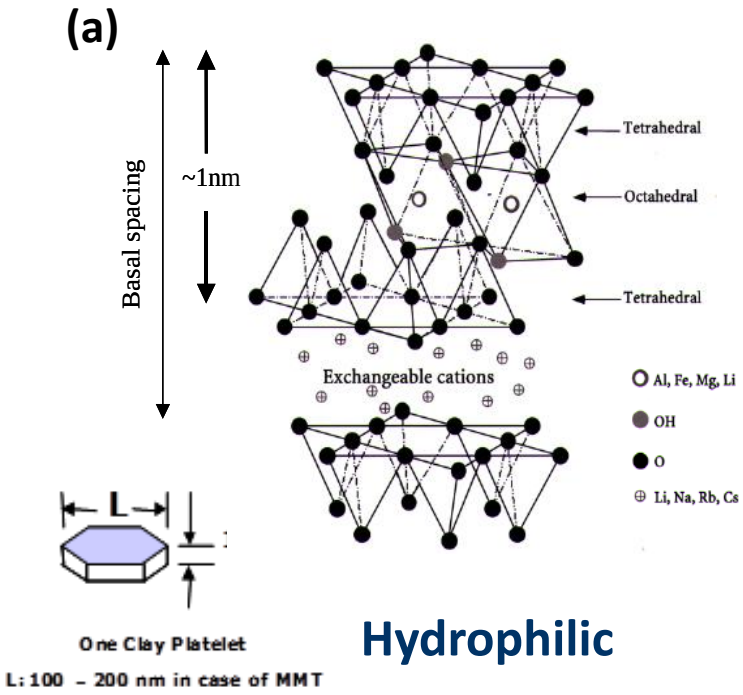
- FDA 21CFR184.1155 GRAS: "Generally recognised as safe"
- High aspect ratio silicate layers 200-300
- Possible inner layer chemistry
- Highly abundant
- Inexpensive

Nanoclay platelets are one-ten thousandth the diameter of a human hair!!!

Benefits of plastic-nanoclay technology

- Mechanical properties improvement
  - Increase stiffness without loss of flexibility
  - Increased dimensional stability
- Enhanced barrier properties
- Chemical and thermal stability
- Flame retardation
- Easy processing and recycling

