BASED ON A LECTURE GIVEN AT
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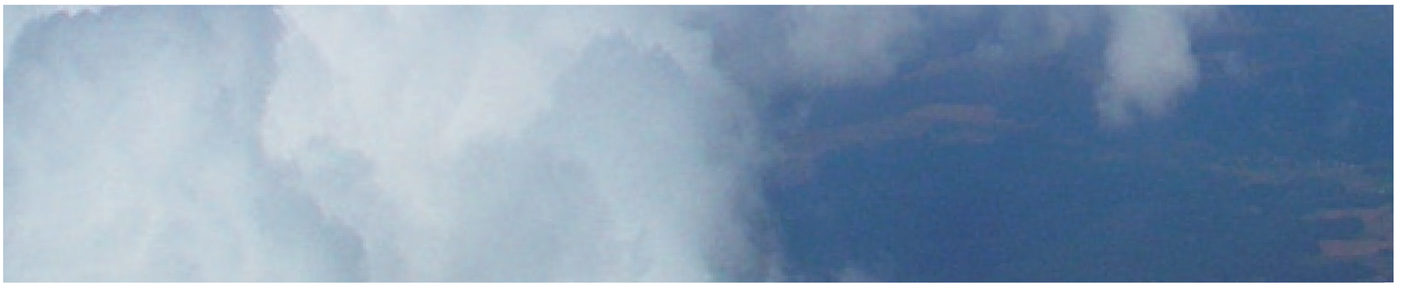
IS THE SKY THE LIMIT?



In this article, we would like to share with you our experience and goals in producing high and ultra-high index monomers for ophtalmic lenses. The sky might be the limit but in our Group, we often talk about wonders of chemistry and dream-inspiring technology. And this is exactly how our MR series were born.

By Hiroyuki Morijiri & Julien Buisson

Our Group, Mitsui Chemicals, Inc. (MCI), with one of its three pillars, the Advanced Chemicals Business Group, has developed the high and ultra-high index monomers, the MR series, as one of the Group's core businesses. The MR series rank No 1 in the world, thanks also to our strong expertise in urethane technology.

DEVELOPMENT OF PLASTIC LENS MATERIAL

One can divide the history of plastic/non mineral lenses in three periods:

- The first period shows the introduction of plastic materials for ophthalmic lenses. PMMA was used for ophthalmic lenses for the first time and CR-39 became the major.
- The second period shows the investigation period to increase the index. At that time many companies tried to increase the Index by using aromatic substance.
- The third period shows the shift in quality to fit the requests for ophthalmic lenses. The first priority for quality was the refractive index. Second and third priority are a high abbe number and high heat resistance.

Mitsui Chemicals started the development of lens materials in 1983 and started to provide MR-6 from 1986. ADC was the main substance for the ophthalmic lens material during the first generation, and is still widely used. The lenses made of ADC have some typical features: e.g. toughness, tintability and a high abbe number. But there is a major drawback: the lens is too thick.

To improve this defect, namely thick lens, many companies tried to develop new materials. For example, DAP had the aromatic ring to increase the refractive index, or TS-26 had not only aromatic rings but also bromine atoms. By using aromatic rings and bromine atoms it was possible to achieve a 1.6 index.

The researchers of MCI, being also a world-wide famous urethane supplier, focused on other atoms, which have high atomic refraction and came to the conclusion that sulfur atom has excellent properties. They tried to introduce the sulfur atoms in the molecule and apply the urethane technology for ophthalmic lens for the first time in the world.

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As a result of some calculations and many experiments, the researchers chose some isocyanate and polythiol compounds for the first ophthalmic materials.

They selected some isocyanate and thiol compounds in order to develop the right polymers and managed to confirm the reactivity, transparency or heat distortion temp, and of course the refractive index, abbe number and other key properties for an ophthalmic lens.

As a result MR-6, with its thiourethane bond in the polymer, was much stronger than CR-39 and we still believe that thiourethane lens is the most suitable material for ophthalmic lenses, as shown in figure 2.

Maybe you can easily understand that MR-6 was the most outstanding material for ophthalmic lenses at that time around 1990s. MR-6 was launched in 1986 and was the prototype for the next MR monomers based on thiourethane materials.

As time passed, MCI´s customers had 3 new major requests:

- Increasing the refractive index to make a thinner lens
- Increasing the abbe number to make the sight clearer.
- Improving the heat resistance to make the hard coating stronger or tougher.

To improve these three requests, the researchers focused on developing the molecular structure itself by using organic chemical synthesis technology.

