

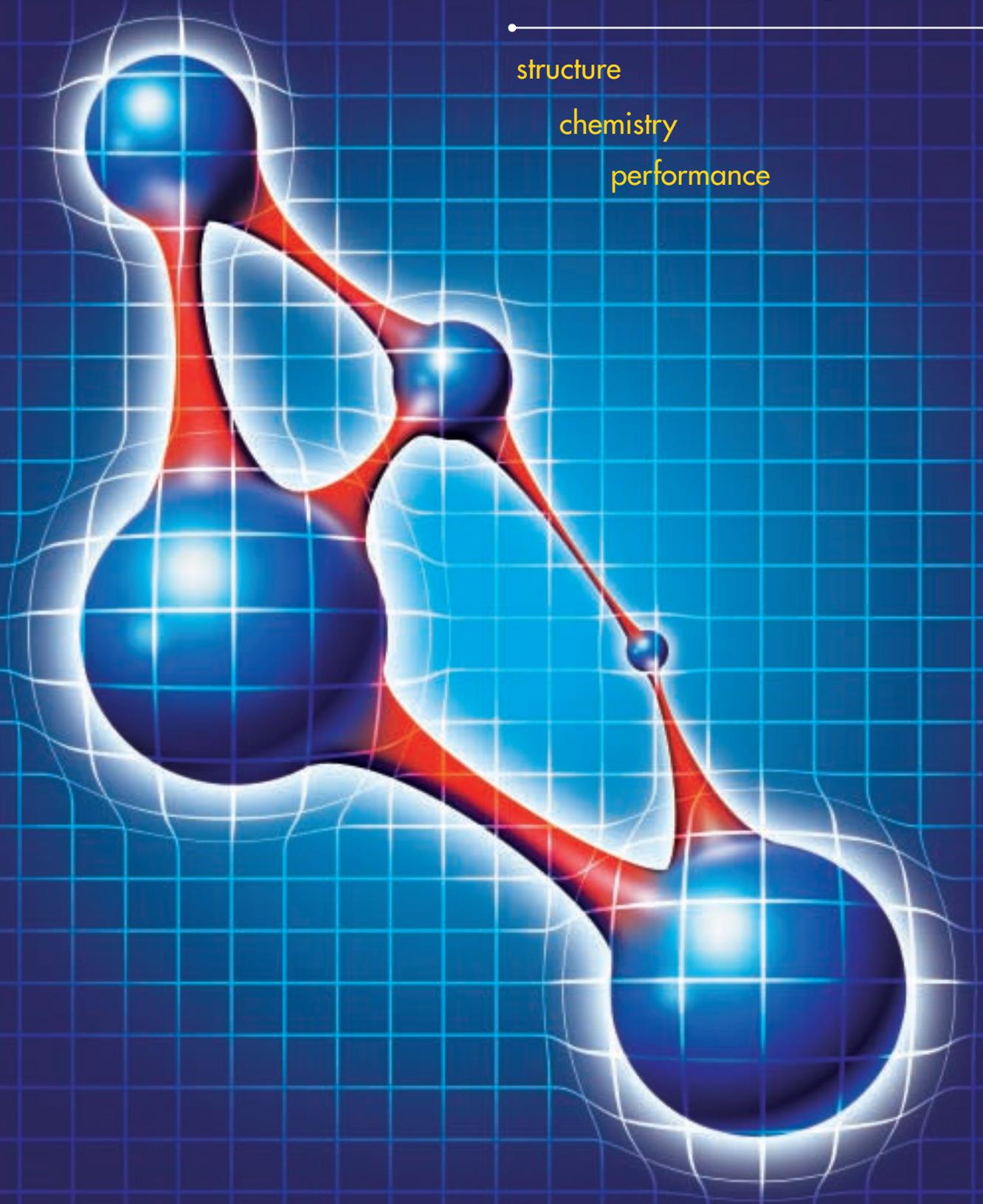
# An Introduction to KRATON<sup>®</sup> polymers

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structure

chemistry

performance



Issue 3

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**KRATON**  
Polymers

# An introduction to KRATON® polymers - structure, chemistry and performance

## Summary

KRATON Polymers LLC and its subsidiaries (the "KRATON Companies") operate world-wide. Research scientists working for this global business invented styrenic block copolymer chemistry in the 60s, and for some forty years have pioneered further innovative developments of products and processes.

By remaining committed to the industry and responding to the needs of their customers all over the world, the KRATON Polymers Group of Companies has become established as the world's leading manufacturer and supplier of styrenic block copolymers (SBCs) and unique polyisoprene grades.

High quality product is manufactured in six countries world-wide: in Brazil (Paulinia), in France (Berre), in Germany (Wesseling), in the Netherlands (Pernis), in Japan (Kashima), and in the USA (Belpre, Ohio). There are well-established research facilities in five countries: Belgium (Louvain-la-Neuve, Brussels), the Netherlands (Amsterdam), the USA (Houston, Texas), Japan (Tsukuba) and Brazil (Paulinia). An international workforce of employees works with customers in over 120 countries, and successful sales, marketing and distribution networks operate globally.

## What are KRATON® polymers?

KRATON® polymers are high performance elastomers engineered to enhance the performance capabilities of a wide spectrum of end products and applications.

There are currently more than 100 grades of KRATON polymers and compounds within the product ranges: KRATON D polymers, KRATON G polymers, KRATON FG polymers and KRATON IR polymers. KRATON D polymers and compounds have an unsaturated rubber mid-block (styrene-butadiene-styrene, SBS and styrene-isoprene-styrene, SIS). KRATON isoprene rubbers (IR) are high molecular weight polyisoprenes. KRATON G polymers and compounds have a saturated mid-block (styrene-ethylene/butylene-styrene, SEBS and styrene-ethylene/propylene-styrene, SEPS). KRATON FG polymers are KRATON G polymers grafted with functional groups such as maleic anhydride.

