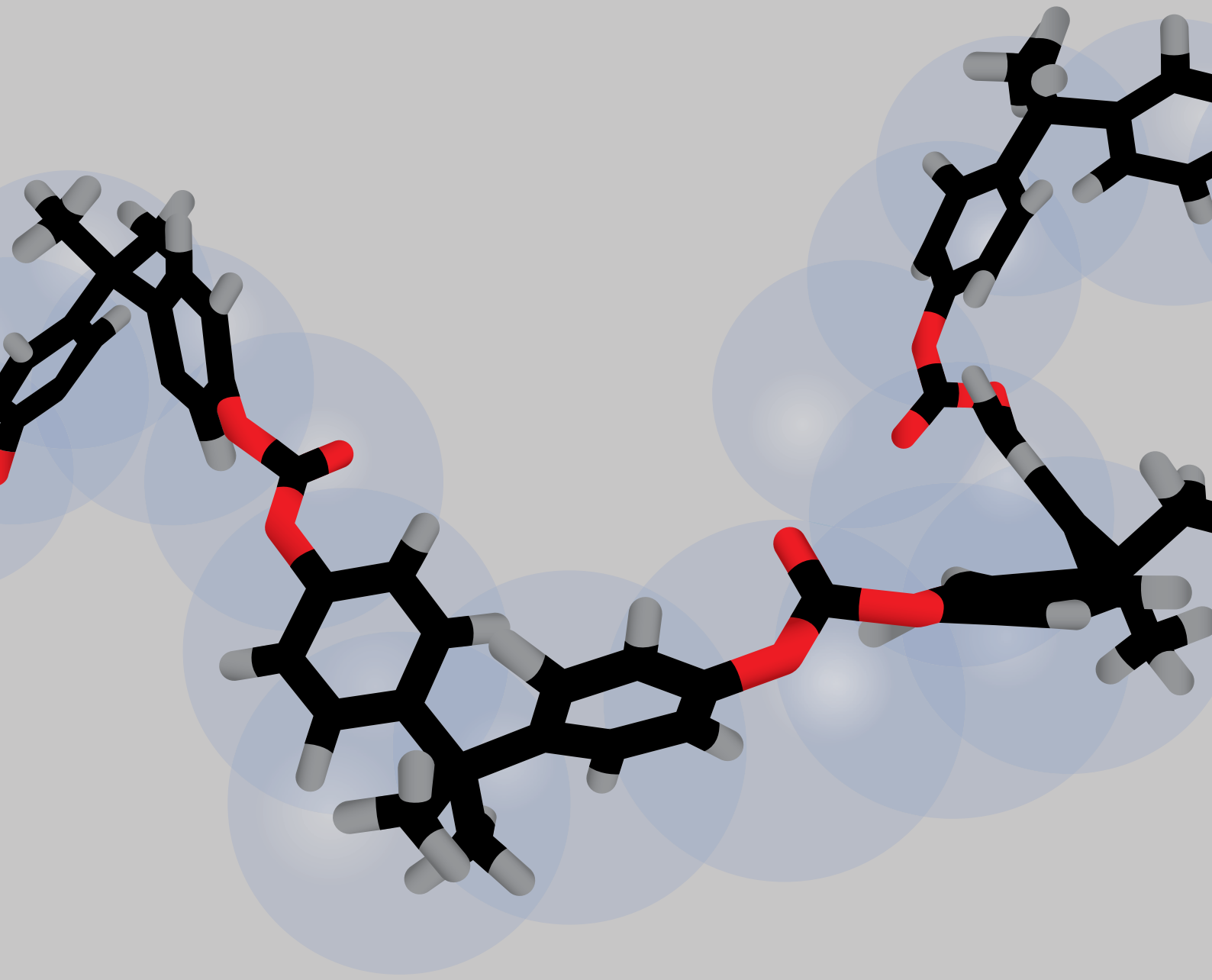
SUPERIOR GRAPHITE

RGC™

RESILIENT GRAPHITIC CARBONS
for Polymer Applications



Resilient Graphitic Carbons for Polymer Applications

Resilient Graphitic Carbons (RGCs) are manufactured from premium carbon sources selected by Superior Graphite. RGCs offer high resiliency in an extremely pure form of graphite as a result of our proprietary high temperature purification process. This material has proven beneficial in a number of advanced technology applications.

