Rosenheim Technical University of Applied Sciences

Effect of Fillers on the Mechanical Properties of Drawn Polypropylene Fibers

Conplasite (13FH068PA6)

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The mechanical properties of polypropylene (PP) can be improved by incorporating fillers in the polymer matrix [1]. The enhancement depends on filler parameters such as shape and aspect ratio as well as the ability to transfer forces between incorporated fillers and the polymer matrix. For this purpose, a good filler polymer adhesion is needed [2, 3]. However, mechanical properties of PP can be also increased due to specific processing methods, such as the draw down of extruded strands into filaments or fibers creating highly orientated polymer chains and crystal modification. The crystalline structure of the polymer changes from spherulitic morphology to a fibril structure, where crystalline and amorphous areas are connected by tie-molecules [4, 5]. Since many polymeric materials are not neat but reinforced with fillers, the following question occurs: **Is it possible to achieve high strength polymer fibers out of filler reinforced polymers?**

Materials

Polymer	Melting Point [°C]	Density [g/cm³]	Tensile Strength [MPa]	Melt Flow Index [g/10 min]
Polypropylene (PP)	165	0.905	34	1
Maleic Anhydride grafted PP (PP-g-MAH)	135	0.904	-	22-4
Vinyltriethoxysilane grafted PP (PP-g-VTES)	165	≈0.9	30.2	>100
Fillers	Particle size d_{50} [µm]	Aspect Ratio	Filler Shape	Surface Modification
Calcium Carbonate ($CaCO_3$)	1.6	1:1	cubic	specific organic hydrophobisation
Mica	1.5	≈1:20 - 1:40	platelet	no
Wollastonite	25	≈1:7	needle	no

Methods

- Compounding with filler loading of 0.5, 1.5, and 2.5 vol.-% and coupling agent with dosage of 5 wt.-%
- **Fiber Draw Down Process**