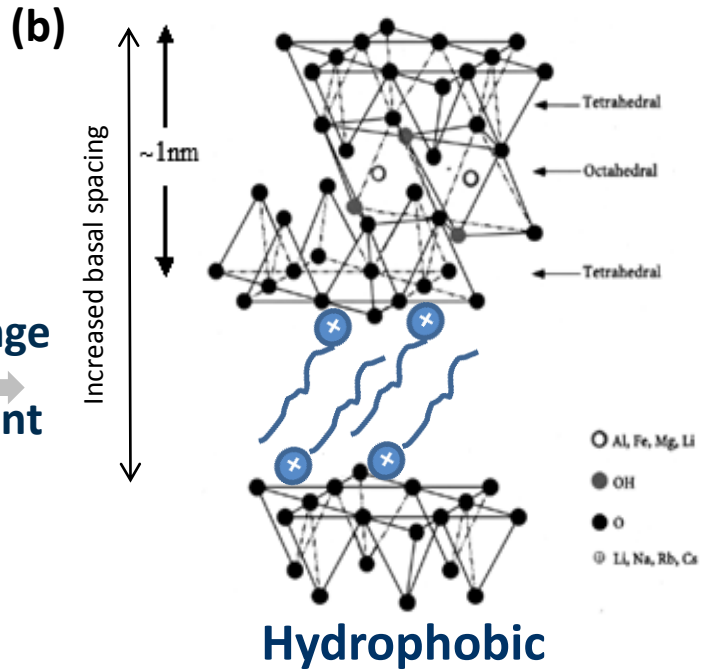
Surface modification



Hydrophilic

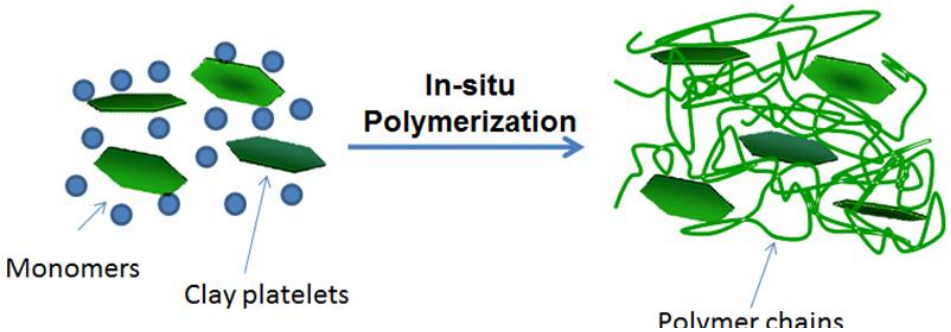
cation exchange

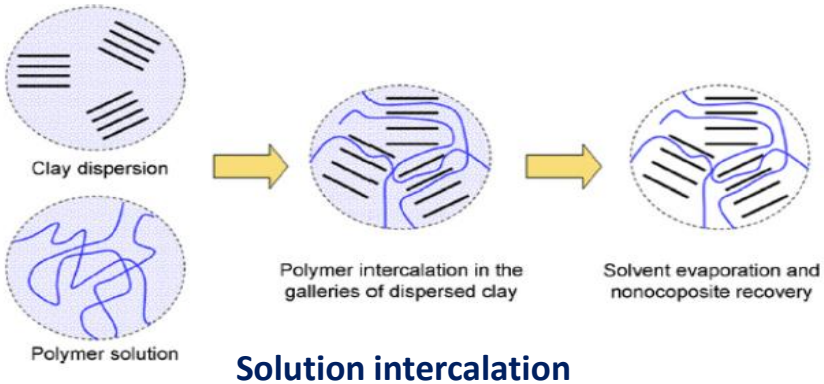
with surfactant



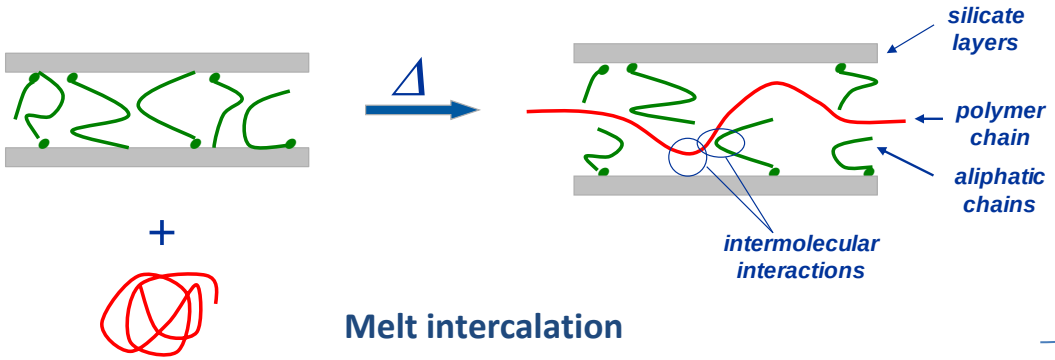
Hydrophobic

Processing and structure

