MELT MIXING OF POLYETHYLENE/MWNT COMPOSITES USING A DSM XPLORE MICROCOMPOUNDER: THE USE OF DIFFERENT SCREW DESIGNS

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Introduction

- The incorporation of multi walled carbon nanotubes (MWNT) in insulating polymer blends improves their electrical conductivity.
- A good dispersion and distribution of primary nanotube agglomerates is a precondition for obtaining a suitable property balance between electrical and mechanical properties.
- The number and size of agglomerates should be minimized which can be done by appropriate mixing conditions. Next to a variation of melt mixing conditions the use of different designs of screws in case of twin-screw extrusion or compounding can be helpful for that purpose.
- Small scale mixing using microcompounders or batch-mixers were shown to be meaningful in order to investigate basic effects of mixing conditions on dispersion of MWNT.
- In this contribution, the influence of four different screw designs used in a DSM Xplore microcompounder with corotating conical screws on the MWNT dispersion and the electrical resistivity of the composite was investigated.
- The system under investigation consisted of high density polyethylene, a material in which due to the incompatibility to (more polar) nanotubes the achievement of a good dispersion was reported to be difficult.

Materials and methods

Materials

- high density polyethylene (HDPE, Lupolen® 4261A)
- MWNT (Nanocyl® 7000) Nanocyl S.A. (Belgium)
- concentrate of MWNT coated with HDPE (22.6 wt%, provided by Nanocyl S.A., Belgium)

Melt compounding

- HDPE was melt mixed with 1-5 wt% MWNT using a 15 cm³ microcompounder (DSM Xplore, Geleen, The Netherlands) operating at 200°C, 50 rpm and a mixing time of 5 min.
- The composites were compounded with four different screw designs.
- The screw designs differentiate in the type of notches arranged on the screws, for what narrow channels (2 mm wide) were machined through the screw flights slots in different ways.

Electrical measurements

- The electrical volume resistivity was measured on compression molded samples (diameter 60 mm thickness 0.5 mm) or strips (approx. 20 x 3 mm²) cut from the pressed sheets.

Screw design 1 (classical screw, non notched)

Screw design 2 (full, vertical notched, backflow)

Screw design 3 (inclined partial notched, backflow)

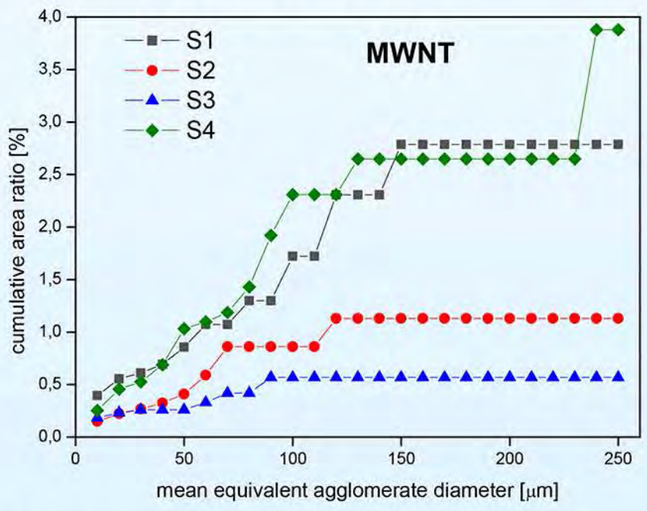
Screw design 4 (angular, trapezoidal notched)

Microcompounder (DSM Xplore, The Netherlands)