Below Right:  
*Using KRATON polymers for improved  
resilience and flexibility in footwear.*

Below:  
*Containers exhibiting good impact strength  
and clarity can be made from KRATON  
polymers.*





*Shoe soles containing KRATON  
polymers can be longer lasting and  
more comfortable.*

## What are the key benefits of KRATON® polymers?

Versatile KRATON polymers add value across a broad range of end-products, and can bring benefits to peoples lives whenever and wherever they are used.

- ❖ Most KRATON D and KRATON G polymers are elastic and flexible. When properly formulated they provide a wide range of properties, which can help improve the performance of numerous end-products and applications.
- ❖ KRATON G polymers can offer enhanced oxidation and weather resistance, higher service temperatures and increased processing stability.
- ❖ KRATON FG polymers, because of the functional groups on the SEBS, can have improved adhesion to polar substrates such as metals and nylon. They can also impact modify polar polymers such as polyesters, nylons and epoxies.
- ❖ KRATON IR polymers are high molecular weight polyisoprenes characterised by their high level of purity, transparency, flow and hysteresis. KRATON IR polymers have been used in speciality fields such as those involving skin or food contact. They can also be chemically modified to make speciality paints and coatings.

## Where are KRATON® polymers used?

The distinctive molecular structure of KRATON polymers brings tremendous versatility.

- ❖ Roads and Roofing - KRATON polymers can significantly enhance the performance of bitumen(asphalt) used in road, runway and racetrack applications by improving life expectancy and reducing maintenance levels. Bitumen roofing applications are enhanced by improved flexibility, and high and low temperature performance.
- ❖ Adhesives, Sealants and Coatings - KRATON polymers can provide improved all-round performance in pressure-sensitive and other adhesive applications. They are used in a variety of tapes, labels, plasters, construction adhesives, medical dressings, sealants, coatings and road marking paints.
- ❖ Footwear - Shoe soles containing KRATON polymers can be longer lasting and more comfortable. These polymers can offer improved resilience, good low temperature flexibility and insulation, and better grip even in wet conditions.
- ❖ Compounds, and Personal Hygiene - KRATON polymers can be compounded to produce materials which enhance the grip, feel, appearance and convenience of a diverse range of applications. Examples would include toys, hygiene, packaging, automotive, sports and leisure, construction as well as moulded and extruded technical goods.
- ❖ Packaging and Polymer modification - KRATON polymers can enhance high styrene applications, films, bags, stretch film and disposable packaging. They can improve the performance of polyolefins, styrenics, polycarbonates, nylons and polyesters.

Below:

*KRATON polymers can help ski and snow-boarding boots to remain tough and flexible in extreme temperatures.*





Prime quality sealants  
can be produced  
using KRATON  
polymers.

## What is the structure of KRATON® polymers?

In order to demonstrate the full potential of KRATON polymers, it is helpful to have an insight into their molecular structure.

KRATON D, G and FG polymers are styrenic block copolymers. Three feedstocks are needed to produce styrenic block copolymers (SBCs), namely styrene, butadiene and isoprene. The styrene is polymerised in a precisely controlled reaction with either butadiene or isoprene.

The inclusion of butadiene or isoprene influences the properties of the end product. For example, styrene-butadiene-styrene (SBS), is a material suitable for footwear and the modification of bitumen, while, styrene-isoprene-styrene (SIS), is preferred for production of pressure-sensitive adhesives. The midblock of specific SBS and SIS block copolymers can be hydrogenated to make KRATON G.

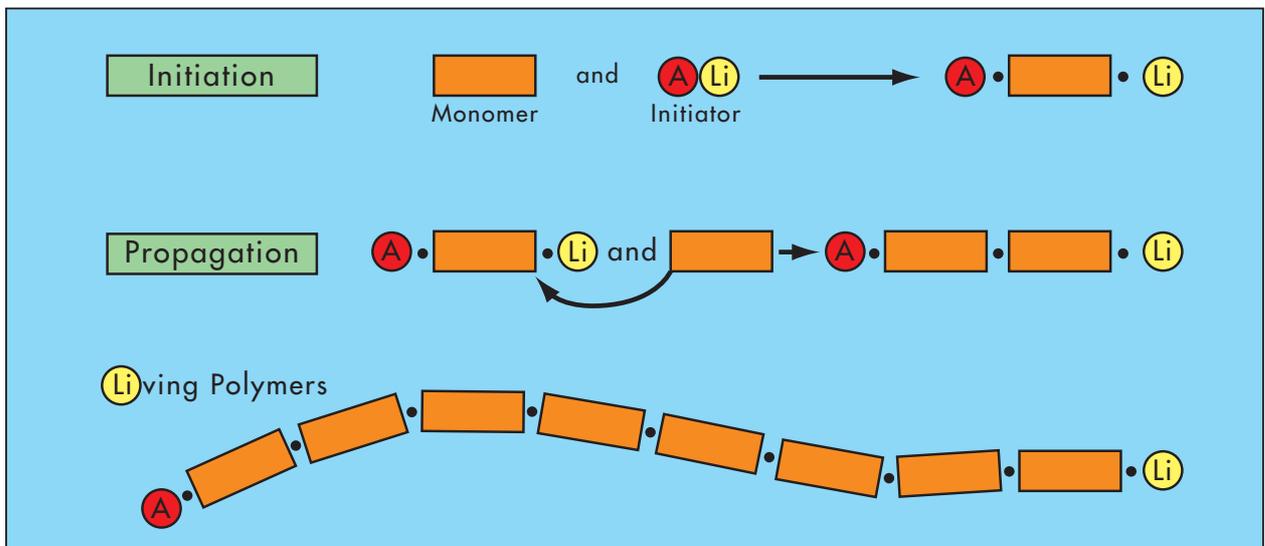


Figure 1. Lithium alkyl polymerisation.

KRATON D, G and IR polymers are produced by anionic polymerisation. Figure 1 shows how the alkyl lithium initiator polymerises the monomers to form a polymer molecule. The end of the polymer chain remains active or “living” until special terminating agents are added.