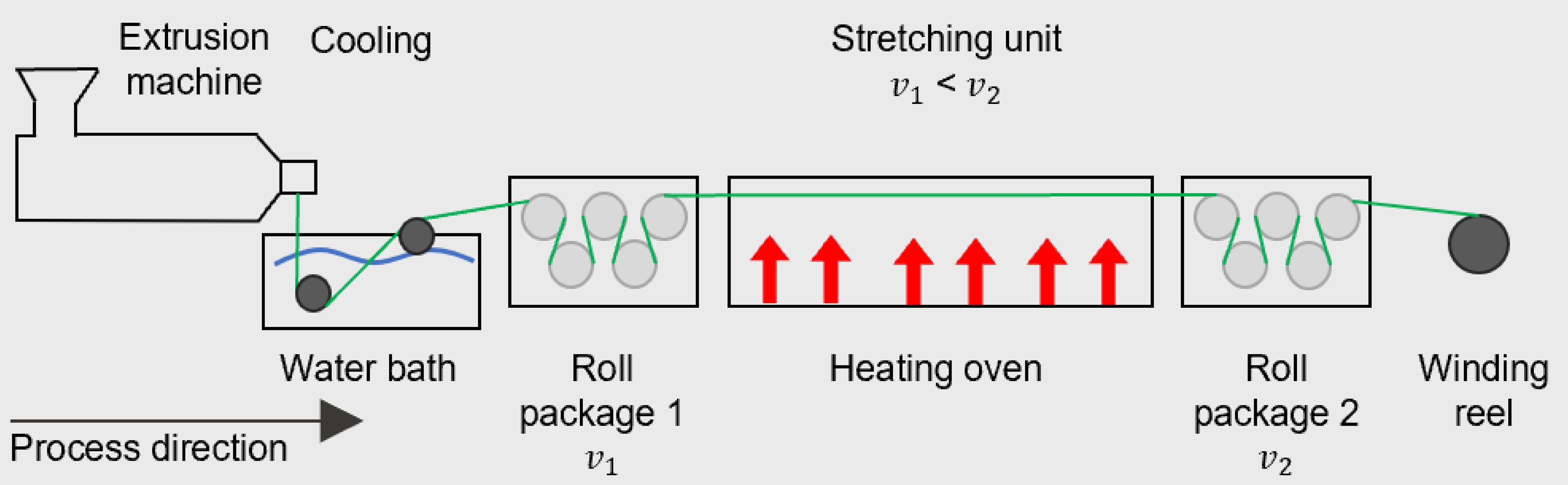
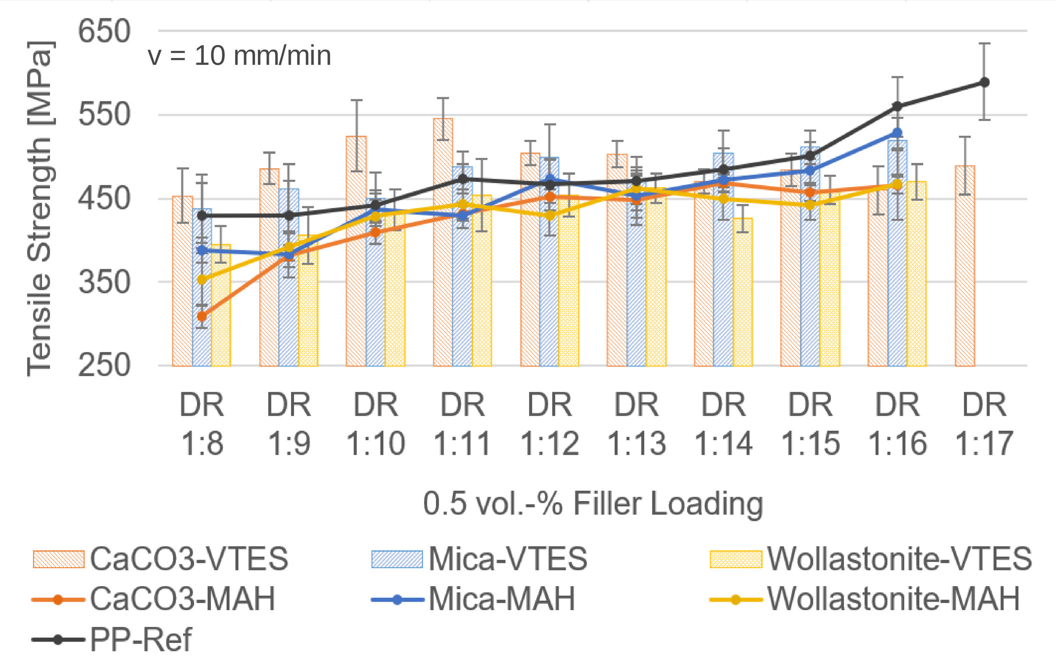
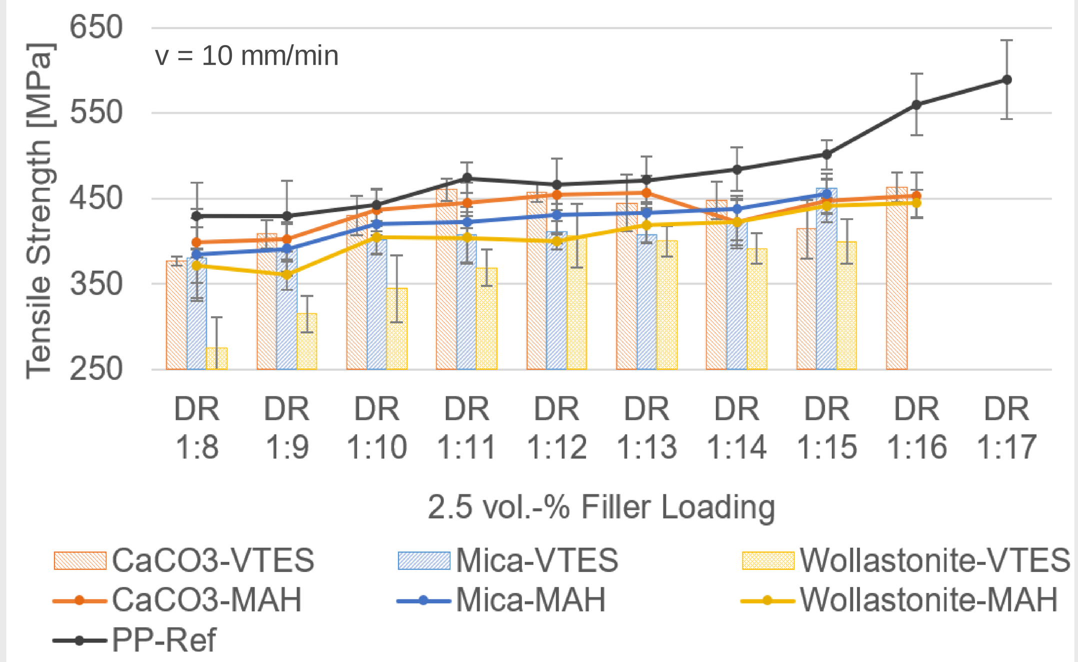


