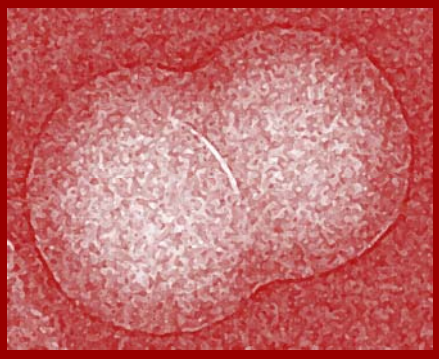
Dirk-Jan Voorn



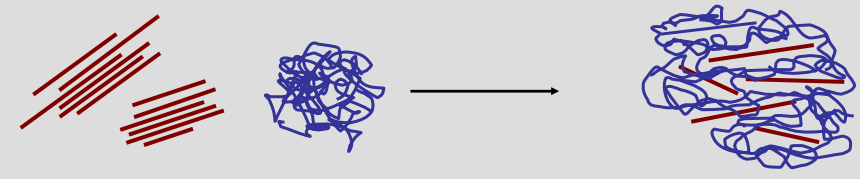
Polymer-clay nanocomposite particles

Encapsulation of platelets by physical and chemical approaches

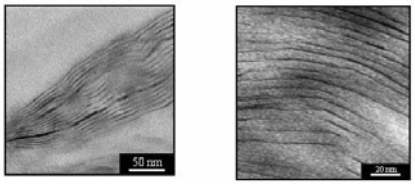
DPI annual meeting, 21 November 2007

Why clay platelets as fillers?

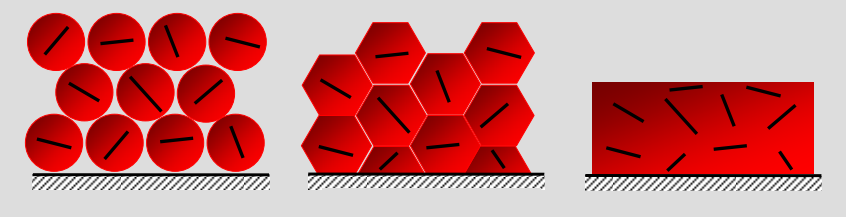
Classical polymer/clay nanocomposites



Improve mechanical, thermal, and barrier properties

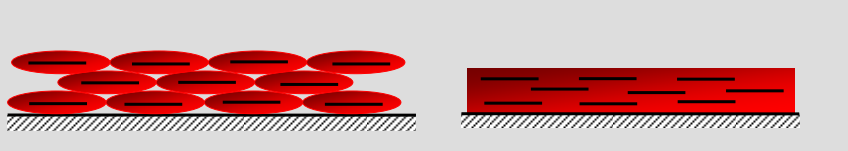


Why clay platelets as fillers?



A requirement is coating transparency:

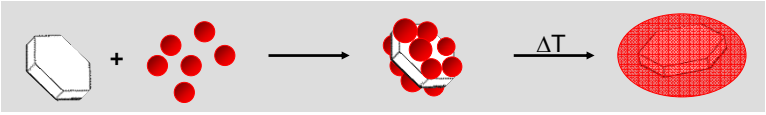
- Better platelet orientation
- Anisotropic hybrid particle formation



Research approach

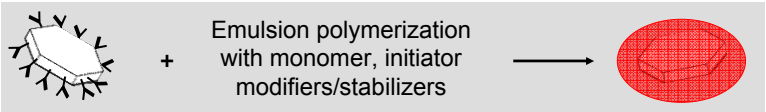
Physical approach

Using exfoliated clay platelets and oppositely charged particles to heterocoagulate. Heat treatment of the polymer on the surface results in film formation and encapsulation.