Left:  
Teats (nipples) for baby feeding bottles can be made from KRATON IR polymer.



*Roads can last longer and require lower maintenance costs when built from bitumen-modified with KRATON polymers.*

Thus the reaction of styrene monomer with alkyl lithium followed by a diene monomer (e.g. butadiene, isoprene) results in a polystyrene-polybutadiene-polystyrene block copolymer, as shown in Figure 2.

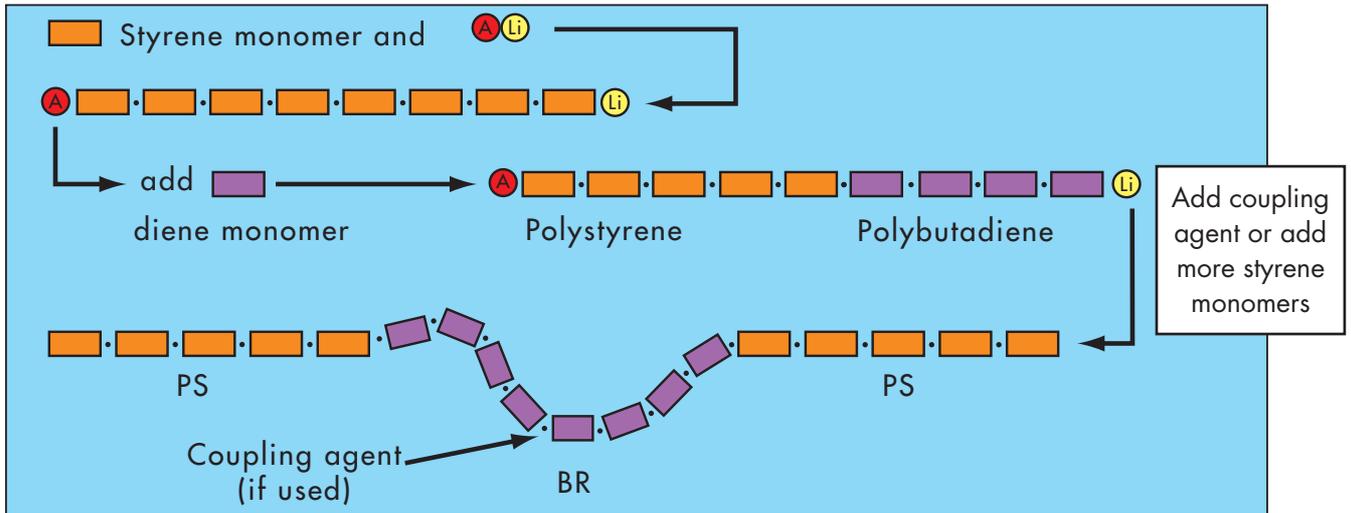


Figure 2. Polymerisation of thermoplastic elastomers.

The structure of styrenic block copolymers can be as shown:

LINEAR	A-B-A type (e.g. styrene-butadiene-styrene)
RADIAL	(A-B) <sub>n</sub> (n is greater than 2)
DI-BLOCK	A-B

KRATON G polymers are synthesised by selectively hydrogenating the rubber midblock of an SBS or SIS to form SEBS or SEPS polymers. KRATON FG polymers are made by grafting maleic anhydride onto the rubber midblock of selected KRATON G polymers.

Because of the chemical incompatibility of the polystyrene end-block and the polydiene mid-block, phase separation occurs on a microscopic scale. The existence of a two-phase system is indicated by the two distinct glass transition temperatures ( $T_g$ s) for each of the respective polymer phases. Figure 3 shows the two transition temperatures of an SBS compared to the single glass transition temperature for a random styrene and butadiene based polymer (e.g. emulsion SBR), which is homogeneous and has no micro-phase separation.

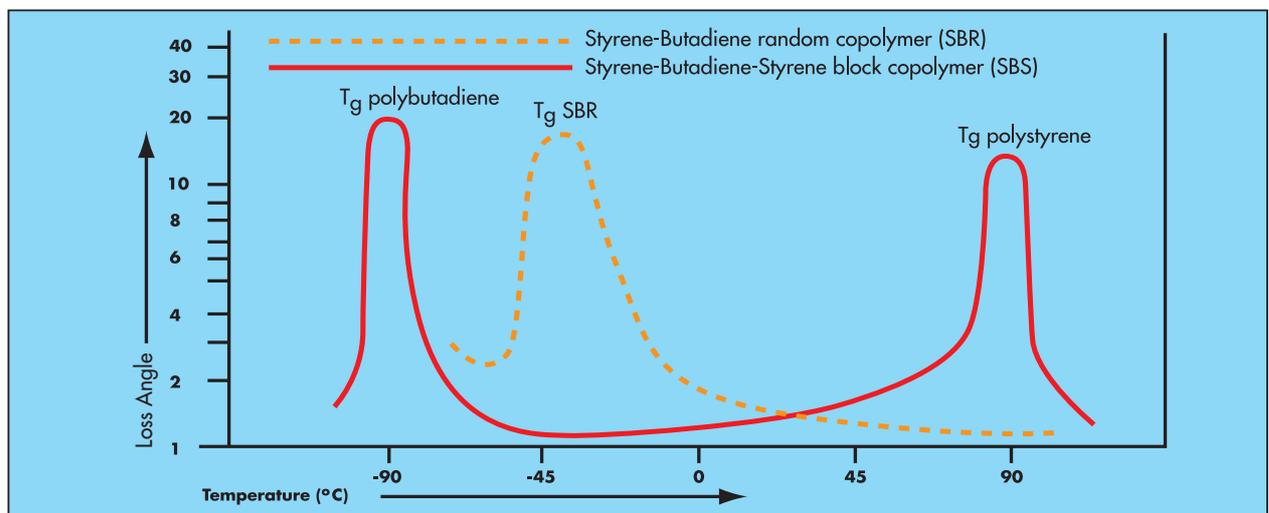


Figure 3. Glass transition temperatures ( $T_g$ s) of random and block styrene-butadiene copolymers.