Fig. 1: Schematic description of the fiber draw down process

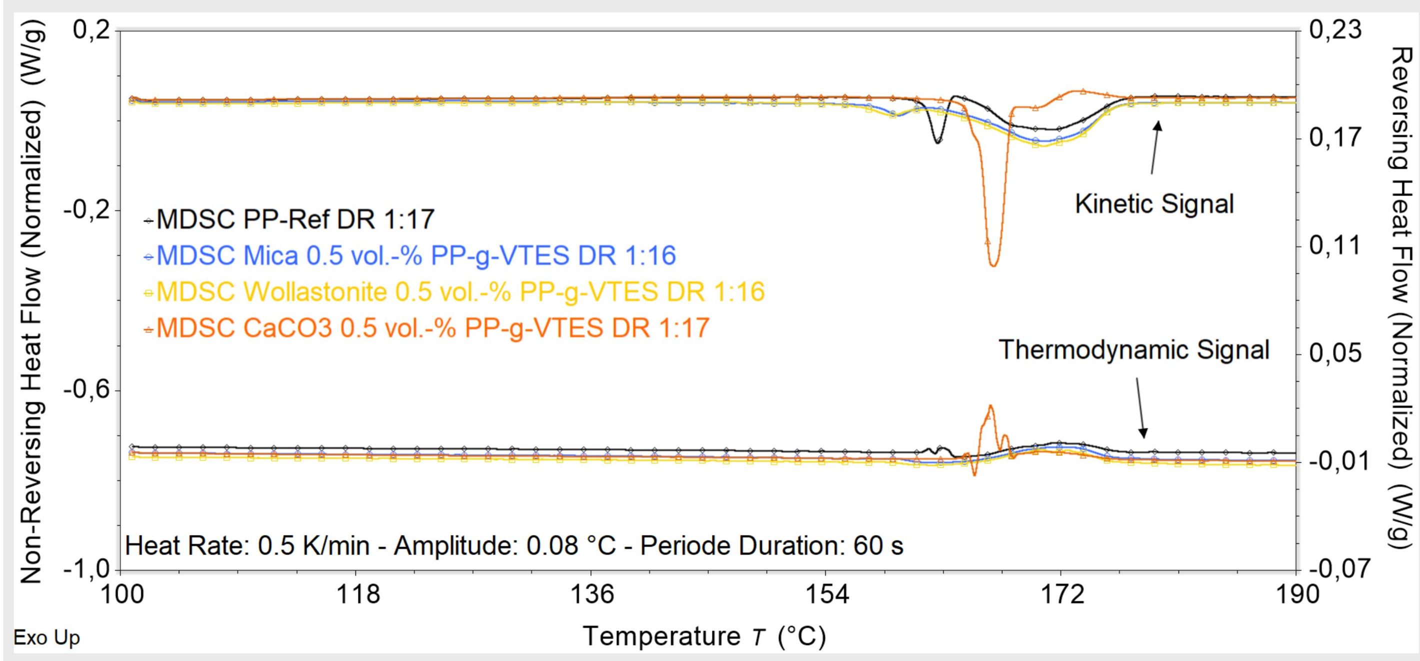
Results

Tensile Tests – Results of different coupling agents with 0.5 vol.-% and 2.5 vol.-% filler loadings