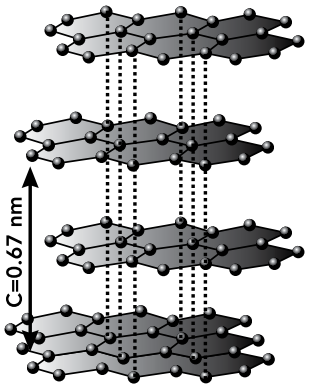


Fig. 1

During the continuous high temperature purification process, the products precursor is partially transformed into the typical hexagonal lattice of graphite (fig. 1). At the same time an extremely high purity and an important change in morphology is achieved. Fig. 2 illustrates a dramatic increase of porosity after treatment. As a result, RGC technological achievements lead to a number of specific and unique features such as:

1. Very high purity
2. Increased particle porosity
3. Controlled degree of graphitization
4. Consistent particle size and shape control for sensitive applications
5. Increased resiliency

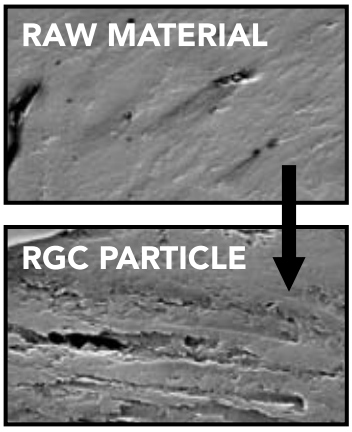


Fig. 2

The most prominent feature of RGCs is the uniquely identified resiliency performance (fig. 2). RGC particles can be compressed from between 50–700 bar (700–10,000 PSI) without significant particle destruction and recover their original shape as pressure subsides. Resiliency is tested by placing the RGCs in a metallic mold and subjecting them to pressure. As shown in fig. 3, the spring back effect is quantified by measuring the heights h_0 and h_r of the columns of compression and decompression, and calculating h_r as a percentage of h_0.

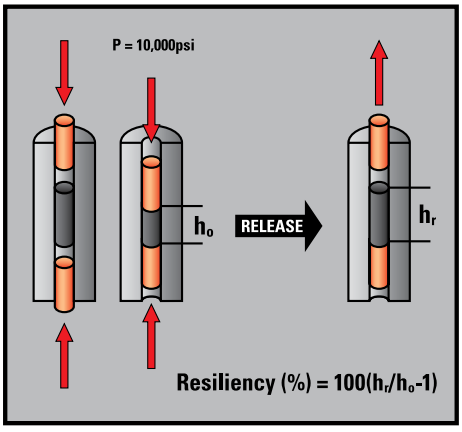


Fig. 3

RGCs were first used as friction modifiers in brake linings, resulting in improved pad compressibility and noise reduction. Finer grades have found a strong following in automotive engineered polymer applications such as:

- Friction torque limiters in dampened flywheel clutches
- Plain bearings
- Anti-friction coatings for engine piston skirts

Due to the intrinsic properties of Superior Graphite produced RGCs, areas under investigation by organizations such as the Institute for Composite Materials of the University of Kaiserslautem (IVW), in close collaboration with producers like KS Gleitlager GmbH, KS Kolbenschmidt GmbH, and LuK GmbH include:

1. Tensile strength and modulus effects
2. Sliding and wear property
3. Tribological performance
4. High temperature applications requiring performance stability

Several papers (sources listed on back page) were presented by the IVW during the "Viennano '07" – exhibition in March 2007 and on other occasions. The following is a very brief summary of the information available.

1. Damped flywheel clutches

A damped flywheel clutch shifts the transmission's resonance frequency below the engine's idle run frequency. It reduces gear rattles and prevents the engine's vibrations from reaching the car's chassis, thus contributing to the driving comfort. The friction torque limiter (the ring shown in fig. 4) is an essential part of a modern flywheel clutch. It limits the transmittable torque during engaging and disengaging, thus protecting engine and transmission from harmful torque peaks. Friction torque limiters are subjected to extreme tribological stress. Their friction surfaces must be highly resistant to sliding wear and maintain a constant coefficient of friction during their entire life cycle.

Fig. 4 with courtesy of LuK GmbH & Co

Two proprietary nano materials of the IVW´s, based on PA46 and PEEK were formulated by IVW and evaluated against two commercially available products.