*Soft touch airbag covers can be made  
from KRATON polymers.*

KRATON D and G polymers typically contain more elastomer than polystyrene. On a microscopic scale, the hard polystyrene domains are embedded in the continuous elastomeric matrix and act as physical cross-links, as illustrated in Figure 4.

During processing, in the presence of heat and shear forces or a solvent, the polystyrene areas soften. After cooling or solvent evaporation, the polystyrene domains re-form and harden, locking the elastomeric part in place again.

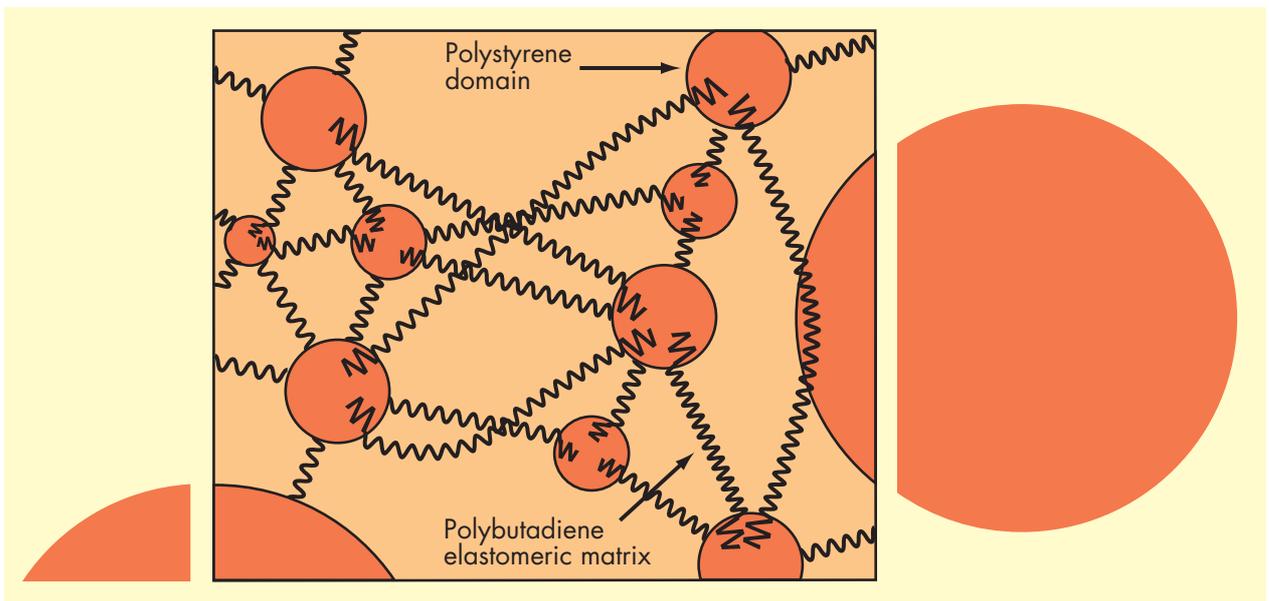


Figure 4. Illustration of three-dimensional SBS network.

This physical cross-linking and reinforcing effect of the polystyrene domains can give KRATON polymers high tensile strength and elasticity.

Below:

The integrated seal made from KRATON polymers - based Evoprene™ TPE compound helps to maintain the moisture of cleansing tissues.

™ Evoprene is a trademark owned by the AlphaGery Group of Companies.



The KRATON IR polymers are high molecular weight, high cis linear polyisoprenes. They are produced by anionic polymerisation using traditional lithium-based initiators. They are characterised by very low levels of impurity from the initiator, good clarity and low gel. Their linearity can impart good solubility in solvents, absence of gel, and good flow in compounds. The colourless KRATON IR polymers can be used as raw material in transparent or coloured articles.



*KRATON polymers can bring performance benefits for pressure-sensitive and other adhesive applications.*

## General performance features of KRATON® polymers

KRATON polymer grades are supplied as either clear block copolymers (1000 series) or as oil-extended block copolymers (4000 series), depending on the end-use application.

The performance properties of the D, G and IR polymers are illustrated in the following table.

KRATON series	D-1000	D-4000	IR	IR	G-1000	G-4000
Composition	SIS or SBS clear	SBS or SIS oil-extended	Polyisoprene clear	Polyisoprene oil extended	SEBS or SEPS clear	SEBS oil-extended
Flexibility	★	★	★	★	★	★
Elasticity	★	★	★	★	★	★
High tensile strength	★	★	★	★	★	★
Good electrical properties	★	★	★	★	★	★
Resistance to prolonged outdoor exposure					★	★
Higher temperature processing stability					★	★
FDA regulated	Most	Some	★		★	★
Steam sterilisable			★	★	★	★
High temperature performance			Some	Some	★	★
Compatibility with other resins	★	★	★	★	★	★
Adhesion	★	★	★	★	★	★
Tackifiable	★	★	★	★	★	★

Below:  
Stretch wrapping film that meets key food safety requirements can be made using KRATON polymers.