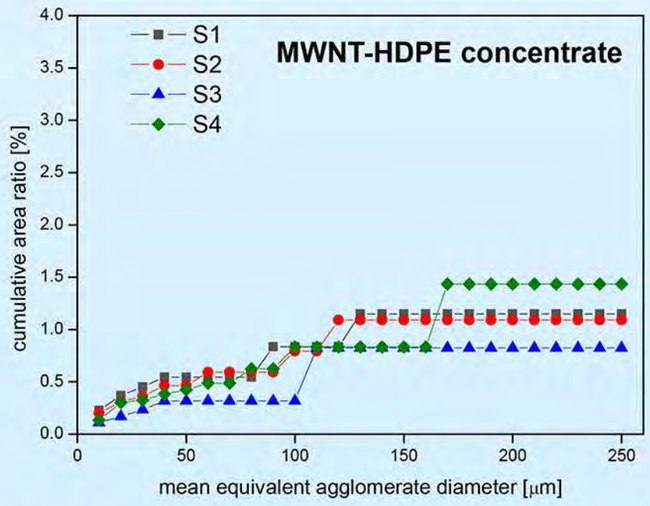
Press (Paul-Otto Weber GmbH, Remshalden, Germany)

Results - Influence of the design screws

Cumulative area ratio

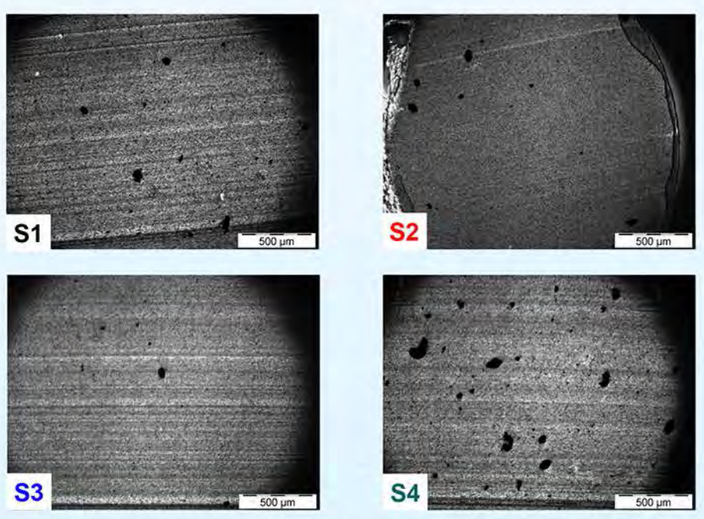


Cumulative area ratio vs. equivalent diameter of agglomerates in HDPE composites with 1 wt% MWNT melt mixed using different screws

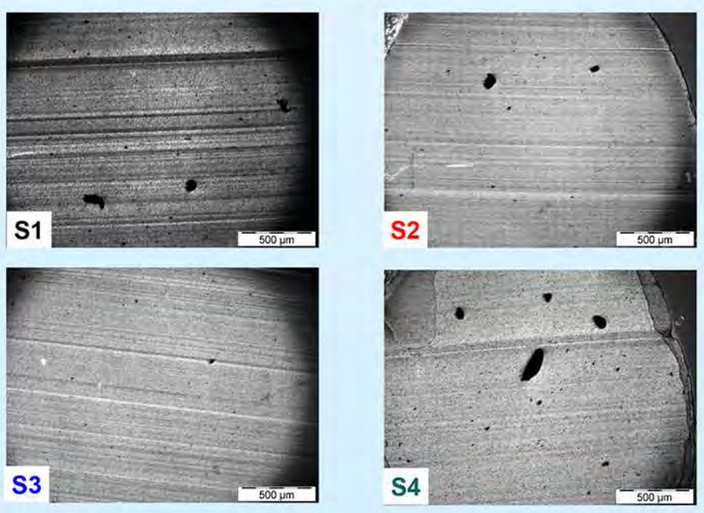


Cumulative area ratio vs. equivalent diameter of agglomerates in HDPE composites with 1 wt% HDPE-coated MWNT melt mixed using different screws