		Nano materials (IVW GmbH)		Commercial micro materials	
		Nano-PA46	Nano-PEEK	Micro-PA46	Micro-PEEK
Micro fillers	SCF	X	X	X	X
	Graphite*	RGC	RGC	X	X
	PTFE	–	–	X	X
Nano fillers	TiO_2	X	X	–	–
	ZnS	X	X	–	–

*RGC materials were used only in Nano-PA46 and Nano-PEEK formulas per F. Haupert-IVW.
An unknown source was used in the commercial micro material composites.

Result: The IVW's Nano-PEEK formulation, which contained RGC from Superior Graphite along with SCF, TiO_2 and ZnS performed best of all materials for this application in terms of improved coefficient of friction and reduction of wear.

2. Plain bearings

The IVW and KS Gleitlager tested the Nano-PEEK in metal-polymer plain bearings. Such bearings are ubiquitous in modern vehicles – in shock absorbers, clutch cross shafts, steering shaft joints, suspension joints and disk brakes (fig. 5). In addition, there are other automotive applications requiring both high temperature resistance and high pv**:

- Transmission mountings
- Camshaft bearings in fuel injection pumps
- Motor bearings

Fig. 5 with courtesy of KS Gleitlager GmbH

Result: As compared to other widely-used compounds such as PEEK containing 30% of SCF (short carbon fibre) – with or without solid lubricants – this compound showed a superior performance at high load levels, and has been adopted by KS Gleitlager as a standard friction material for plain bearings.

The following details might be of interest: The IVW embedded varying quantities of nano-sized ZnS in PEEK. It was found that the tensile modulus of the compounds increased with the quantity of filler. 15% vol. of ZnS increased the tensile modulus by 44% without reducing the tensile strength. Fillers are known to lower the wear resistance of PEEK. It was found that in compounds subjected to severe tribological stress, abrasion resistance decreased with the filler level. But as far as non-abrasive sliding behavior was concerned, the specific wear rate turned out to be a non-linear function of the filler level, with a pronounced minimum at 3% vol. of ZnS – plus small quantities of RGC.

3. Anti-friction coating for piston skirts

A new class of anti-friction coatings was developed and tested by the IVW and KS Kolbenschmidt for piston skirts (fig. 6). This is an important application, considering that in combustion engines significant energy losses are caused by friction, with 25% of the total losses occurring at the piston module. The new anti-friction coatings for piston skirts are based on proprietary mixtures of a polymeric binder, a solvent, and functional fillers – mostly nano-scaled TiO_2, ZnS and RGC.

Fig. 6 with courtesy KS Kolbenschmidt GmbH

Result: The optimum content of RGC was found to be in the range between 5% and 10%, which is considerably lower than the graphite content in conventional anti-friction coatings.

Conclusion: In all applications tested, performance of Nano-materials using RGC in combination with SCF and nanofillers like TiO_2 and ZnS surpassed performances of commercial micro materials.

RGCs are manufactured by Superior Graphite in Sweden. They are available in a wide variety of qualities with average particle sizes ranging from a few microns to 9mm. A general leaflet on RGCs as well as specific product information and safety data sheets are available on request.

**A pressure x velocity rating for polymer bearing surfaces.

SUPERIOR GRAPHITE

Superior Graphite specializes in thermal purification, advanced sizing, blending, and coating technologies, providing value added graphite and carbon-based solutions globally.

Combining 90 years of experience and advanced technologies into every facet of the organization, a wide range of markets are served such as; agriculture, battery/fuel cells, ceramic armor, carbon parts, ferrous/nonferrous metallurgy, friction management, hot metal forming, polymer/composites, powder metals, lubricity, and performance drilling additives.

