From Isoprene Monomer to Synthetic Polyisoprene Latex and its Uses
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Abstract
Natural rubber is produced as a latex by Mother Nature. In order to produce a synthetic equivalent, the polymer industry has to polymerise isoprene monomer in solvent and manufacture the latex via post-emulsification of the intermediate polyisoprene (IR) solution. Emulsion polymerisation is not an option. Therefore, the properties of a synthetic IR latex are not only a function of the emulsification step, but also of the solvent polymerisation step. Most applications – such as sheets, dipped goods (e.g. gloves) and adhesives – currently relying on natural rubber latex as a raw material could be based on a synthetic IR latex, providing that the IR is treated in accordance with its specificity by the goods manufacturer.
1. Introduction

KRATON Polymers is a leader in the field of styrenic block co-polymers (SBCs), having production sites in six countries, and R&D centres in Belgium, Japan, Holland and USA (Figure 1). Our global capacity of SBCs, amongst others SIS†, SBS‡ and SEBS**, is almost double that of our closest rival.

KRATON Polymers is also a producer of polyisoprene, the synthetic equivalent of natural rubber.

Our polyisoprene and SBCs have in common the monomer, namely isoprene, the anionic polymerisation process and a number of end uses.

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† SIS stands for “Styrene-Isoprene-Styrene copolymers”.
‡ SBS stands for “Styrene-Butadiene-Styrene copolymers”.
** SEBS stands for “Styrene-Ethylene-Butylene-Styrene copolymers”.

Figure 1

KRATON Polymers Research & Manufacturing

K:IR = KRATON IR plant / K.D = KRATON D plant / K.G = KRATON G plant
2. Manufacturing & properties of polyisoprene

2.1 Target polymer

The manufacturing of polyisoprene (IR) having the desired properties is not a trivial task. Indeed the polymerisation of isoprene monomer can lead to various repeating units: 1,2-IR; 3,4-IR and 1,4-IR. Two isomers of the 1,4-IR unit are possible: trans 1,4-IR and cis 1,4-IR. All four types of units can potentially alternate in a single polymer chain (Figure 2).

Figure 2

Natural rubber consists almost exclusively of cis 1,4-IR (~99%). Cis 1,4-IR is therefore the target polymer when replacement of natural rubber by a synthetic equivalent is the ultimate goal.

2.2 Polymerisation processes

Various processes may be envisaged (Figure 3). Co-ordination polymerisation, often known as Ziegler-Natta polymerisation, allows cis 1,4-IR, trans 1,4-IR and 3,4-IR to be tailor made. This is the most widely used industrial process to produce cis 1,4-IR having a cis 1,4 content above 96%.
Figure 3  
Isoprene Monomer Polymerization

- Coordination Polymerization (Ziegler-Natta; tailor made polymer: high cis, high trans or high 3,4)
- Anionic Polymerization (High cis or medium 3,4)
- Radical Polymerization (>65% 1,4 trans, low Mw)
- Radical Emulsion Polymerization (low cis, high branching/gel, low conversion)
- Cationic Polymerization (built-in cycles, low Mw)
- ... Biosynthesis in trees

The anionic polymerisation process leads to cis 1,4-IR having a cis 1,4 content of more than 90%. This is the process employed by our company. This process can also be exploited to produce 3,4-IR with a 3,4 content of about 60%.

Radical polymerisation so far is not an option to produce cis 1,4-IR; mostly trans 1,4 repeating units are generated and only low molecular weight (Mw) chains can be obtained at a reasonably high conversion rate. Radical emulsion polymerisation is even more difficult to control, and can unfortunately not be used to produce a suitable IR latex in one step.

IR produced via cationic polymerisation suffers from low Mw, and high level of built-in cycles.

The last process is the one at the origin of natural rubber (NR), occurring in *Hevea Brasiliensis* trees. Contrary to the Ziegler-Natta and the anionic polymerisation processes, NR is produced as a latex (emulsion).

2.3 Relative polymer properties

We are left with only three methods to get polymers of the “high cis 1,4-IR” type. Although the polymers are of the same type whatever the process selected, clear and important differences do exist (Figure 4).