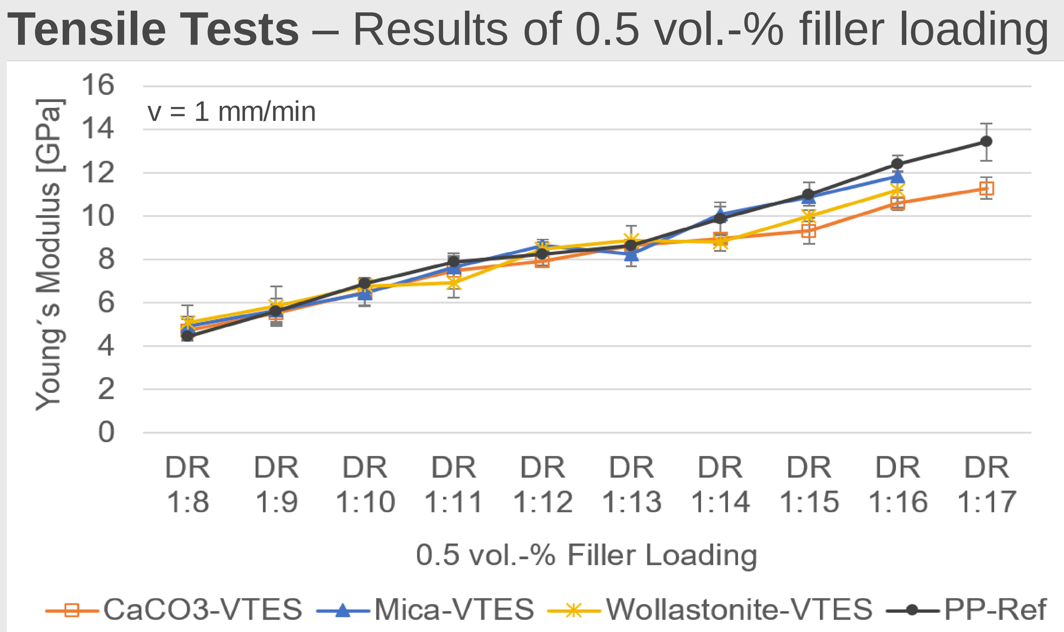


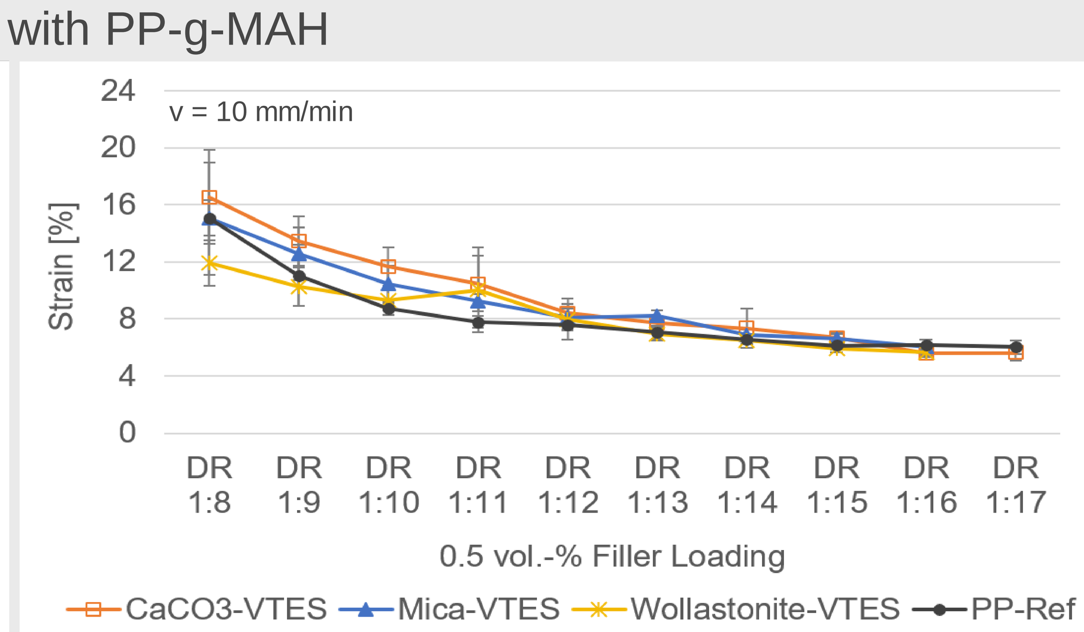


Modulated Differential Scanning Calorimetry – Results of 0.5 vol.-% filler loading with PP-g-VTES