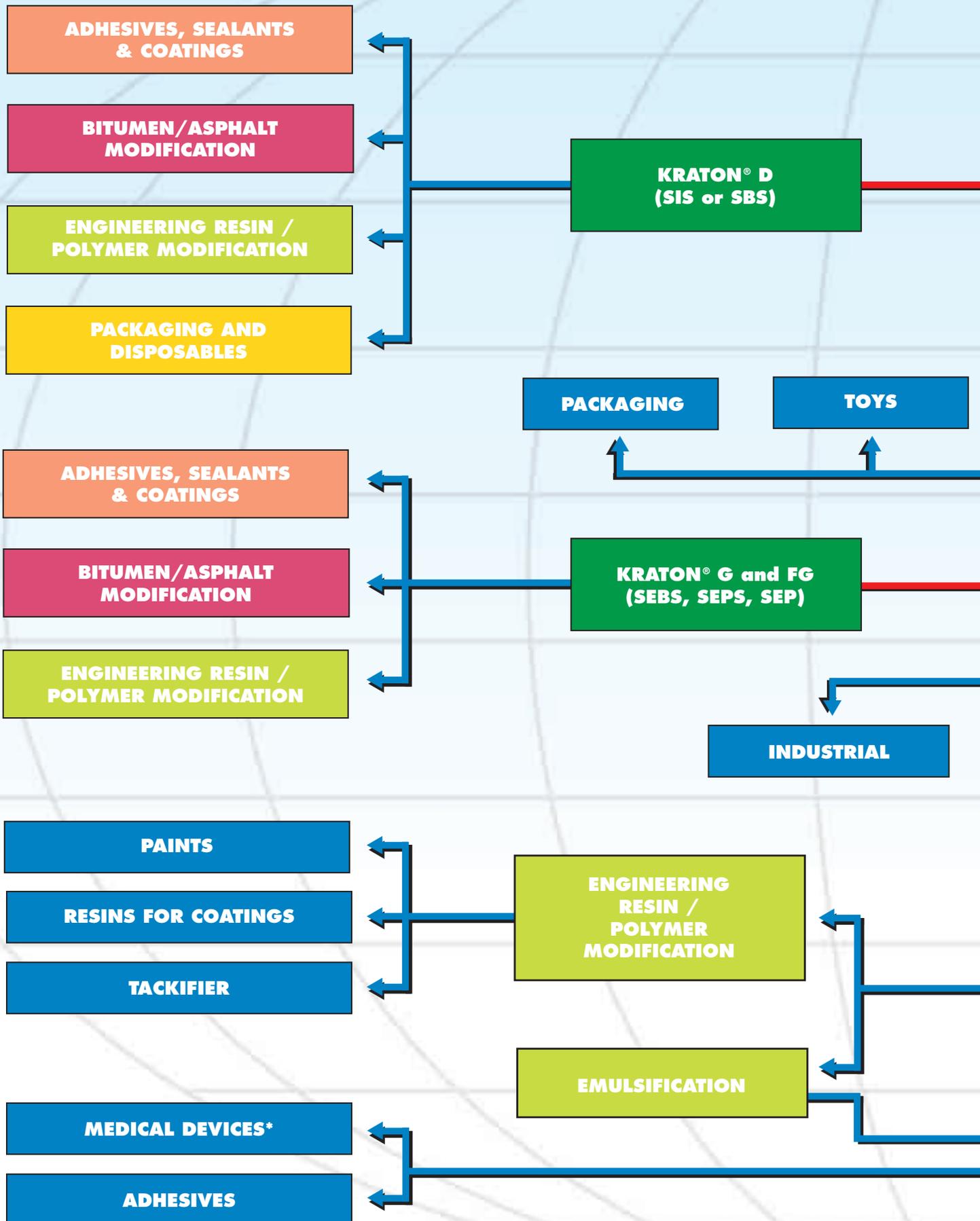
Table 1. General performance features of KRATON polymers.



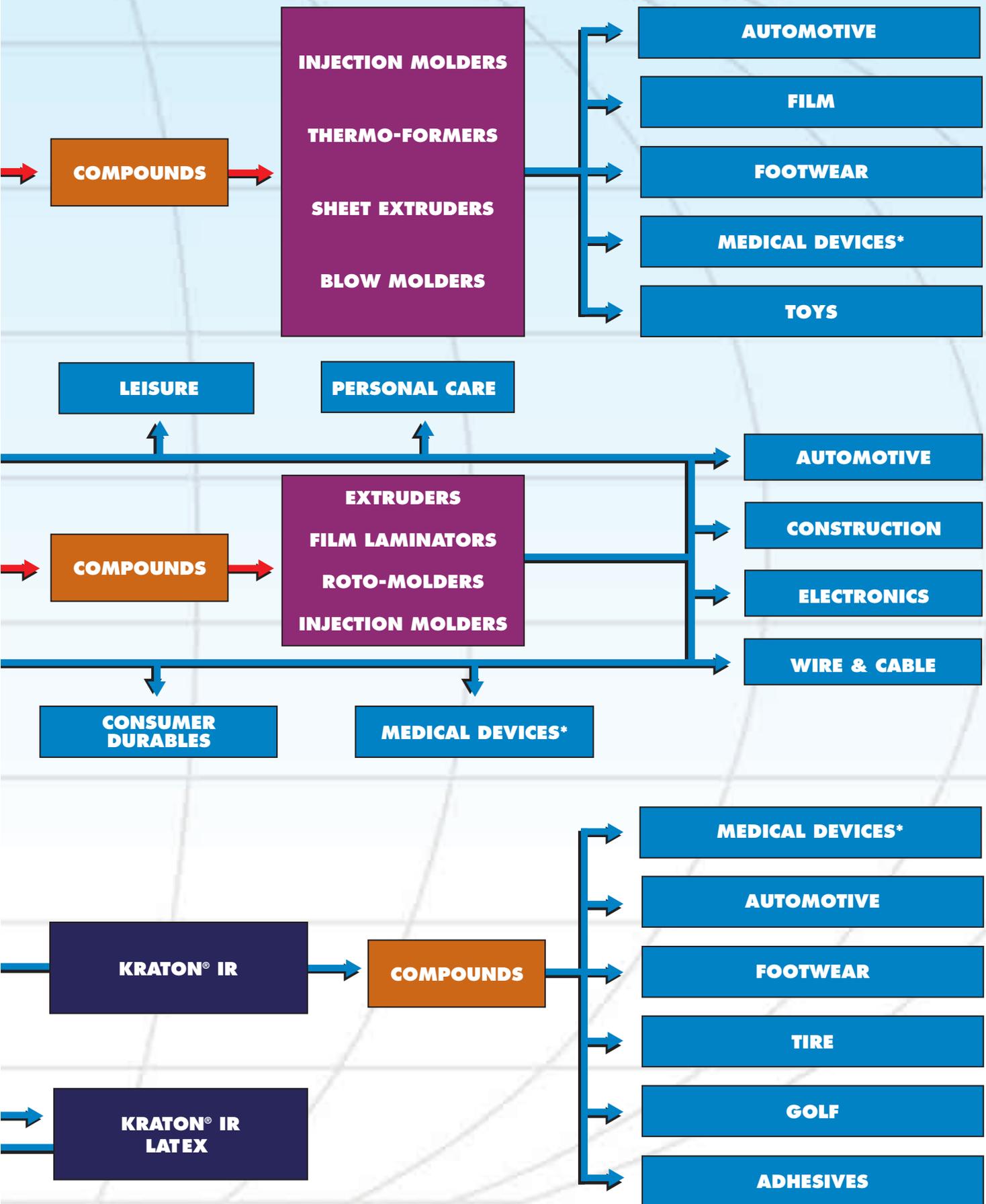
Bringing soft touch and functionality, KRATON polymers are used to make the case of the Kodak Sport one-time-use camera.