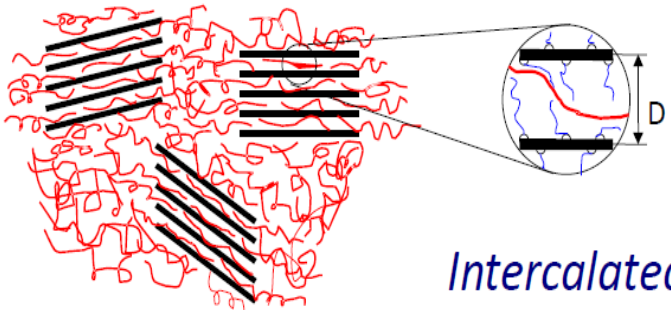




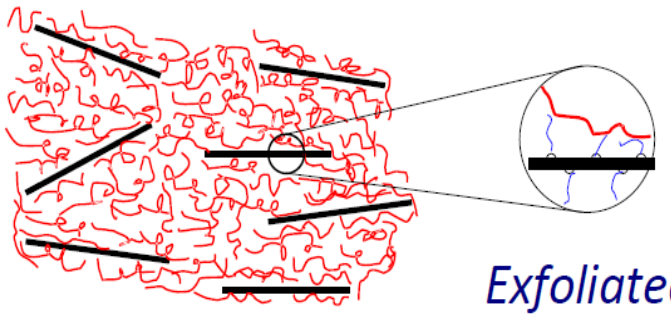
Solution intercalation



Melt intercalation

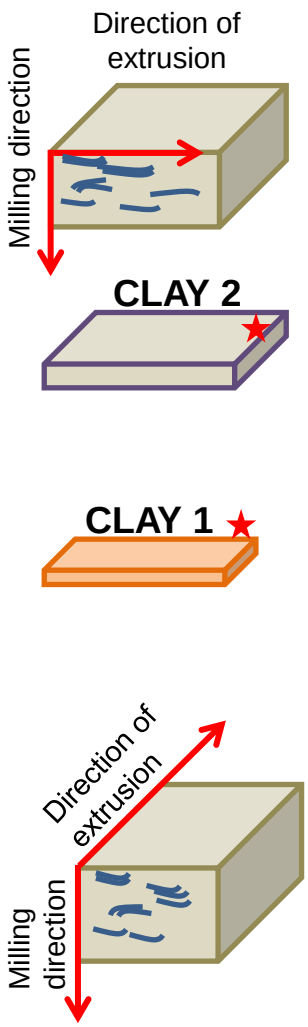


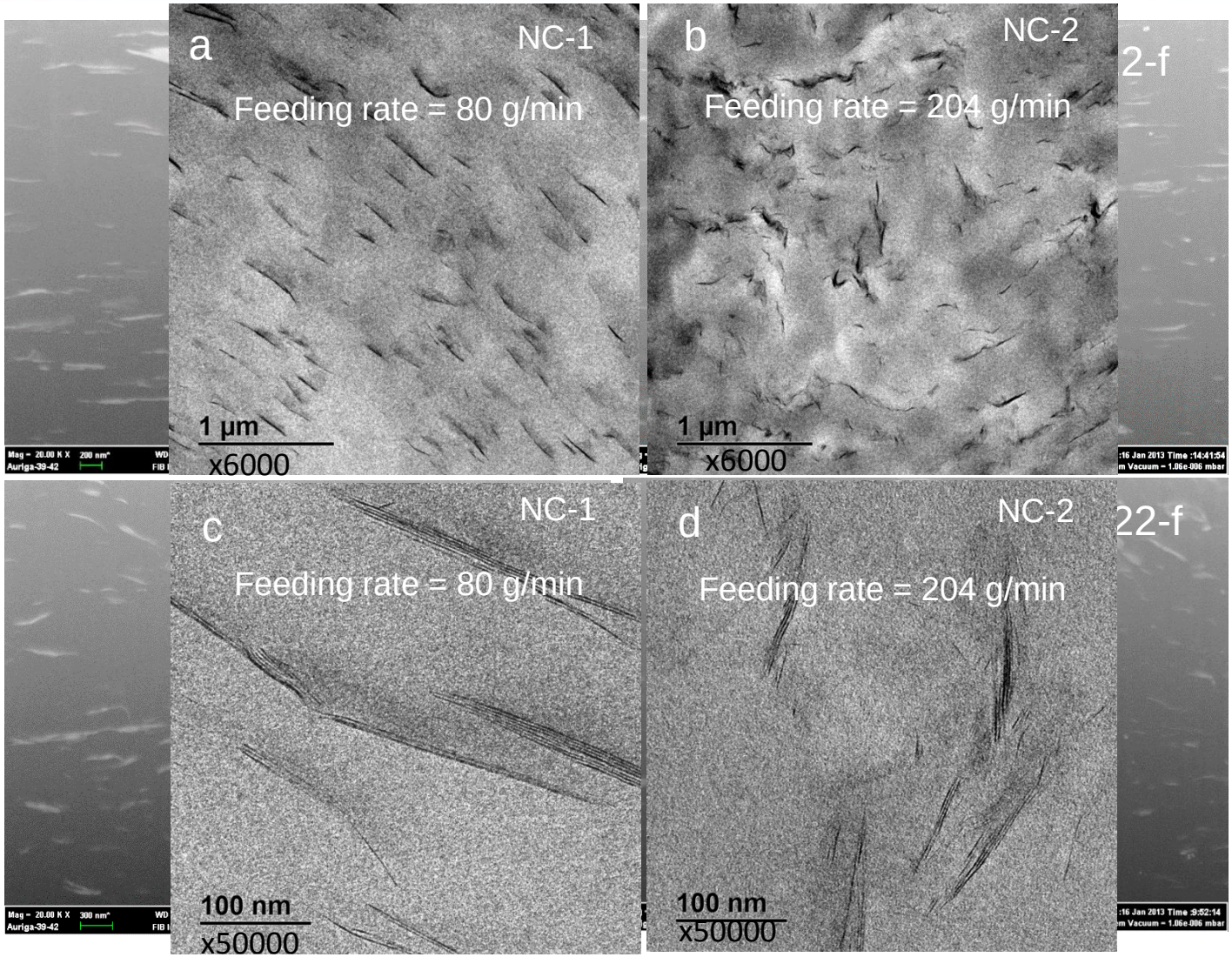
Intercalated



Exfoliated

Dispersed structure and morphology





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Advanced plastics