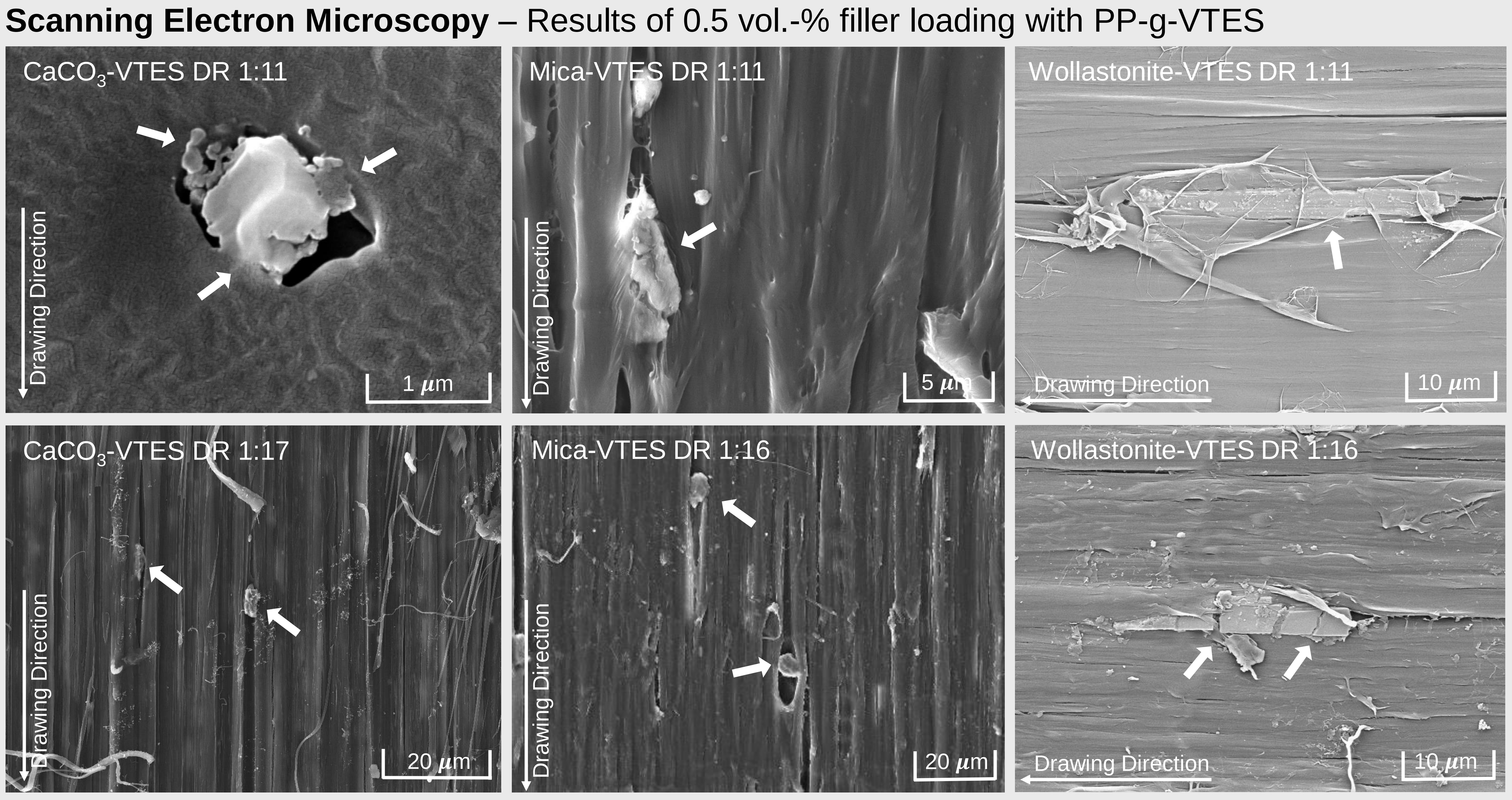


Tensile Tests – Results of 0.5 vol.-% filler loading with PP-g-MAH





Scanning Electron Microscopy – Results of 0.5 vol.-% filler loading with PP-g-VTES



Conclusion

Tensile Tests:

- Tensile strength can be increased at low filler loading and medium draw ratios.
- Coupling agents can increase the tensile strength of PP with certain filler types.
- Best results with $CaCO_3$ and Vinyltriethoxysilane grafted PP: Improvement of 15 %
- Young´s Modulus depends on the draw ratio: The higher the draw ratio the higher the Young´s Modulus.
- Strain decreases due to the draw down process.
- Although the tensile strength is increased, there is no loss in stiffness and elongation at medium draw ratios.

Scanning Electron Microscopy (SEM):

- SEM shows a good adhesion between filler and polymer at medium draw ratios.
- $CaCO_3$ and Mica show a debonding from the polymer with higher draw ratios.
- Wollastonite has a better filler-polymer adhesion, but the filler breaks with higher draw ratios.

Modulated Differential Scanning Calorimetry:

- 2^{nd} melting peak at 155 °C indicates a partly "ultra-drawn" micro fibrillar structure.
- $CaCO_3$ may act as a nucleating agent and increases the crystallinity of the polymer: Further tests with Wide-angle X-ray diffraction would be necessary.

References:

[1] H. Unal, F. Findik, and A. Mimaroglu, "Mechanical behavior of nylon composites containing talc and kaolin", J. Appl. Polym. Sci., vol. 88, no. 7, pp. 1694-1697, 2003
[2] K. Friedrich and Z. Zhang, "Effects of various fillers on the sliding wear of polymer composites", Comp. Sci. Technol., vol. 65, 15-16, pp. 2329-2343, 2005
[3] S. Ahmed and F. R. Jones, "A review of particulate reinforcement theories for polymer composites", 1990
[4] A. Peterlin, "Molecular model of drawing polyethylene and polypropylene", J Mater Sci, vol. 6, no. 6, pp. 490-508, 1971
[5] F. J. Balt-Calleja and A. Peterlin, "Plastic deformation of polypropylene", J Mater Sci, vol. 4, no. 8, pp. 722-729, 1969