## KRATON® polymers end-use application opportunities

The distinctive molecular structure of KRATON polymers can be precisely controlled and tailored to offer customers imaginative end-use opportunities.



\*Consult KRATON Polymers Sales Managers for details of our Medical Policy.



## KRATON® polymers in bitumen (asphalt) modification

Bitumen (asphalt) is a cost-effective thermoplastic material. However, especially in more sophisticated applications, the performance properties of conventional bitumens have the disadvantage of being too sensitive to temperature.

The addition of a suitable KRATON polymer grade can bring superior properties to the modified bitumen. In particular KRATON-modified bitumens are much tougher at all temperatures and thus resist cracking at low temperature and deformation at high temperature much better.

In the bituminous roofing felt or membrane market, which is one of the major markets for polymer-modified bitumens, KRATON polymers have enabled manufacturers to develop a new generation of high performance roofing felts capable of performing well across a wide temperature range. These felts have a track record of excellent resistance to ageing and cracking, are easy to handle and allow the roofing season to be extended well into winter. In addition, the use of KRATON polymers can permit roofing constructors to give customers substantially increased lifetime and performance guarantees. Similarly, the performance of roof shingles for homes in parts of the USA can be enhanced by use of KRATON polymer-modified asphalt. Improved resistance against storm damage and hail impact damage has been demonstrated even under the most severe conditions as can occur in Florida and Texas.

Road construction also benefits from KRATON-modified binders. Resistance to permanent deformation (rutting) at high ambient temperatures, and to cracking at low temperatures, has been substantially improved. Other potential deficiencies like premature hardening, 'shoving' and 'flushing' are also reduced. The outstanding performance of KRATON polymer-modified asphalt mixes throughout the world (Europe, USA, Japan, China, Australia) has led to their worldwide acceptance.

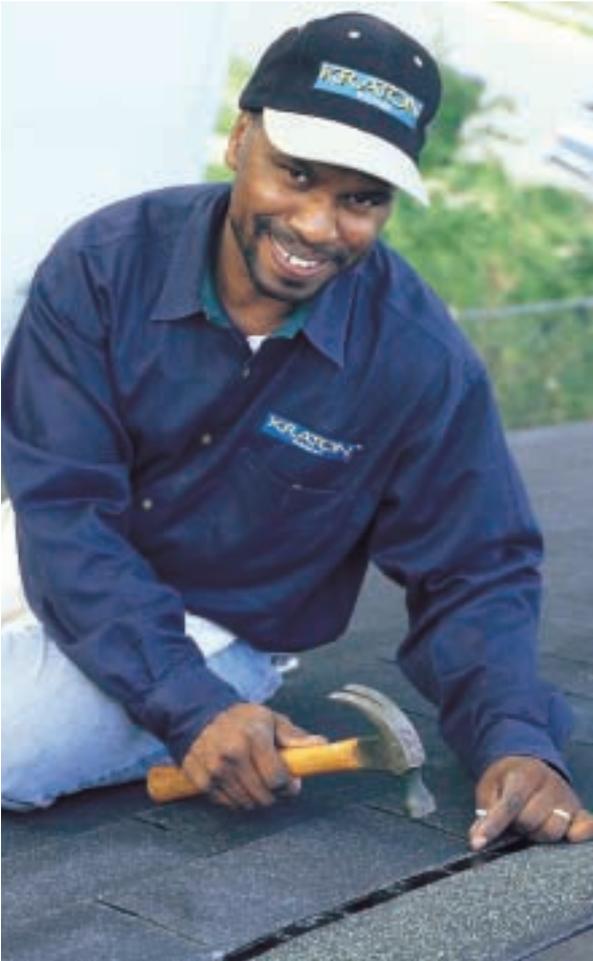
In Kazakstan, use of KRATON polymer-modified bitumen enabled the laying of a runway at the Almaty airport resistant to harsh conditions, where air temperatures can range from minus 45°C to + 30°C.

The use of KRATON polymers as a modifier in porous asphalts (also known as drainage asphalt and friction course), in surface dressings, in thin surfacings, in stress absorbing membrane interlayers (SAMIs) and in bridge decks can also result in a markedly improved performance.

Additionally, KRATON polymer-modified bituminous systems for mopping adhesives and pipe coating are other areas where an improvement in performance has been observed.

## KRATON® polymers in Adhesives, Sealants and Coatings

KRATON D and KRATON G polymers are used widely in pressure-sensitive adhesives for the production of a variety of tapes, labels, decals, plasters and hygienic disposable products. Other applications include sealants, mastics, coatings, sound deadening compounds and road marking paints.



Above:  
Roofing shingles made from asphalt-modified with KRATON polymers can withstand assault from severe hail storms.

Below:  
At Almaty airport in Kazakstan, bitumen-modified with KRATON polymers was used in a runway that must perform well in extreme cold and hot temperatures.