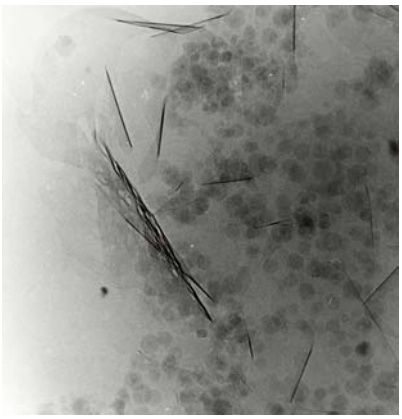


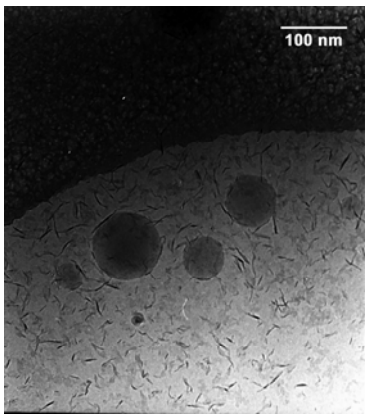
Chemical approach

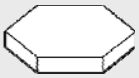
In-situ polymerization of native, physical, chemical or dual modified clay platelets in direct of inverse emulsion polymerization.



Physical approach



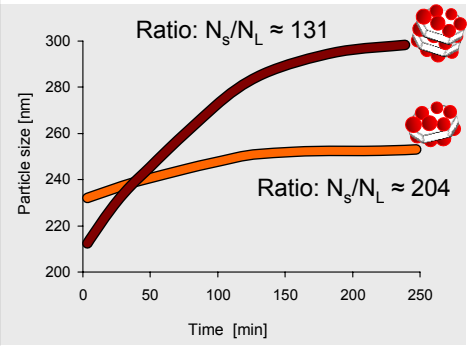




The need for a model colloidal platelet: gibbsite
10 nm thick, 100-200 nm wide

Voorn, Ming, van Herk. ***Macromolecules***,*38(9)*, 3653-3662 **2005**
Voorn Ming, van Herk et al. ***Langmuir***, *21(15)*, 6950-6956 **2005**.

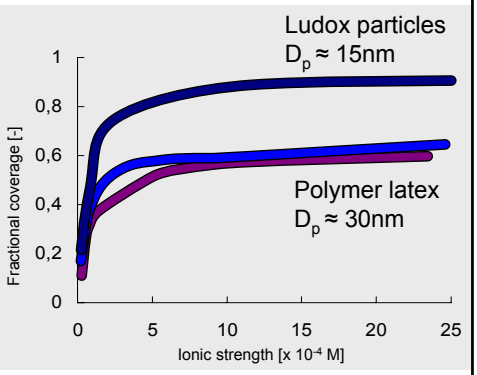
Physical approach



The effect of small particle size on the average fractional surface coverage of gibbsite platelets as a function of ionic strength

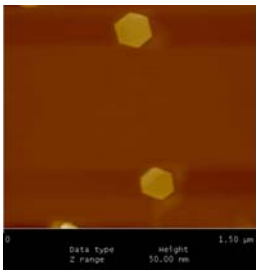
The effect of the ratio of small particle to large platelet

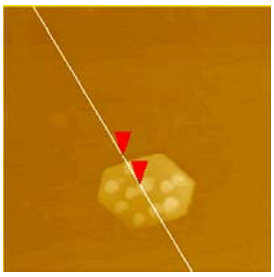
Ratio: $N_s/N_L \approx 204$



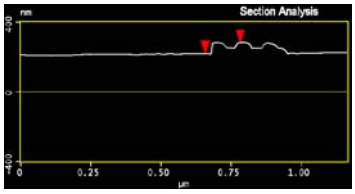
Voorn, Ming, van Herk et al. ***Langmuir***, *21(15)*, 6950-6956 **2005**.
Voorn, Ming, van Herk et al. ***Colloids Surf. A***, *294(1-3)*, 236-246 **2007**.

