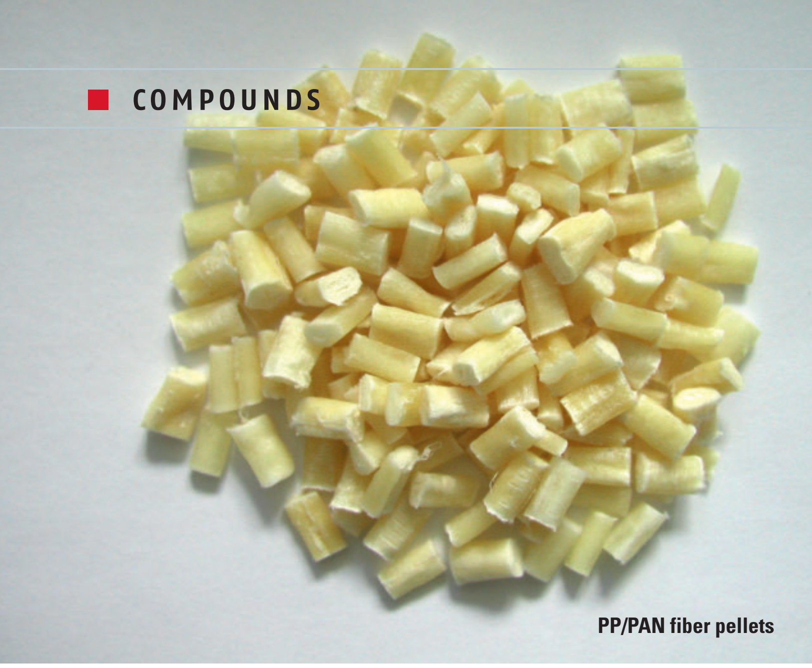
PP/PAN fiber pellets

PP/PAN Fiber Compounds. Inexpensive and light with excellent mechanical properties. Due to their low specific gravity and balanced property profile a broad spectrum of applications, particularly in lightweight construction and as cost effective alternatives to technical polymers, is opening up for fiber-reinforced thermoplastic compounds based on polypropylene and polyacrylonitrile fibers.

Exploiting Opportunities in Lightweight Construction

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With their excellent properties fiber-reinforced polymers are becoming increasingly popular and displacing classic materials. Technical polyacrylonitrile (PAN) fibers are extremely interesting for the development of thermoplastic composite materials. They can not only replace glass fibers in composites , but also open up significant new potential for the development of a new class of cost effective materials with exceptional impact absorption that are also suitable for applications with highly demanding mechanical property requirements.

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The initial path finding results for the reinforcement of polypropylene with PAN fibers have already been presented [1] and possible applications listed. Within the framework of a research project at the Thuringian Institute of Textile and Plastics Research (Thüringisches Institut für Textil- und Kunststoff-Forschung e. V. – TITK), Rudolstadt, Germany, further investigations have been made into the manufacturing and processing characteristics as well as an optimization of the mechanical properties, particularly the behavior under impact loading. Based on these, further synthetic fiber-reinforced polymers with new property profiles were developed [2].

Producing PP/PAN Compounds

Following the basic tenets of real world formulation development only commercially available material components were considered that both from a logistics as well as a capacity stand point would be available for an industrial implementation.

PAN grades, for example Dolanit 10 (manufacturer: Dolan GmbH), that are primarily intended for technical applications, such as the reinforcement of cement and bitumen based products, offer alongside high mechanical strength adequate chemical and thermal stability for processing with thermoplastic materials. They are available as cut fibers (4–12 mm) in various fiber thicknesses as well as continuous crimped fiber roving.

The compounds are produced on a co-rotating twin screw extruder as a cylindrical pellet (8 mm long, Title picture). These are suitable for further processing using injection molding, extrusion and blow molding techniques.