The unique two-phase structure of KRATON block copolymers creates opportunities to use formulating resins which associate specifically with the elastomeric mid-block or the polystyrene domains. This powerful formulating tool, which can be supplemented by the use of plasticisers, fillers and antioxidants, allows the formulator to modify a wide range of adhesive properties such as tack, cohesive strength, holding power, stiffness and temperature resistance.

Much of the success of KRATON polymers in these fields has been achieved by applying adhesives as hot melts. Many manufacturers prefer more efficient modern hot melt mixing and high speed coating processes to solvent-based systems, which have certain environmental and safety restrictions. Also, there is no need to pre-masticate KRATON polymers, and their pellet form makes handling easier.

However, when solvent based systems are required, KRATON polymers can bring advantages such as low viscosity, high solids contents and short dissolving times.

SIS grades are used for pressure-sensitive applications. SBS grades are preferred for mastics. KRATON G polymers offer improved resistance to ageing and degradation at elevated temperatures. Consequently, G grades can be used for sealants and for long pot life hot-melt adhesives.

### KRATON® polymers for the modification of polymers

KRATON polymers are widely used to improve the performance of polyolefins, styrenics and engineering thermoplastics such as polycarbonates, nylons and polyesters. Impact resistance properties of these plastics at low and ambient temperatures can be enhanced by the incorporation of KRATON polymers.

KRATON polymers also can permit the compatibilisation of some dissimilar plastics resulting in materials possessing a combination of properties, which could not be achieved otherwise. The use of KRATON polymers can allow the upgrading of scrap and regrind materials by both toughening and compatibilisation.

KRATON polymers are used as additives to control shrinkage in polyester moulding compounds, and are capable of providing finished mouldings with automotive Class A surfaces. They can improve impact resistance and hot strength, which helps avoid damage in de-moulding operations.

### KRATON® polymers for Packaging

Clear and transparent blends meeting the exacting demands of the packaging industry can also be produced. Packaging successes with KRATON D polymer -1400 series (high-styrene) include clear high quality, resilient plastic cups, plates, trays and films.



Above:

*Disposable baby diapers are assembled with block copolymer-based adhesives and may also contain stretchable elastic components based on KRATON rubber compounds.*

Below:

*For containers with good clarity and impact strength, use high styrene SBC polymers. Their melt-flows suit injection, co-extrusion and thermoforming processes.*



## KRATON® polymers in Compounding

KRATON polymers are extremely versatile base polymers which can be compounded with a wide variety of other polymers, oil and fillers. The resulting compounds are used in food packaging, medical\*, footwear and automotive applications, and in moulded and extruded technical goods.



Above:  
KRATON polymers can bring comfort and design to grips.

Compounds based on KRATON D polymers, for instance, can satisfy a broad range of footwear markets from very soft and flexible materials for home footwear to medium hardness products for casual and sneaker-type shoes, to thin hard soling. All of which can be formulated to provide a particular physical performance level. Soles based on KRATON D compounds can be lightweight, flexible, comfortable and durable. A wide variety of surface appearances (e.g. crepe, smooth, translucent) are possible with a range of hardnesses.

Many colours, textures and patterns can be produced with KRATON D polymer-based compounds, allowing the design of a wide variety of soles. In addition, the compounds can be injection moulded as unit soles or directly on to the upper. KRATON D compounds are also suitable for side-support welts in joggers and are well established as heel counters and toe caps.

The versatility of KRATON D and G polymers permits the formulation of compounds exhibiting a wide range of properties. The elasticity and flexibility of KRATON compounds means that they may be used in diverse applications including household appliances, pharmaceutical products, toys, carpet tile backing, films, tubings and profiles.

KRATON Polymers also supplies a selection of KRATON branded-compounds to end users worldwide. Many customers enjoy the ready-to-use compounds with guaranteed quality and performance.

*Please contact your local KRATON Polymers sales manager for advice and any assistance regarding grades and compounds available in your region.*

## Sensitive Applications and KRATON Polymers Good Manufacturing Practices

Sensitive applications are those where specific regulatory controls governing end-use exist such as in food contact, medical\*, pharmaceutical, cosmetics and toys. Based on long experience with these markets, KRATON Polymers has developed its own standard of Good Manufacturing Practices (GMP) that apply to all activities along the supply chain delivering KRATON polymers products to be used in these sensitive applications.

Most KRATON polymer clear grades can be used in food contact articles, and comply with relevant regulations, for example those of the Food and Drug Administration (FDA) in the USA and the Bundesgesundheitsamt (BGA) in Germany, the Warenwet regulations in the Netherlands as well as the relevant European directives. Further details of these and other compliances can be provided, as required. Manufacturers of final products should ensure that all other ingredients used also comply with the appropriate regulations.

Several KRATON polymer grades meet the requirements under Class VI of the USP (United States Pharmacopoeia) and comply with various other legislations world-wide.

Optimised compounds and Adhesives/Sealants/Coatings products based on such grades of KRATON polymers are currently used in several medical and food contact applications.

\*See page 19 for KRATON Polymers medical policy.

### International Organisation for Standardisation (ISO) certifications and KRATON Polymers

Our dedicated KRATON Polymers manufacturing facilities in the USA, France, Germany, The Netherlands, Brazil and Japan are all certified to meet the international standards of ISO 9001 on Quality Management.

Whilst we are currently implementing ISO 14001 standards for the US site, our sites in Europe, Brazil and Japan already have fully established Environmental Management Systems to ISO 14001.

KRATON Polymers commercial operations in Europe, USA and Brazil also operate to the ISO 9001 standard. In line with our target of continuous improvement, the manufacturing operations in Brazil and France already comply with OHSAS 18001 BSI standards for Health and Safety Management, and it is our objective to attain this qualification across all our manufacturing operations.

### Leading with Innovation

During recent years, KRATON Polymers has accelerated the pace of successful innovation. Bringing benefits to a wide range of customers, KRATON A polymers were amongst the latest developments to emerge.