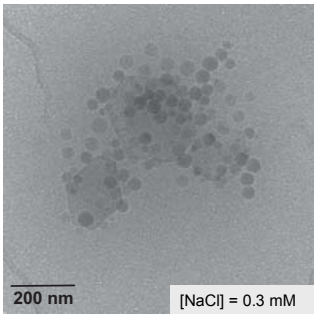
Physical approach characterization





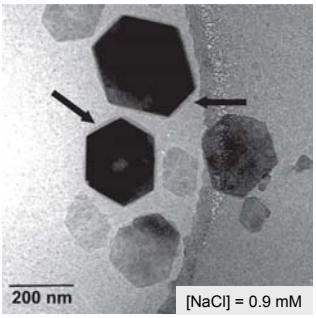
Ratio: $N_s/N_L \approx 204$





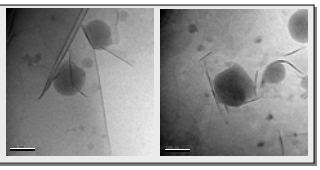
PBMA/gibbsite
$N_S/N_L \approx 198$

ΔT →

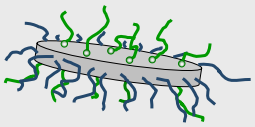


The chemical approach

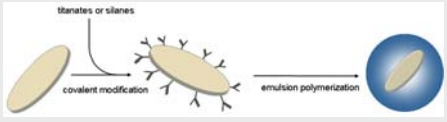
Electrostatic face modification with cationic, hydrophilic monomers to increase the hydrophilicity and subsequent emulsion polymerization



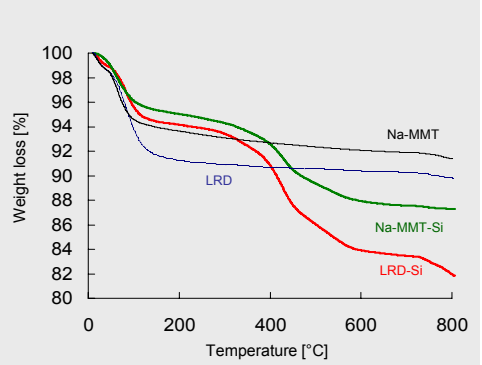
Dual functionalization to increase the hydrophilicity and covalent anchoring to prevent polymerization center shift

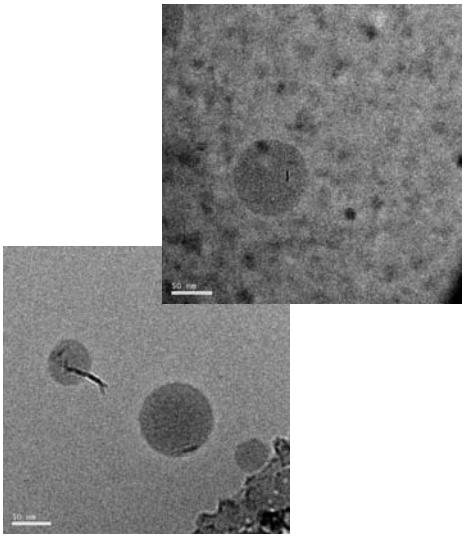


Covalent edge modification and subsequent emulsion polymerization under controlled conditions