NR does not require any *synthetic* catalyst. It is a branched polymer characterised with a high Mw and a wide molecular weight distribution (MwD). The stereoregularity is extremely high with about 99% cis 1,4 content. Due to the combination of branching and high Mw, NR contains gel particles. The level of natural impurities, such as proteins, is quite high.
NR is produced as an emulsion, and can be converted, if required, into a solid rubber at a later stage.

**Figure 4**

<table>
<thead>
<tr>
<th>Natural rubber</th>
<th>Ziegler-Natta IR</th>
<th>Anionic IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branched Product</td>
<td>Branched Product</td>
<td>Linear Product</td>
</tr>
<tr>
<td>Wide MWD</td>
<td>Wide MWD</td>
<td>High MW, Narrow MWD</td>
</tr>
<tr>
<td>98+% Cis Content</td>
<td>96+% Cis Content</td>
<td>90+% Cis Content</td>
</tr>
<tr>
<td>High Gel content (loose)</td>
<td>High Gel content (loose)</td>
<td>Intrinsically NO Gel</td>
</tr>
<tr>
<td>Contains natural impurities (e.g. proteins)</td>
<td>Catalyst residuals</td>
<td>Low Impurity Level</td>
</tr>
<tr>
<td>Produced as an emulsion</td>
<td>Produced as an organic solution</td>
<td>Produced as an organic solution</td>
</tr>
</tbody>
</table>

Ziegler-Natta high cis 1,4-IR (abbreviated hereafter as ZN-IR) is polymerised in the presence of a Titanium/Aluminium catalyst. It is also branched and characterised with a wide MwD. The stereoregularity is high with about 97% cis 1,4 content. The gel content is as much as 10 to 20%\(^3\) despite the typical Mw of only about 1,000,000. ZN-IR usually contains catalyst residuals.

The anionic polymerisation of isoprene into anionic IR is initiated with an Alkyl-Lithium initiator. Anionic IR is, hereafter, referred to as Li-IR. It is a fully linear polymer with a relatively narrow MwD. The Mw appears to be two to three times as much as that of ZN-IR. However, a true comparison would require to take into account the branching level of ZN-IR, in which case the Mw of the latter would probably be much higher. The cis 1,4 content of Li-IR is typically 91%. It contains a gel level close to zero, and a very low level of metal residuals.

Both ZN-IR and Li-IR are produced in organic solutions, which can be subsequently coagulated and dried into solid rubber, or converted into a latex via a post-emulsification step. The gel content may have an impact on the quality, and thus handling, of solutions, as can be seen on the attached
photograph (Figure 5), showing diluted solutions of NR, ZN-IR and Li-IR. A settled gel layer can easily be seen in the NR solution. Although it cannot be seen on this photograph, a similar layer is observed in reality in ZN-IR solutions. The wet gel analysis gives evidence of the presence of gel even in ZN-IR #2. In solution, the presence of gel is translated into haziness. The ZN-IR #2 solution, somewhat less hazy, is based on a ZN-IR grade that has undergone an extra purification step. Standard Li-IR in solution is crystal clear.

The differences between NR, ZN-IR and Li-IR at the molecular level induce obvious macroscopic dissimilarities (Figure 6). Although ZN-IR and Li-IR have a similar viscosity in bulk, the solution viscosity of Li-IR is higher, which is typical of the behaviour of a linear polymer.