Since organic polymer fibers have very poor solid flow properties due to their low density and strong fiber-to-fiber attraction conventional dosing techniques cannot be used. Special dosing and feeding

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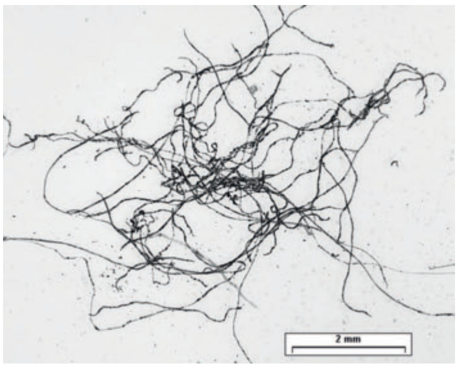

Fig. 1. PAN fibers from the compound after dissolving the PP matrix

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Mechanical Properties

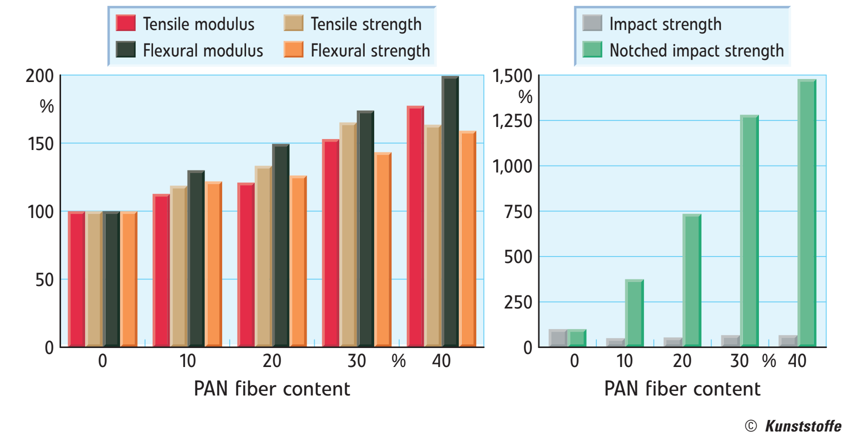

Fig. 2. The dependence of relative changes in mechanical properties of PP/PAN compounds on fiber content

devices were developed to meter the PAN fibers into the extruder.

Impact Resistant even when Cold

In comparison to glass fibers, PAN fibers are significantly more elastic and so less fiber breaks occur during the shear intensive processing steps. The extruder configuration and the process conditions were designed to deliver a homogeneous distribution of the fibers with a high degree of fiber impregnation and the least possible fiber damage. Mid range fiber lengths of 3 to 5 mm in the component (Fig. 1) deliver a much higher aspect ratio (> 200) compared to conventional short fiber-reinforced plastics (approx. 20 to 30).

Mechanical testing of standard injection molded test bars shows that this results in exceptionally impact resistant materials. The skeletal fiber structure in the compound absorbs the impact energy and distributes it in the test piece.

The property profile of the compound varies according to the amount of short fiber PAN added (Dolanit 10; 1.5 dtex, 4 mm long) (Fig. 2). The degree of reinforcement increases continuously up to about 40 % PAN fiber content. It should be particularly emphasized that the extremely high level of notched impact strength is seen in combination with significantly raised strength and stiffness. This applies not only at room temperature, but also at low temperatures. Variants with 30 % PAN fibers offer unnotched impact strengths (Charpy) of ≥ 75 kJ/m^2 and notched impact strengths of 13 kJ/m^2. Table 1 shows an example of key property values of a PP/PAN compound in comparison to unfilled and 30 % glass fiber-reinforced polypropylene.

The fibers sticking out of the fracture surface (Fig. 3) demonstrate just how long they are in the compound. It is interesting to note that the fibers do not break at the fracture surface, but instead are pulled out of the matrix, which is known as the fiber pull out effect. This advantageous effect can also be clearly seen with biaxial impact loading, which occurs much more often in practice than

! Company Profile

Based on the research and development achievements of the Institute for Textile Technology of Synthetic Fibers (Institut für Textiltechnologie der Chemiefasern) the industrial research of the Thuringian Institute of Textile and Plastics Research **(Thüringisches Institut für Textil- und Kunststoff-Forschung e.V. – TITK)**, whose initial focus was purely on the use of fiber materials in the textile industry, has developed into a globally recognized institute for functional and construction polymer materials.