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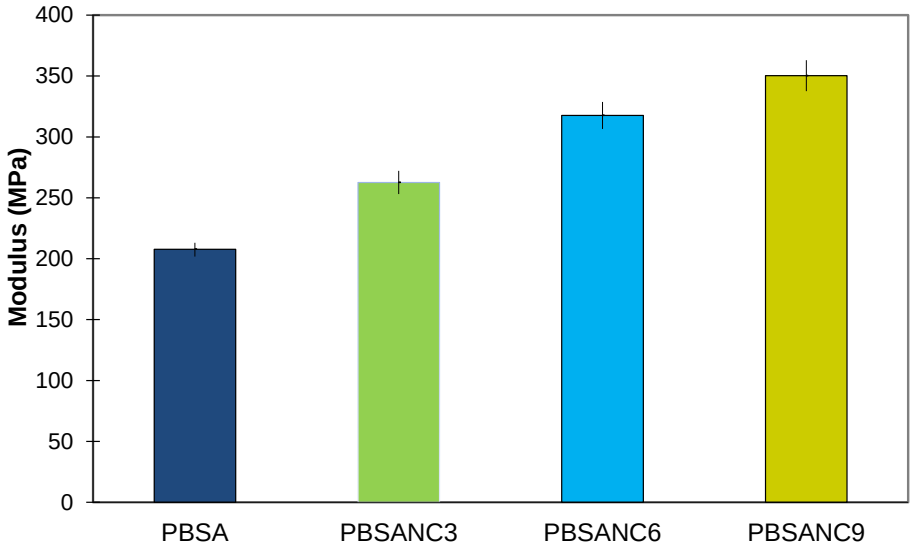
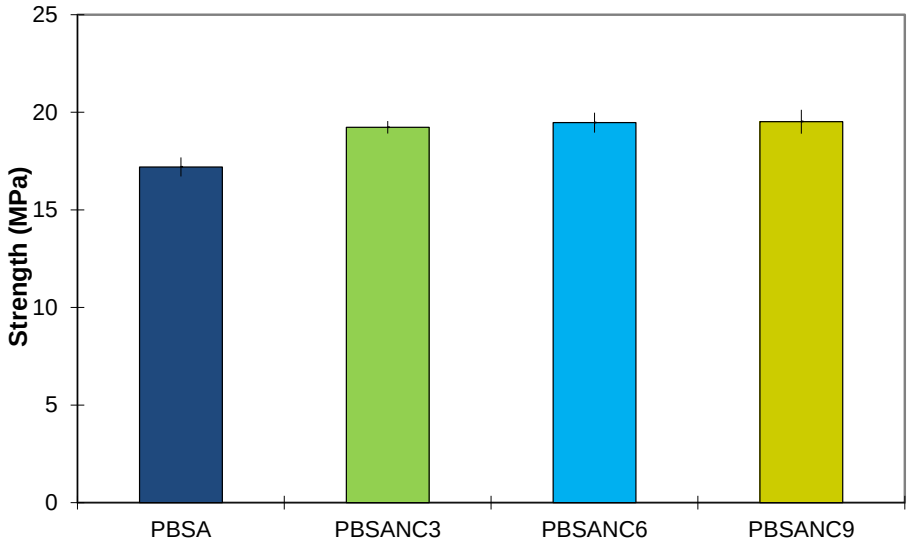
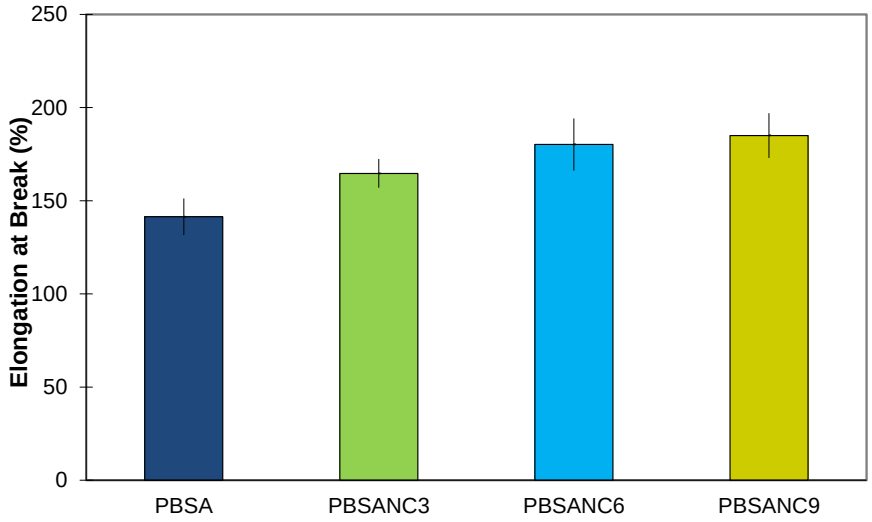
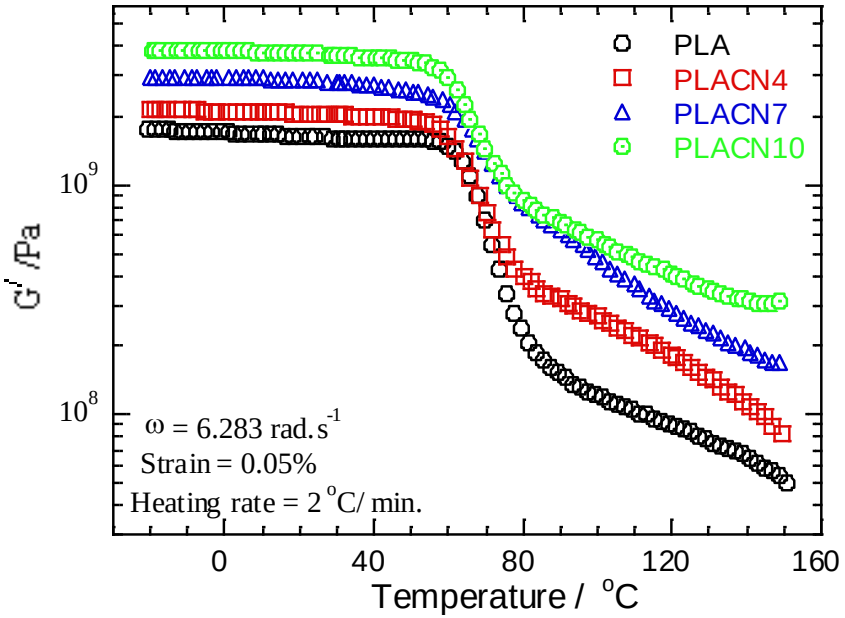
Concurrent improvement in tensile properties