### Figure 5
**Gel content – 4% solutions in toluene**

**Gel content – Wet gel analysis**

<table>
<thead>
<tr>
<th>Properties</th>
<th>Natural rubber (Ribbed Smoked Sheet #1)</th>
<th>Ziegler-Natta IR</th>
<th>Anionic IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mooney Viscosity (ML[1+4] 100°C)</td>
<td>120</td>
<td>50 - 90</td>
<td>40 - 90</td>
</tr>
<tr>
<td>Limiting Visco Number (LVN, dl/g)</td>
<td>6.0 - 7.0</td>
<td>2.5 - 4.5</td>
<td>6.5 - 9.5</td>
</tr>
<tr>
<td>Colour</td>
<td>dark/yellow-brown some</td>
<td>yellow/amber some</td>
<td>crystal clear</td>
</tr>
<tr>
<td>Smell</td>
<td>high</td>
<td>moderate</td>
<td>light/neutral</td>
</tr>
<tr>
<td>Green Strength</td>
<td>high</td>
<td>moderate</td>
<td>moderate/cold flow</td>
</tr>
<tr>
<td>Flow of compound</td>
<td>moderate</td>
<td>moderate</td>
<td>high</td>
</tr>
<tr>
<td>Shore Hardness/Modulus</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>High</td>
<td>Moderate</td>
<td>Lower</td>
</tr>
</tbody>
</table>
Colour and smell are better in Li-IR. NR and ZN-IR have brown or yellow colours, and relatively strong smells, while Li-IR is crystal clear and has a light smell.

The green strength of Li-IR and ZN-IR are on a par4, both significantly lower than that of NR. Thanks to linearity, Li-IR flows exceptionally well, the counterpart of which is cold flow during storage.

Since there is a direct link between cis 1,4 content and tensile strength, it is not surprising that vulcanised rubbers based on ZN-IR are slightly less strong than those based on NR and slightly stronger than those based on Li-IR5. On the other hand, Li-IR will have the lower moduli and the highest elongation at break.

**Figure 7**

<table>
<thead>
<tr>
<th>Non polyisoprene content</th>
<th>Natural rubber</th>
<th>Ziegler-Natta IR</th>
<th>Anionic IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash (% wt)</td>
<td>0.50</td>
<td>0.15 - 0.30</td>
<td>0.05 - 0.10</td>
</tr>
<tr>
<td>Stabiliser content (% wt)</td>
<td>2.0 - 3.0</td>
<td>0.5 - 1.0</td>
<td>0.05 - 0.3</td>
</tr>
<tr>
<td>Metal content (ppm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>180</td>
<td>120-300</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Ti</td>
<td>4</td>
<td>180-360</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Li</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>2.5</td>
</tr>
<tr>
<td>Fe</td>
<td>116</td>
<td>3-10</td>
<td>2</td>
</tr>
<tr>
<td>Na</td>
<td>35</td>
<td>13-150</td>
<td>5</td>
</tr>
<tr>
<td>K</td>
<td>490</td>
<td>10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Ca</td>
<td>625</td>
<td>10-160</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Mg</td>
<td>120</td>
<td>2-10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cu</td>
<td>2</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Zn</td>
<td>7</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cd</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Pb</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Total</td>
<td>&gt;1579</td>
<td>&gt;503</td>
<td>&gt;340</td>
</tr>
</tbody>
</table>


Purity is the most obvious advantage of Li-IR (Figure 7). Not only is the ash content low, but also the anti-oxidant level, leaving freedom to the formulator. The total metal content is the lowest of all types of IR and NR. More specifically, Li-IR contains no catalyst residual since the highly reactive alkyl-lithium initiator ends up as a volatile alkane, removed during the solvent stripping operation, and a water soluble Li⁺ salt; the total lithium content in dry Li-IR is typically below 5 ppm. In the case of IR, low catalyst residual is the best guarantee of stability³, thereby explaining why the level of added anti-oxidant can be kept low in Li-IR.
The nice thing about Li-IR is that you can actually SEE the difference (Figure 8).

Figure 8
3. Manufacturing & properties of polyisoprene latex

Li-IR can be turned into a latex via a post-emulsification process (Figure 9).

In short, the organic solution containing the polymer must be blended with an aqueous soap solution in a high shear emulsification unit. The resulting intermediate product is a highly diluted emulsion containing a high amount of organic solvent (VOC).

The next steps consist of stripping the solvent out, and then concentrating the still diluted aqueous emulsion to the right solids content so as to produce the IR latex with the targeted properties.

Presented in this way, the process looks rather simple . . . until you try. The process parameters and the know-how of the operators are actually key to the success.