As a research facility with a strong commercial bias the TITK conducts preliminary and also applied research in close cooperation with the industrial sector. The TITK supports innovation efforts of small and medium sized enterprises with interdisciplinary expertise, innovative ideas, industry knowledge as well as a modern technical infrastructure.

The objective of this cooperation is the development of processes and competitive products according to individual requirements of clients from a wide range of chemical, polymer and textile technology backgrounds.

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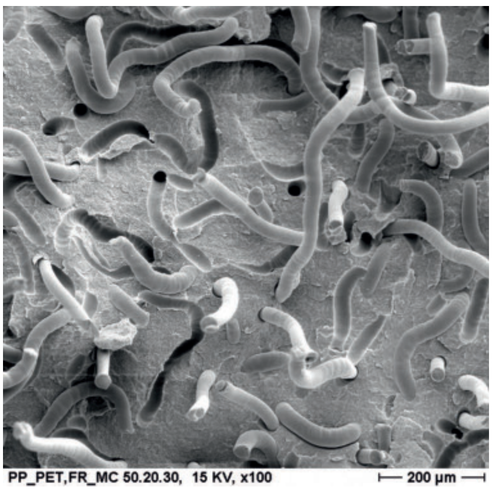

Fig. 3. The fracture surface of the component shows a fiber pull out effect

Compound		PP	PP / PAN	PP / GF
Fiber content	[%]	0	30	30
Density	[g/cm^2]	0.90	0.98	1.14
Tensile E-modulus	[MPa]	1,670	2,850	4,800–8,300
Tensile strength	[MPa]	34	61	55–80
Flexural E-modulus	[MPa]	1,320	2,500	3,800–7,600
Normal flexural stress	[MPa]	33	55	48–140
Impact strength 23°C	[kJ/m^2]	124	85	15–45
Impact strength -30°C	[kJ/m^2]	13.2	75	8–42
Notched impact strength 23°C	[kJ/m^2]	2	25.6	6–10
Notched impact strength -30°C	[kJ/m^2]	1,1	13	4–7
HDT/A	[°C]	52	66	138
Vicat / B	[°C]	90	112	110–130
Ball indentation hardness	[N/mm^2]	72	93	110