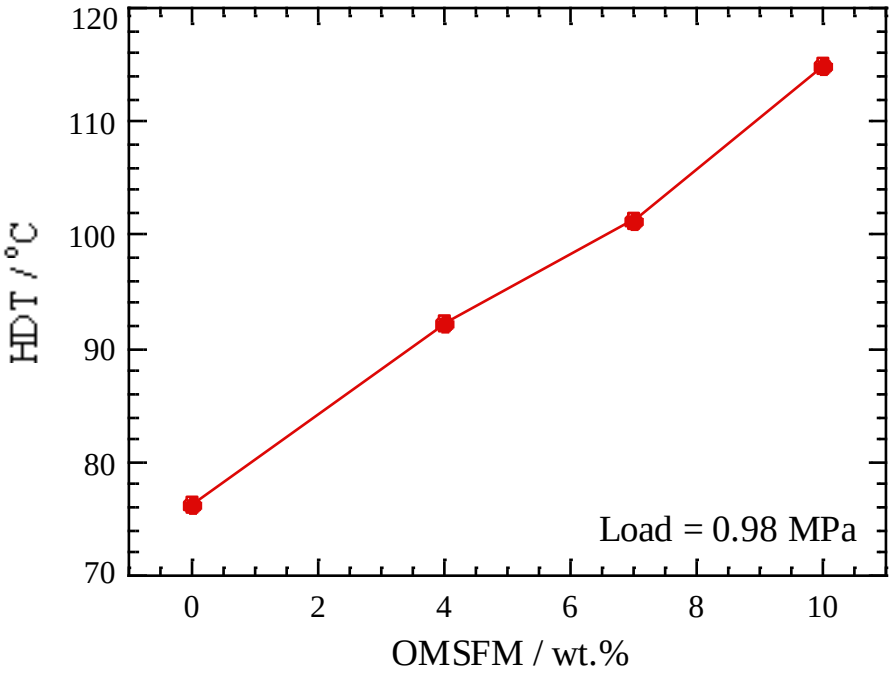




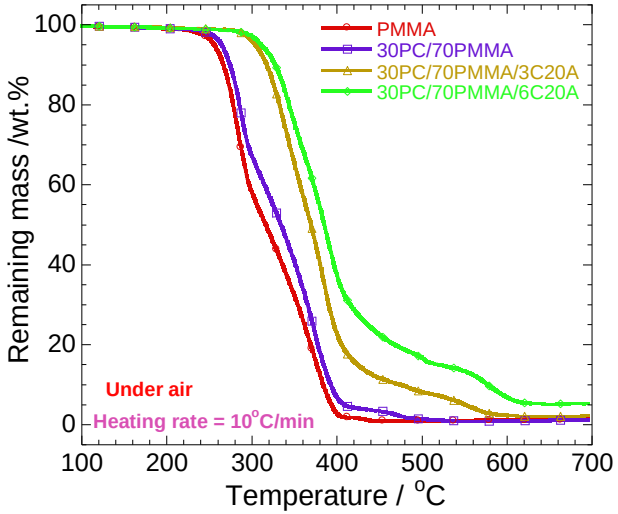


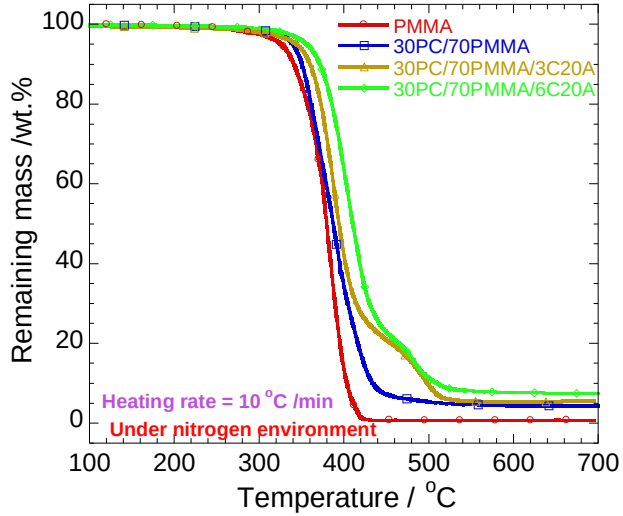
Improved thermomechanical properties

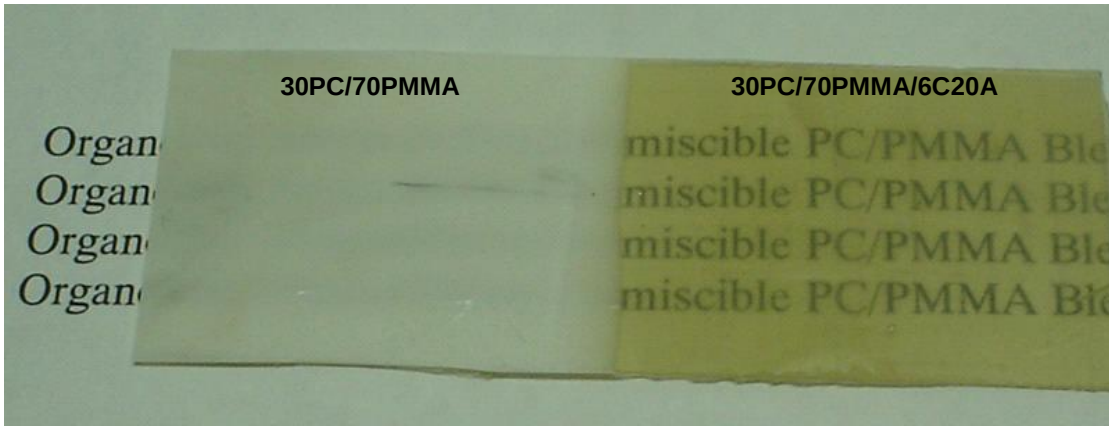




Thermal stable super strong and tough engineering composite





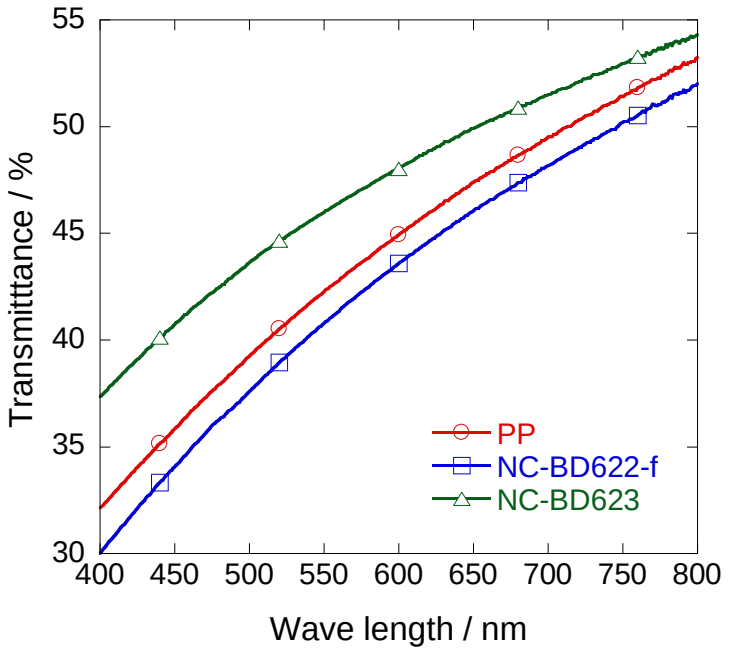


Improved optical transparency in visible range

PP

NC-BD622f

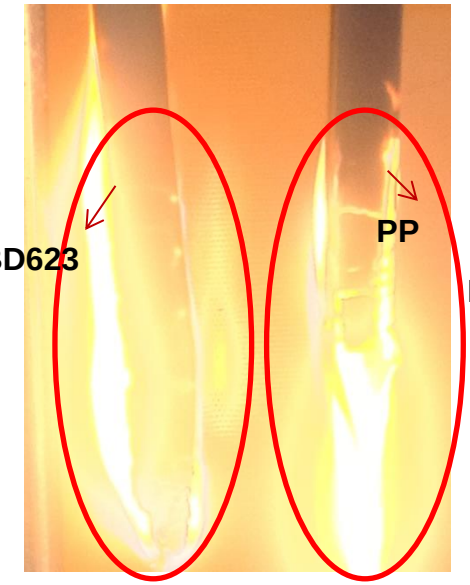
NC-BD623

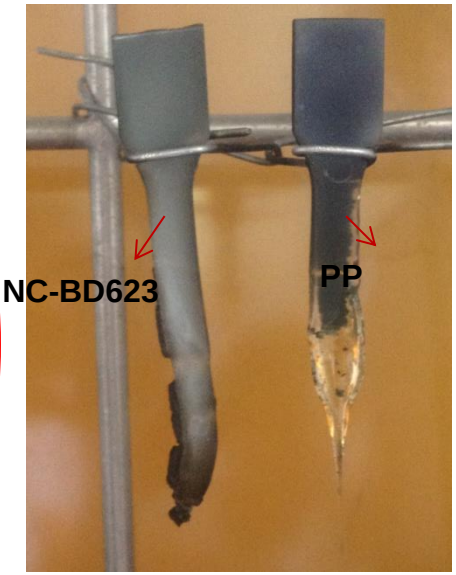


at λ=400 nm,
Transmittance improved by 16.5% in PP-NC-BD623 compared to neat PP.