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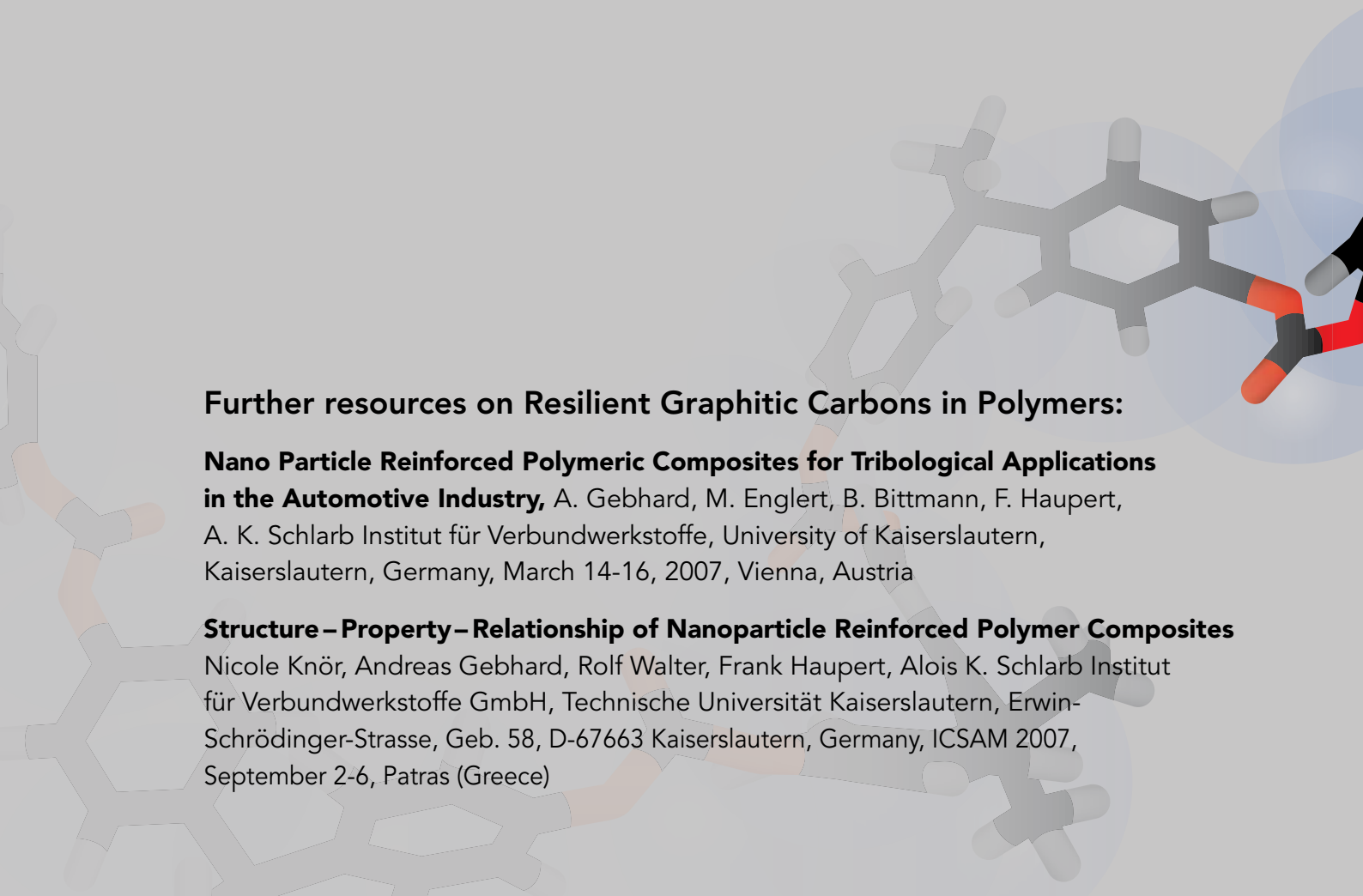

Further resources on Resilient Graphitic Carbons in Polymers:

Nano Particle Reinforced Polymeric Composites for Tribological Applications in the Automotive Industry, A. Gebhard, M. Englert, B. Bittmann, F. Haupert, A. K. Schlarb Institut für Verbundwerkstoffe, University of Kaiserslautern, Kaiserslautern, Germany, March 14-16, 2007, Vienna, Austria

Structure – Property – Relationship of Nanoparticle Reinforced Polymer Composites Nicole Knör, Andreas Gebhard, Rolf Walter, Frank Haupert, Alois K. Schlarb Institut für Verbundwerkstoffe GmbH, Technische Universität Kaiserslautern, Erwin-Schrödinger-Strasse, Geb. 58, D-67663 Kaiserslautern, Germany, ICSAM 2007, September 2-6, Patras (Greece)

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