Table 1. PP/PAN compound in comparison to unreinforced PP and PP30GF

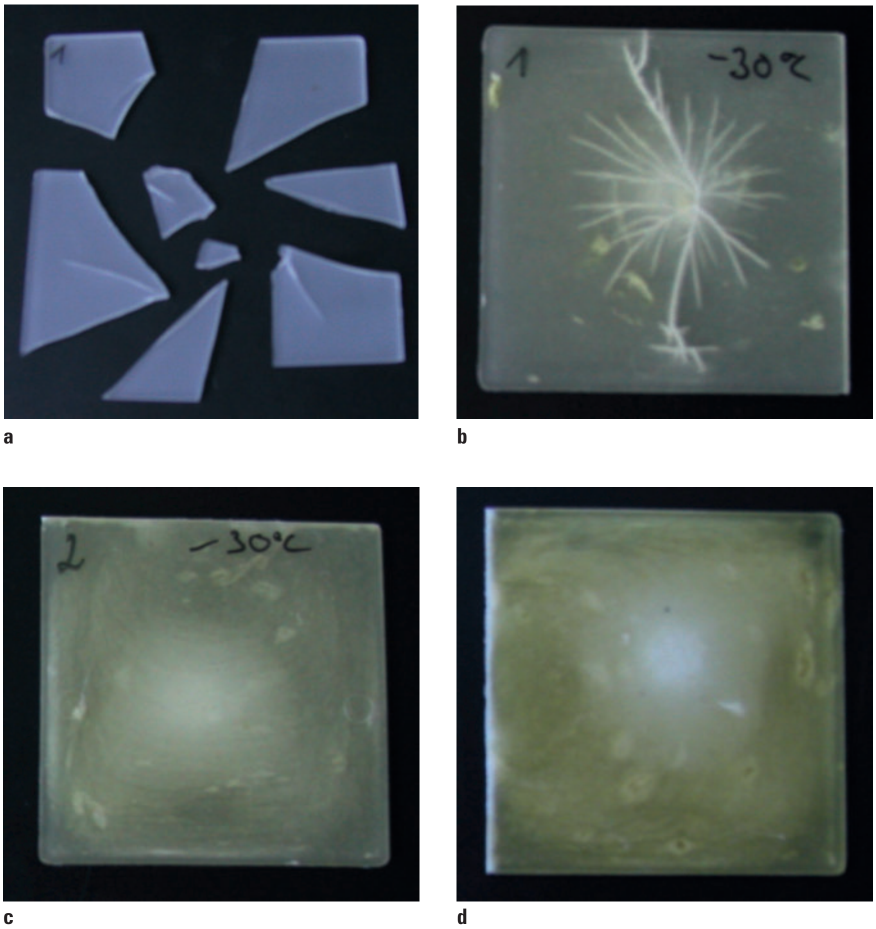

Fig. 4. Pictures showing damage in a ball drop test (temperature: -30°C): a = unreinforced PP, b = PP with 10 % PAN, c = PP with 20 % PAN, d = PP with 30 % PAN

pure impact bending or tensile impact loading. The pictures of the ball drop test at low temperatures (Fig. 4) show that even at low fiber loadings the brittle break with a strong tendency to splinter which is common for pure polypropylene can be prevented. Above 20 % fiber content the material is only lightly dented and no longer shows any crack formation.

A Question of Length

Since the behavior of the composite material is largely determined by the characteristics of the fibers and the degree of impregnation the modification of the PP matrix has only a marginal effect on the properties of the compound.

The key mechanical values are directly related to the length of the reinforcing material in the finished component. The median fiber length in the compound can be raised by a further 1 to 2 mm by the use of uncut input fibers, which further improves the properties (Fig. 5).

Surprisingly the excellent reinforcement can also be achieved using coarser PAN fibers with approx. 30 % lower specific strengths (Dolanit 12) (Fig. 6). Since such families of fiber deliver compounds with even better flexural properties than the high strength grades and only come in slightly behind on tensile strength these can also be recommended for some applications.

Conventional adhesion promoters as used mainly for glass fiber reinforcement show only limited effects in the polypropylene/PAN system. Test results with products based on maleic anhydride grafted polypropylene and functionalized amino silanes are shown in Fig. 7. Whilst tensile properties and impact strength are positively influenced across the board the addition of adhesion promoters has in some cases a negative influence on the flexural strength and notched impact strength. In this context account has to be taken of the fact that the PAN fibers contain production relat-