Nanoclay as fire retardancy additive

Vertical tests



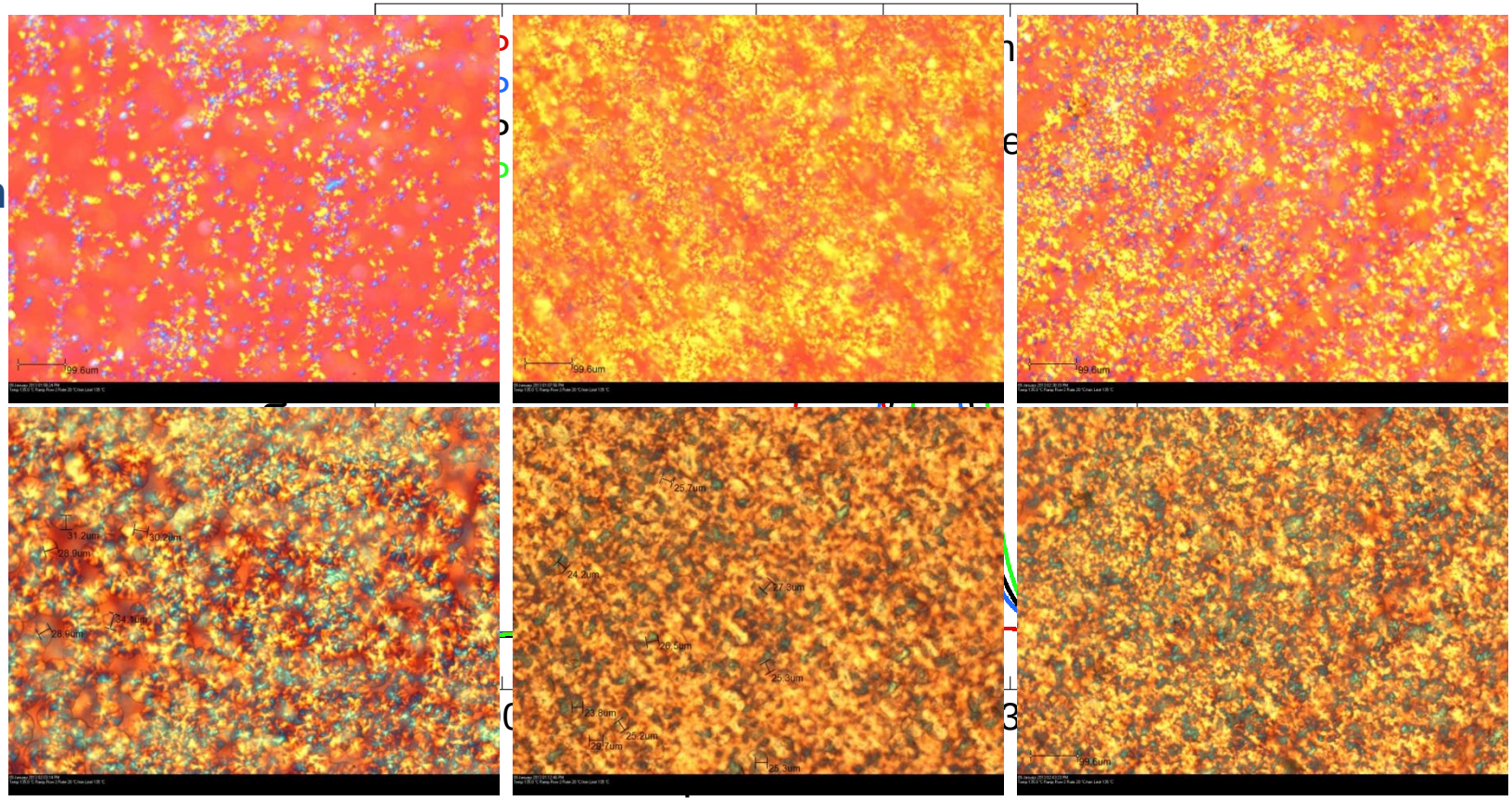


t=3 min t=4 min

Char formation in NC-BD623 is homogeneous due to homogeneous dispersion of clay layers in the PP matrix

Conecalorimeter tests

Nanoclay as nucleating agent



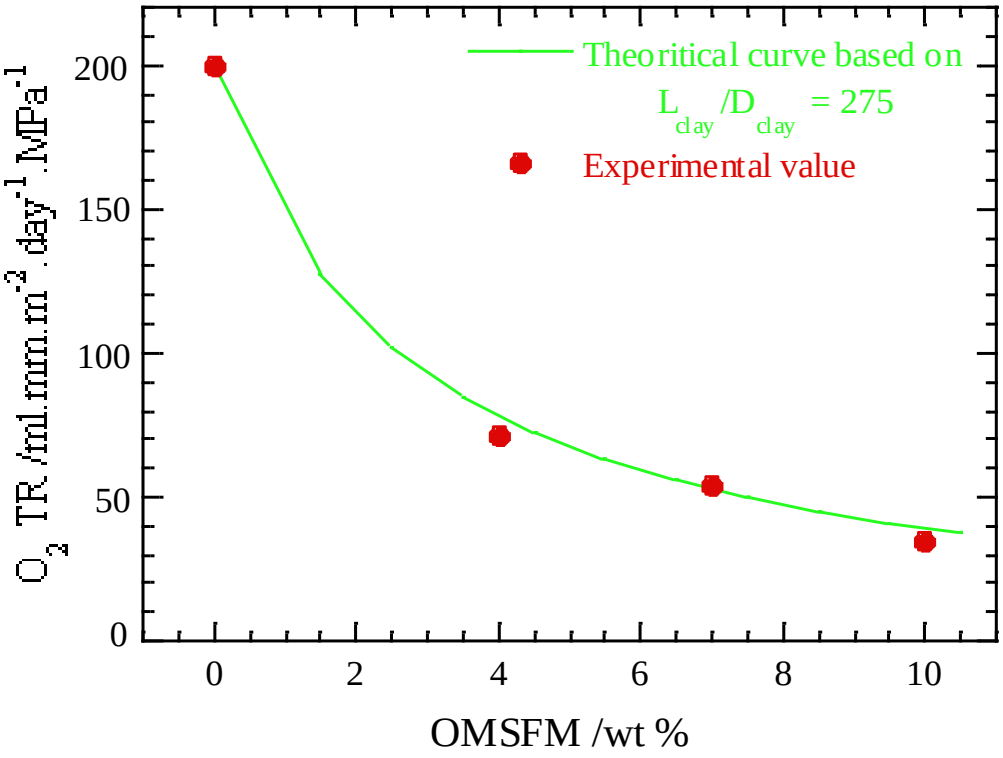
Average radius of spherulite = 30μm

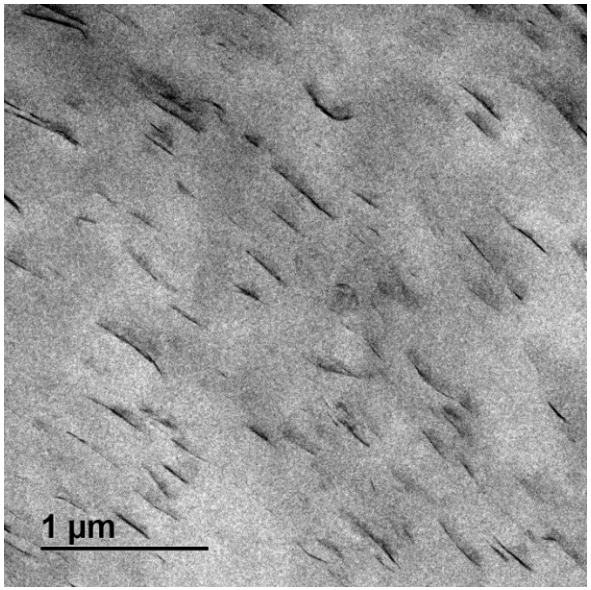
Average radius of spherulite = 25μm

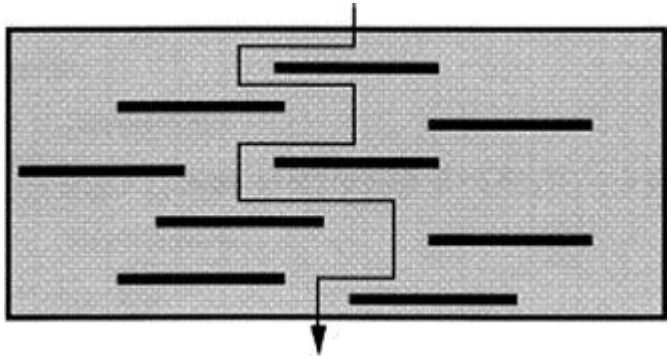
Difficult to distinguish spherulite

Our spherulite is much smaller than Svoboda et al.