The properties of our Li-IR latex have been designed such as to match the ones of NR latex (Figure 10). The total solids contents are similar but the impurity level is higher in NR lattices which is translated into a lower
rubber content. In our synthetic IR latex, the non-rubber content corresponds to the surfactant content. The pH is typically between 10 and 11, again like NR latex, with the advantage that there is no ammonia, thus no ammonia smell, in the synthetic IR latex. Employees used to working in a NR latex manufacturing environment will appreciate this. The particle size of the synthetic latex is larger than that of NR latex, but it does not affect the mechanical stability of the product. The viscosity of the material is low, once more matching typical viscosity of NR latex.

**Figure 10**

<table>
<thead>
<tr>
<th>Typical Properties</th>
<th>Anionic IR</th>
<th>Natural rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solid content (% w)</td>
<td>65</td>
<td>similar</td>
</tr>
<tr>
<td>Total rubber content (% w)</td>
<td>64</td>
<td>lower</td>
</tr>
<tr>
<td>pH</td>
<td>10.3</td>
<td>similar</td>
</tr>
<tr>
<td>Ammonia (% w)</td>
<td>0</td>
<td>0.2 - 0.8</td>
</tr>
<tr>
<td>Average particle size (µm)</td>
<td>1.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Mechanical stability (sec)</td>
<td>&gt;1500</td>
<td>&gt;900</td>
</tr>
<tr>
<td>Brookfield viscosity (mPa.s)</td>
<td>50 - 150</td>
<td>similar</td>
</tr>
</tbody>
</table>
4. Technologies and Applications

4.1 Technologies

Figure 11

Potential Technologies

Dipping Process
Water-Borne Adhesives & coatings
Heat coagulation
Extrusion of threads

Thanks to the good match of properties between the synthetic and NR lattices, about the same wide range of technologies can be used (Figure 11), including dipping process, water-borne adhesives and coatings, heat coagulation, extrusion of threads, . . .

Actually the Li-IR latex could also be of interest to some industry segments where NR latex is not an option because of, e.g. colour, smell or low gel requirements.

Articles based on Li-IR latex can be produced on existing manufacturing lines used to run with NR latex. Manufacturers of goods only have to adapt compounding recipes and processing conditions.

Compounding and processing parameters are very specific to industry segments and it is not possible to comment on all of them within the scope of this paper. Instead we will show a few selected concrete examples of potential applications.

4.2 Dipping process

4.2.1. General Recommendations for Coagulation Dipping

The procedure to prepare goods via a standard coagulation dipping process can be broken down into six major steps:

- **Step 1.** preparation of a latex formulation, of the right composition
- **Step 2.** pre-vulcanisation
- **Step 3.** dipping the form in an appropriate coagulant bath
- **Step 4.** dipping the form in the latex bath
- **Step 5.** (pre-drying)/washing/leaching
- **Step 6.** drying and vulcanisation
The Li-IR latex is not stabilised with the same surface active molecules as NR latex. Our latex is stabilised by an anionic surfactant. It is important, in step 1, to check that all compounding ingredients are compatible with the stabiliser to ensure proper stability of the compounded latex. The pH should be kept above 10 to prevent coagulation from happening. The synthetic latex often appears to be less reactive. Proper selection of accelerators is the most obvious way to compensate, although not the only one (Figure 12).

Optimal pre-vulcanisation (step 2) is another option to handle the reactivity difference (Figure 12). Mixing and mild heating contribute to reducing the required pre-vulcanisation time.

Not only the recipe of the latex compound, but also, in step 3, that of the coagulant bath is the key to success (Figure 13). Films of the same thickness based on the same latex compound but prepared via dipping in various coagulants may have tensile strengths ranging from very poor (~5 MPa or 730 psi) to medium (~12 MPa or 1750 psi) or very good (~17 MPa or 2485 psi).
The duration of the dipping step may have a slight impact on properties (step 4). More important is the leaching step (step 5). Efficient leaching can not only lead to higher quality end articles but also contribute to bringing reactivity back and positively impact the tensile strength to a great extent (Figure 13).

**Figure 13**

**Dipped Goods**

Some tips . . . (continued)

- **Dip form in appropriate coagulant bath**
  
  A- CaNO₃ (30%), IPA (54.5%), H₂O (15%), Dresinate 214 (0.5%)  
  → 21 days pre-vulc., 12 MPa. Tensile strength.
  