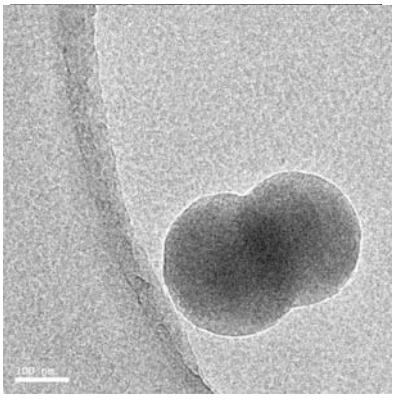


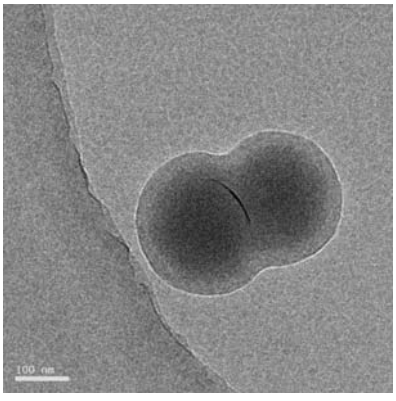
The chemical approach

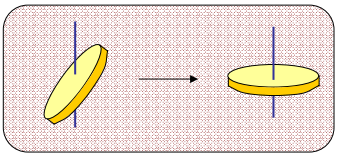




The chemical approach

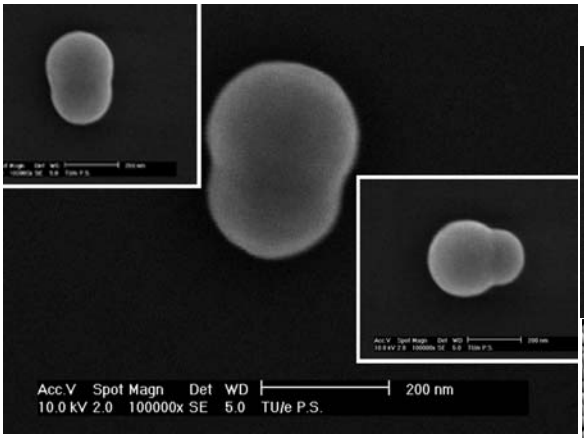


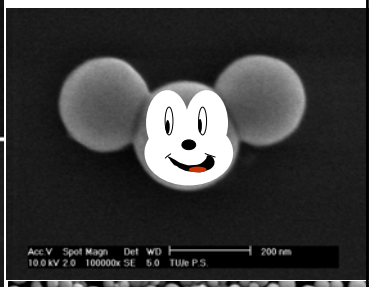


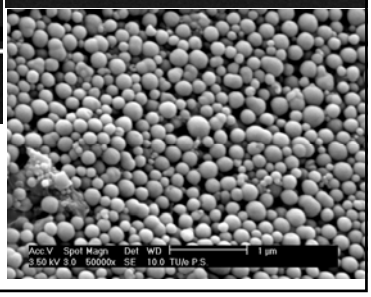


Cryo-TEM with stage tilt

The chemical approach







Voorn et al. ***Macromolecules***, *39(14)*, 4654-4656 **2006**.
Voorn et al. ***Macromol. Symp.***, *245–246*, 584–590 **2006**.

Conclusions

Why we succeeded with the chemical approach?

- Encapsulation is possible with covalent side-group modification.
- Only cationic face modification is not sufficient to encapsulate clay platelets.
- Dual functionalization is also feasible for the encapsulation.
- Keeping in mind that working under starved-fed and below cmc are a prerequisite to avoid secondary nucleation.

What have we achieved with the physical approach?

- Gibbsite as model platelets showed to be successful, although extension to clay did not appear to work.
- Interplay of mixing, size ratio and other experimental conditions is crucial for efficient, controlled heterocoagulation.
- Heat treatment of heterocoagulated structure led to the formation of single-platelet-encapsulated, anisotropic hybrid particles.

Acknowledgements

Supervision

Prof. Alex van Herk, Dr. Marshall (W.) Ming, Prof. Bert de With

Collaborators

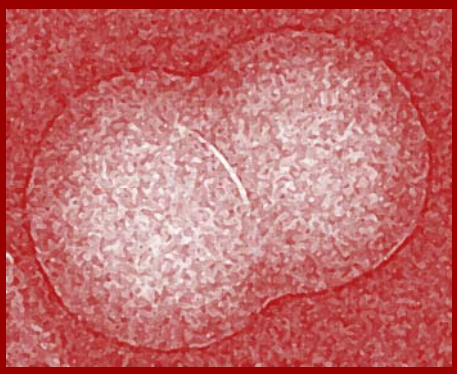
Dr. Peter Frederik & Paul Bomans (Univ. Maastricht)

Prof. Diethelm Johanssmann & P. Gasemjit (Clausthal Univ. Technol.)

Prof. Henk Lekkerkerker & Dr. David van der Beek (Utrecht University)

Dr. Jan Meuldijk, Dr. Jos Laven and Pauline Schmidt (TU/e)

Financial support from the
Dutch Polymer Institute



For the first time, clay platelets inside latex particles have been encapsulated

D. J. Voorn et al., Macromolecules, 2005 38(9) 3653-3662
D. J. Voorn et al., Langmuir, 2005 21(15) 6950-6956
D. J. Voorn et al., Macromolecules, 2006 39(6) 2137-2143
D. J. Voorn et al., Macromolecules, 2006 39(14), 4654-4656
D. J. Voorn et al., Macromol. Symp., 2006 245–246, 584–590
D. J. Voorn et al., Colloids Surf. A, 2007 294(1-3), 236-246
D. J. Voorn et al., Polymer, 2008 in preparation