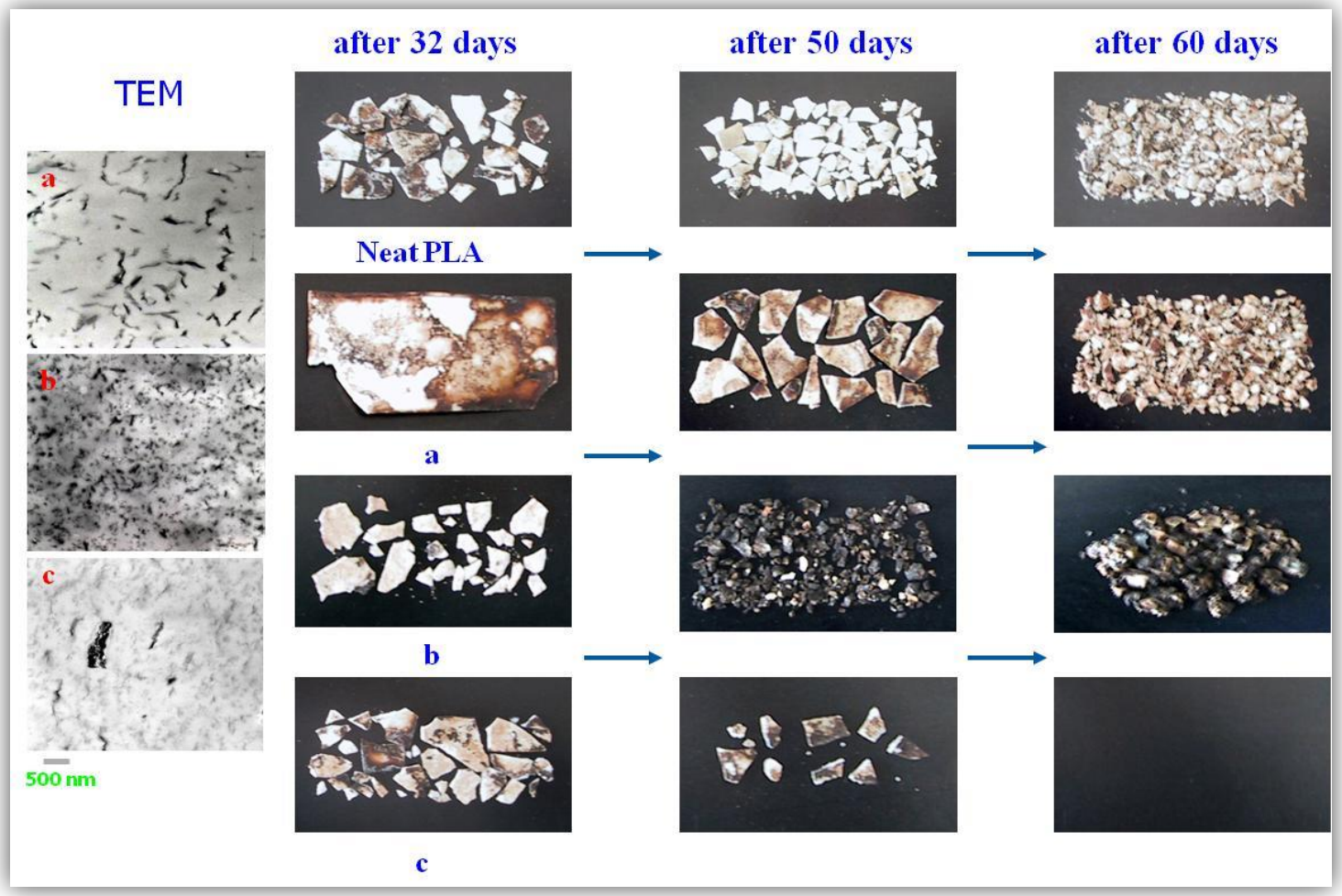
Improved oxygen barrier







Controlled compostability of bio-based polymer nanocomposites



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Advanced cosmetics

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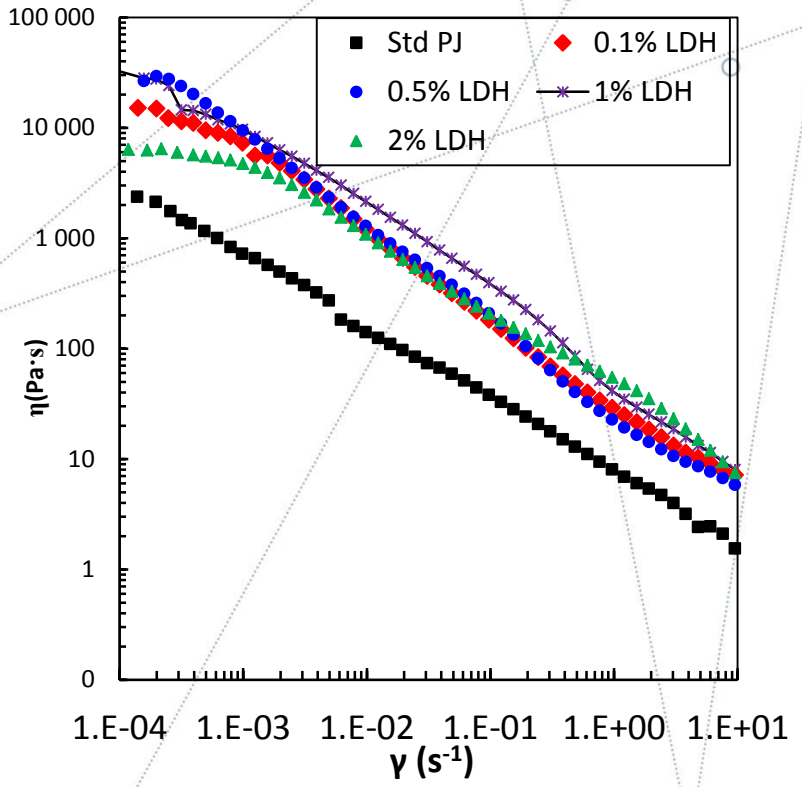
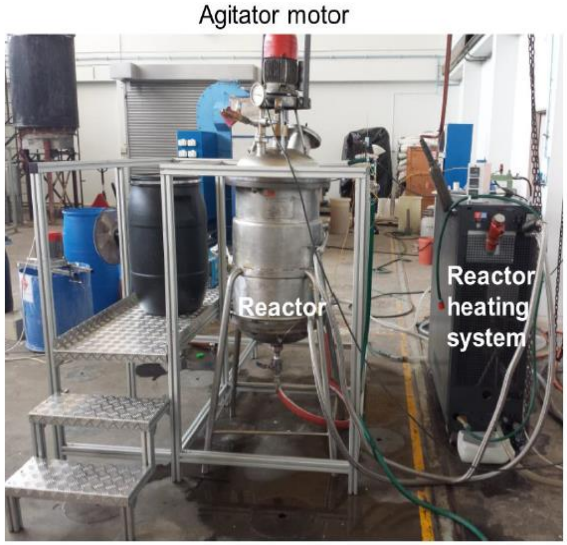
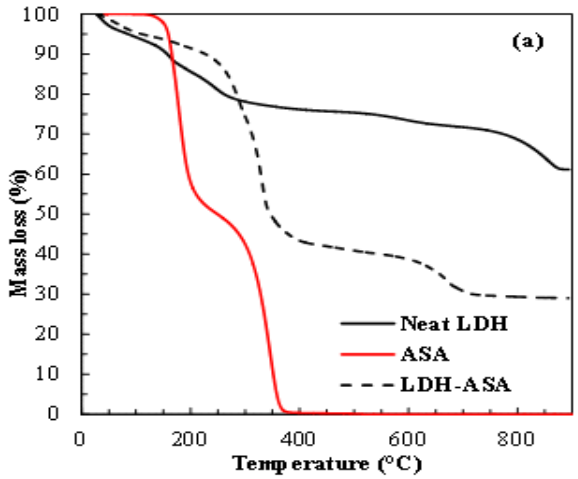
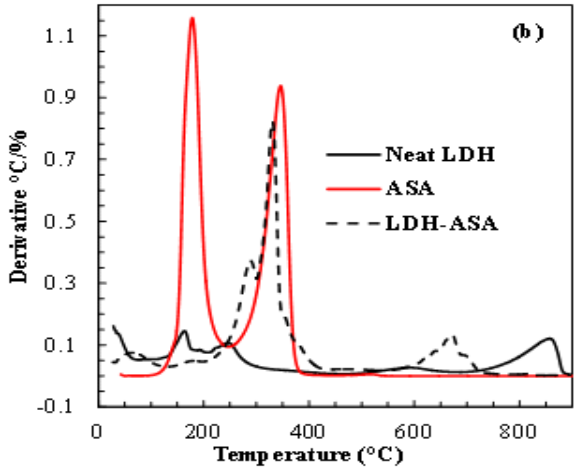
Improved rheological properties

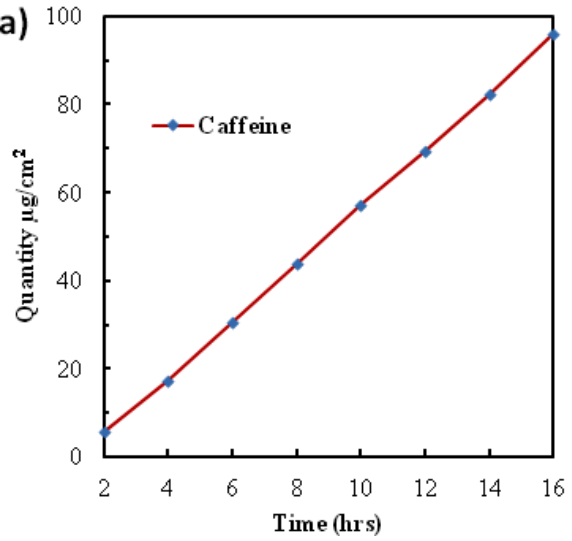


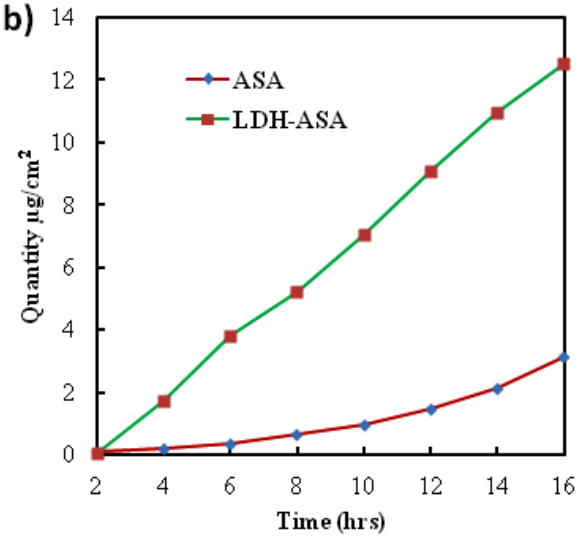