  B- CH₃COOCa (20%), H₂O (79.5%), Dresinate 214 (0.5%)  
  → 21 days pre-vulc., 17 MPa. Tensile strength.

- **Dip form in latex bath**
  ⇨ Duration (see below)

- **Wash / leach**
  ⇨ Efficient leaching leads to higher reactivity and improved tensile strength (and higher quality end article)

<table>
<thead>
<tr>
<th>21 days pre-vulcanisation time</th>
<th>no leaching</th>
<th>30 min. leaching at R.T.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dipping time (s)</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Sample thickness ( )</td>
<td>260</td>
<td>330</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>6.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>1026</td>
<td>1045</td>
</tr>
</tbody>
</table>

The Li-IR latex can allow films characterised by a good tensile strength and a high elongation at break to be produced. Especially attractive for glove applications is the low modulus at elongation up to 700% (Figure 14), which helps to provide a high degree of comfort.
4.2.2. Dipped goods – Examples
KRATON Polymers has sampled customers with a research product of Li-IR latex*. Apex Medical Technologies, Inc. was one of the companies to evaluate this latex in potential products made via a dipping process. The following comments were kindly provided by Apex to illustrate the potential of the Li-IR latex.
Based on our latex, Apex has developed a unique curing system which can be used in either of two ways:
1 – with conventional vulcanisation chemicals, or
2 – in absence of all traditional accelerators and activators, including absence of zinc derivatives.
Apex found the latter method especially attractive since it can lead to extremely low levels of toxicity: it does not support the formation of nitrosamines and type IV allergic reactions should be significantly reduced, if not eliminated. The method works also with NR, de-proteinized NR, and poly-chloroprene, and does not require maturation or prevulcanisation. The final curing time can be less than 10 minutes. Finally, the end articles are white or translucent, thereby helping to increase further the perception of quality.
Apex found that both methods can be used to produce articles such as gloves, toy balloons and protective sheaths.

Figure 15
Stress/Strain curves

(Ring test ASTM D3492: 0.25 mm thickness, 20 mm width)

* For use of KRATON Polymers’ products in medical and healthcare applications, please see back page.
At 0.25 mm thickness level (ASTM D3492 method), the tensile strength exceeds the 25 MPa level (~3650 psi) and the elongation at break is at about 1000%, while the modulus remains low (Figure 15).

Preliminary experiments carried out at Apex suggest that the ‘Novel Curing Technology’ could be adapted to straight dipping procedures, allowing articles such as condoms to be produced. Mechanical properties of goods produced via straight dipping are not available yet. However, rings of condom-like thickness (~3.2 mils, i.e. 0.08 mm) produced via coagulation dipping at 42.5% solids content show an encouraging average tensile strength of 22.9 MPa (3317 psi) and elongation at break of 866% (ASTM D3492 method).

Goods produced with the Novel Curing System should have the following typical characteristics:

- **Raw material:** Synthetic Polyisoprene rubber.
- **Additives:** No traditional accelerators, activators or zinc derivatives. Contains an anti-oxidant.
- **Toxicity:** A 3rd party independent laboratory, contracted by Apex to evaluate a test article, concluded that the article is considered non-cytotoxic and meets the requirements of the Elution Test, USP 24.
- **Colour:** Translucent to clear.
- **Tensile Set:** Too low to measure – balloons recover to original dimensions.
- **Environmental Stability:** Expected to be similar to that of NR.
- **Elongation at break:** >950%.
- **Tensile Strength:** >25 MPa (>3600 psi)
4.3 Heat Coagulation Process

Wide and thin rubber sheets can be produced via the heat coagulation process. This is another process in which Li-IR latex can be successfully utilised. The sheeting process involves casting the liquid compounded latex onto a carrier belt and passing it under an infra-red heater to activate the heat sensitive compound and initiate the gel formation. The wet sheet is then carried on the belt into a conventional air heated oven to dry and cure the rubber.