Morphology

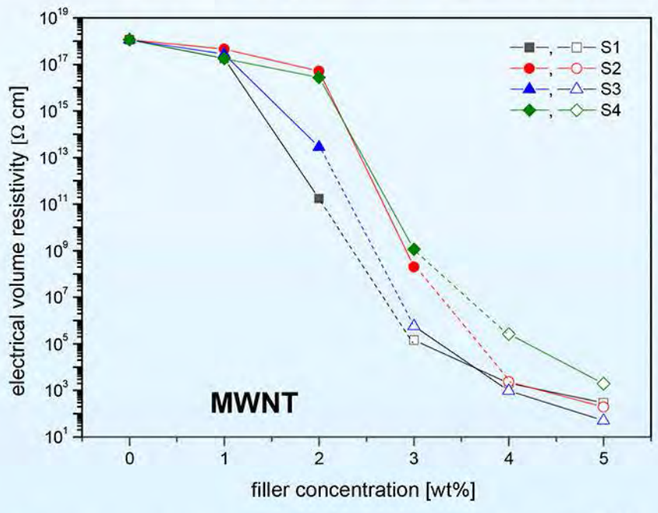


Light microscopy image of HDPE composites with 1 wt% MWNT melt mixed using different screws

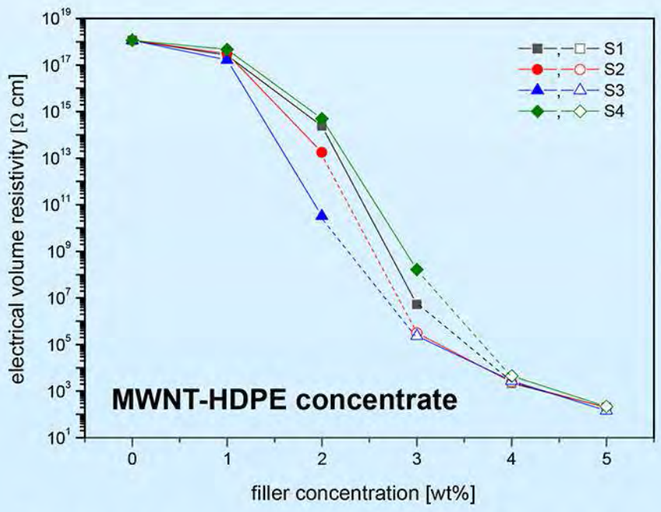


Light microscopy image of HDPE composites with1 wt% HDPE-coated MWNT melt mixed using different screws

Electrical volume resistivity

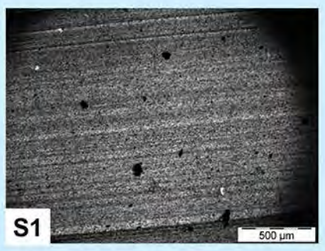


Electrical volume resistivity vs. MWNT content of HDPE-MWNT composites melt mixed using different screws



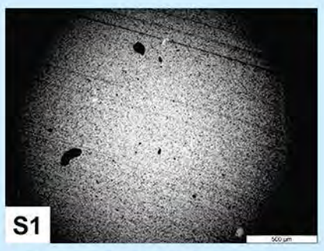
Electrical volume resistivity vs. MWNT content of composites with HDPE-coated MWNT melt mixed using different screws

Variation of the screw speed



Screw design 1
PE/MWNT composite
(1 wt%, 50 rpm)

Screw design 2
PE/MWNT composite
(1 wt%, 50 rpm)



Screw design 1
PE/MWNT composite
(1 wt%, 200 rpm)

Screw design 2
PE/MWNT composite
(1 wt%, 200 rpm)

Light microscope images of composites which were compounded with the screw designs 1 and 2 at 50 rpm and 200 rpm

Summary

- In conclusion the design of the screw and the variation of the screw speed have an influence on the dispersion MWNT agglomerates in the HDPE matrix.
- These effects on the dispersion of carbon nanotubes are smaller when using HDPE-coated MWNT compared to the use of pure MWNT.
- The design of the twin screws has only a small impact on electrical percolation and the values of the electrical volume resistivity.
- In summary, the design of screws 3 having inclined partial notches inducing a certain amount of backflow seems to be suitable to affect affirmatively the dispersion of the MWNT and also revealed comparatively low resistivity values.

References

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