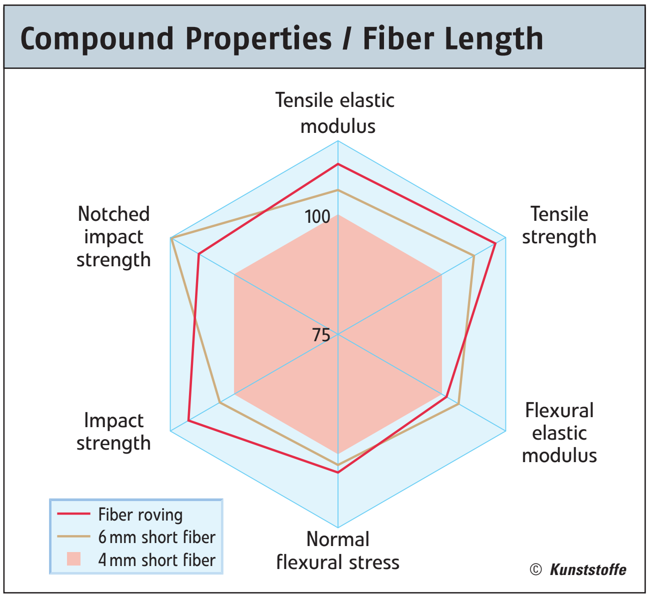

Fig. 5. The dependence of relative compound properties on fiber length

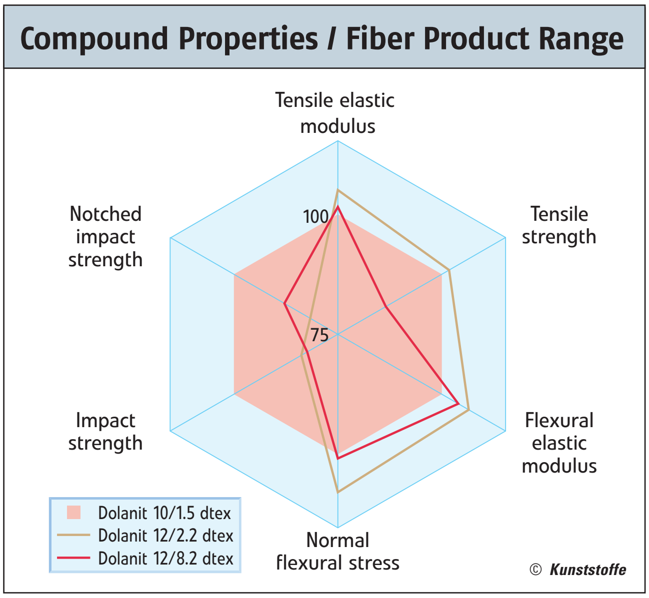

Fig. 6. The dependence of relative compound properties on the fiber product range

ed treatment additives whose influence on the fiber matrix adhesion has not yet been studied.

Outlook

Compounding polypropylene with PAN fibers delivers an interesting combination of material properties that could significantly expand the application spectrum of reinforced polypropylene – not only in the automobile segment.

As a low cost alternative to technical plastics the new compounds offer the following advantages:

- they fulfill exacting demands for impact loading even when cold,
- high heat distortion resistance and softening temperature,
- reduced material use and low density make light weight construction possible,
- high cost effectiveness through low material and manufacturing costs.

In lightweight construction new potential is opened up by the replacement of glass fiber due to the following advantages:

- low material density of < 1g/cm³ up to 30 % fiber content,
- exceptionally high notched and unnotched impact strength combined with raised strength and stiffness,
- simple and low wear manufacture and processing,
- residue-free thermal recycling possible.

Compound Properties / Adhesion Promoters

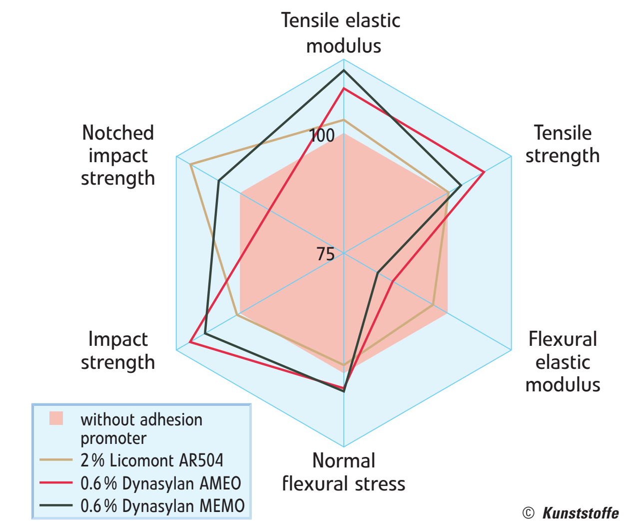

Fig. 7. The dependence of relative compound properties on adhesion promoters

However, they are also suitable as additives. Particularly in combination with embrittling additives such as natural fibers and flame retardants they behave as excellent impact modifiers even at low concentrations.

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