An innovative extension of existing polymer technology, KRATON A polymers are unique, high-performance elastomers. The extraordinary versatility of KRATON A polymers is due to their distinctive molecular structure, which can be precisely controlled and tailored to perform in specific applications. KRATON A polymers can be compounded to produce materials which can improve the adhesion, elasticity, feel, and appearance of a diverse range of applications including toys, packaging, automotive, sports, construction and molded and extruded goods. Design advantages include: improved adhesion to polar substrates, better mold definition, improved dimensional stability and a broader range of stiffness. Processing advantages include: better flow, improved low-shear processing, better dimensional stability of molded parts and the opportunity for reprocessing.

### Commitment to customers long term

The KRATON Polymers Business is committed to customers and to the industry long term. Our efforts are focused on:

- ❖ providing our customers with products that can perform in accordance with specific requirements,
- ❖ enhancing the performance of other materials with cost-effective benefits.

Market trends, the needs of specific industries and individual customer requirements are given full consideration by experts in KRATON Polymers research laboratories when tailoring new block copolymer molecules.

Should you require any further detailed information on any of the grades of KRATON polymers and the applications outlined in this brochure, or if you have identified any opportunity in which KRATON polymers could prove beneficial, please contact your local KRATON Polymers sales manager who will be pleased to assist with your inquiry.

(For contact information, please go to page 19)

**Our innovations will make you shine.**

**The innovations continue at KRATON Polymers with new grades and applications supported by research and development around the globe.**

**There is a KRATON® polymer for your next bright idea.**

**KRATON Polymers**

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### End Use Requirements

If the finished article is intended for use in food contact applications, toys, or human contact areas, manufacturers of the final product should observe all relevant regulations. Detailed information is available from KRATON Polymers.

For food packaging, manufacturers of the final product should ensure that all ingredients used comply with applicable regulations. Some of these regulations require tests to be carried out on the final product, e.g. migration. These are the responsibility of the final product manufacturer.

### Restriction on Medical/Healthcare Applications and Trademark Usage

Products or compounds made from KRATON Polymers' products shall not be used in any of the following applications: (a) cosmetics, (b) drugs and other pharmaceuticals, and (c) Class II and Class III Medical Devices, as defined in 21 CFR 860.3 (hereinafter collectively referred to as "Medical/Healthcare Applications"). KRATON Polymers requires that it give its prior written approval before its products are used in such Medical/Healthcare Applications. Please contact your KRATON Polymers Sales Representative for more details before using our products in these specific applications.

**KRATON POLYMERS HAS NO SPECIFIC EXPERTISE IN THE MEDICAL/HEALTHCARE MARKET OR MEDICAL/HEALTHCARE APPLICATIONS AND DOES NOT INTEND TO PERFORM TESTING, CLINICAL STUDIES OR OTHER INVESTIGATIONS OF THE SUITABILITY OF ITS PRODUCTS FOR THESE SPECIFIC APPLICATIONS. KRATON POLYMERS MAKES NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE (INCLUDING MEDICAL/HEALTHCARE APPLICATIONS) FOR ITS PRODUCTS.**

EACH CUSTOMER OR USER OF KRATON POLYMERS' PRODUCTS IS SOLELY RESPONSIBLE FOR DETERMINING THE SUITABILITY OF THE MATERIALS IT SELECTS FOR THE INTENDED PURPOSE. FOR MEDICAL/HEALTHCARE APPLICATIONS, EACH CUSTOMER OR USER MUST CONDUCT ITS OWN STUDIES, REGISTRATIONS, AND OTHER RELATED ACTIVITIES TO ESTABLISH THE SAFETY AND EFFICACY OF ITS PRODUCTS.

Do not use KRATON Polymers' tradenames, trademarks, logos or other similar identifying characteristics for the manufacture, sale or promotion of products intended for Medical/Healthcare Applications.

### Safety and Handling Precautions

Read the Material Safety Data Sheet for KRATON Polymers' products carefully and thoroughly before beginning any work with such products.

Additional information relating to the health, safety, storage, handling and processing of KRATON Polymers' products can be found in the KRATON Polymer HSE Fact Sheet (K0155), available from your local KRATON Polymers Sales Representative. KRATON Polymers also recommends that customers or users consult other sources of safety information, for example, the current edition of the "Code of Practice on the Toxicity and Safe Handling of Rubber Chemicals," British Rubber Manufacturers Association Limited ([www.brma.co.uk](http://www.brma.co.uk)).

KRATON Polymers' products and compounds can accumulate electrostatic charges when rubbed, chafed or abraded. Processing and storage equipment for use with KRATON Polymers' products should provide a means of dissipating any charges that may develop.

When processing KRATON Polymers' products, maintain a fire watch if the material reaches 225°C (437°F) for KRATON IR and KRATON D (polymers and compounds), and 280°C (536°F) for KRATON G (polymers and compounds). The temperatures listed above are indicated only for safety reasons (risk of fire and product degradation) and are not necessarily recommended for processing. Degradation of the polymer (polymer breakdown) will start at lower temperatures depending on the specific processing conditions. Therefore, operating below these temperatures does not guarantee the absence of product degradation.

KRATON Polymers' products (the neat resin or the base product) are high molecular weight polymers which by all accounts are non-toxic and biologically inactive.

### Warranty

The information contained in this publication is, to the best of KRATON Polymers' knowledge, true and accurate, but any recommendations or suggestions that may be made are without guarantee, since the conditions of use and storage are beyond KRATON Polymers' control. The customer understands that it shall make its own assessment to determine the suitability of a KRATON Polymers' product for a particular purpose. Further, nothing contained herein shall be construed as a recommendation to use any KRATON Polymers product in conflict with existing patents. All products purchased from or supplied by KRATON Polymers are subject to terms and conditions set out in the applicable contract, order acknowledgement and/or bill of lading. KRATON Polymers warrants only that its products will meet those specifications designated therein.

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