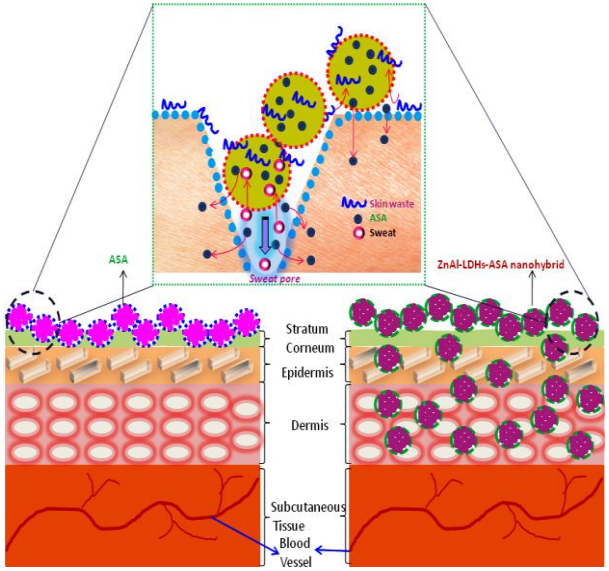
Improved thermal stability and release property











Summary

- Nanoclays are effective additives to make advanced plastics and cosmetics
- Nanocomposites offer same processing and recycle benefits
- Use of nanocomposites have good envirnmental impact
    - Thinner plastic packaging
    - Tougher and lighter auto parts
    - Improved fire property, thermal stability, scratch and UV-resistance
    - Improved compostability of bio-based polymeric materials

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