Similar to the dipping process, a pre-vulcanisation step may be of varying importance depending on the type of formulation selected. A typical compound would count the following ingredients:

- Rubber latex, e.g. NR latex or Li-IR latex
- Conventional vulcanising systems, e.g. Sulphur, ZnO, ZDEC, DPG
- Anti-Oxidant, e.g. 2,2’-methylene-bis (4-methyl-6-t-butylphenol)
- Anti-thickening agent, e.g. non-ionic ethoxylates
- pH modifier to increase heat sensitivity, e.g. glycine
- Pigments as required, e.g. TiO₂
- Anti-foam agent such as refined mineral oils, to reduce bubbling
- Heat sensitiser, e.g. organopolysiloxanes

The heat coagulation sheeting process is the core technology of Four D Rubber Co. Ltd., located in the United Kingdom. Using their in-house expertise, they successfully switched part of their production from NR latex to a synthetic rubber material, namely our Li-IR latex product. As indicated in the section about dipped articles, one to one replacement does not work. The same basic recommendations are applicable here to assist in the reformulation process.

Four D Rubber produces vulcanised rubber sheets with a thickness ranging from 0.18 mm to 3.0 mm, and up to 4 metres wide without joins. Like dipped goods, the Li-IR latex-based sheets produced by Four D Rubber offer the low modulus, high tensile strength and low tensile set key features that are relatively difficult to reach with synthetic materials. A 0.27 mm thin sheet will typically exhibit a tensile strength above 20 MPa together with elongation at break around 1200% (Figure 16) and tear strength around 16 N/mm.
The field of applications explored by Four D Rubber covers amongst others dental dams, exercise bands, drapes and various types of release membranes (Figure 17). See footnote in section 4.2.2 for restricted uses.
4.4 Water-Borne Adhesives

The Li-IR latex appears to be suitable also for adhesives, such as the so-called ‘Cold Sealable Adhesives’ (CSA)\(^\text{10}\). CSA allow the bonding of plastic, foil, paper, etc to each other without the application of heat. In order to bond two substrates, a layer of CSA is applied to both substrates, which are then brought together under pressure. CSA are used for the food, medical and industrial packaging industry segments (see footnote in section 4.2.2 for restricted uses). An example is the sealant applied at both ends of the packaging of chocolate bars (Figure 18).

Traditionally such CSA are water-based and often derived from NR latex. A key feature of CSA based on NR latex is the absence of tackiness, allowing reels of pre-coated substrate to be unwound at the packing station without blocking problems. To date, synthetic CSA have usually not matched the low level of tackiness achieved with NR latex-based CSA, thereby reducing their attractiveness.

Li-IR latex can be turned into a CSA formulation having not only a low tackiness, but also having better sealing properties and better printability than their NR latex-based equivalents.
A typical formulation could contain the following ingredients:

- Li-IR latex as main CSA component
- Synthetic polymer or copolymer based on acrylic or vinyl acetate monomers, used to increase adhesion to polymeric films
- Non-ionic surfactant and anti-foaming agent to improve processibility
- Anti-oxidant and biocide to ensure appropriate resistance to ageing
- Thickening agent to achieve the desired application viscosity

Once optimised, a formulation of this type will match or exceed the sealing strength of commercially available CSA based on NR latex, and pass blocking tests.
5. Conclusion

With this synthetic Li·IR latex, KRATON Polymers is offering a product

- with properties similar to those of NR latex,
- which can be used in the same wide range of technologies and applications,
- and on the same manufacturing lines.

But it is also

- free of NR related proteins,
- based on a very pure polyisoprene polymer,
- free of ammonia smell,
- free of gel particles.

Last but not least, it can lead to vulcanised articles, such as gloves, sheets and bands, having low modulus and high elongation at break. In the field of non-vulcanised goods, it is particularly interesting for Cold Sealable Adhesives. See footnote in section 4.2.2 for restricted uses.

References

1 see Internet site: www.KRATON.com
5 same as ref. 3, pp.173.
8 see Internet site: www.apexmedtech.com
9 see Internet site: www.4drubber.com
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Visit us at www.KRATON.com, or contact your local KRATON Polymers sales manager.

KRATON Polymers U.S. LLC,
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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.

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.

Selling agents on behalf of the manufacturer are 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).

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.

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