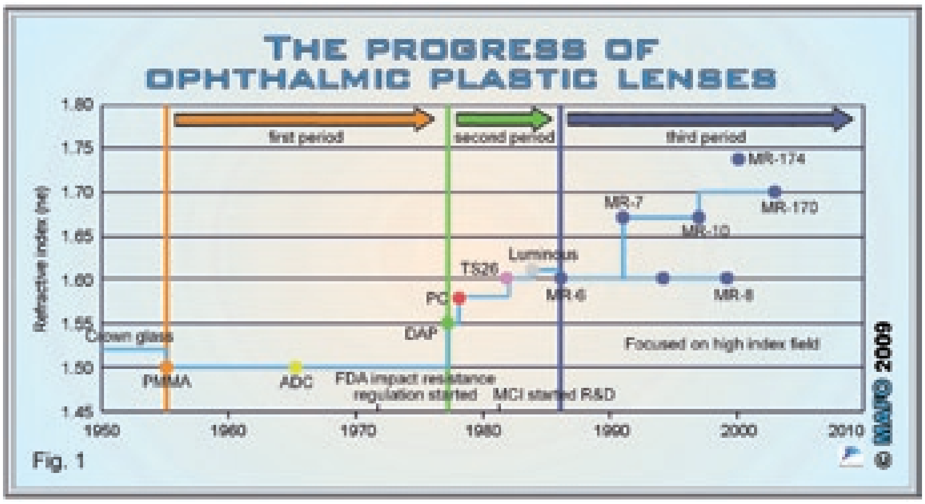
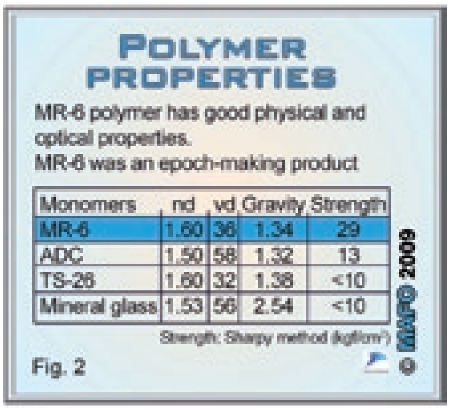


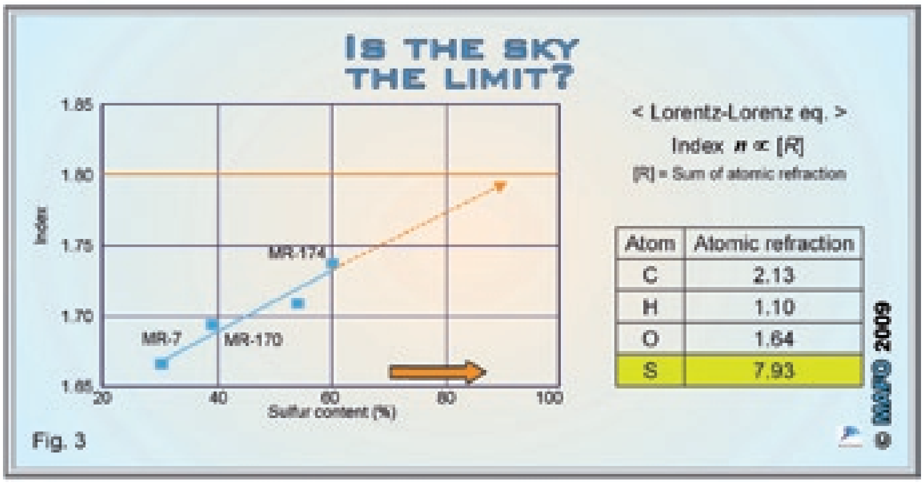
Fig. 1



Monomers	nd	vd	Gravity	Strength
MR-6	1.60	36	1.34	29
ADC	1.50	58	1.32	13
TS-26	1.60	32	1.38	<10
Mineral glass	1.53	56	2.54	<10

Strength: Sharpy method (kgf/cm²)

Fig. 2



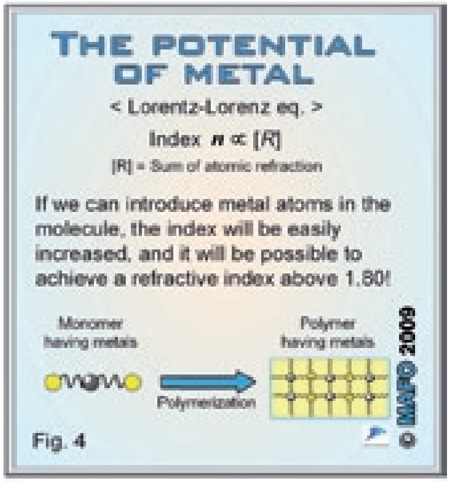


Figure 3: As far as using sulfur atom to increase the index, it is very hard to design a molecule which can be higher than 1.80

INCREASING THE REFRACTIVE INDEX

As this article is focusing on higher refractive index, we will now concentrate on the story of increasing the refractive index. The refractive index will be higher than previous ones by decreasing the carbon atoms and/or oxygen atoms and by increasing sulfur atoms in the basic structure of the molecule.

MCI has tried to design a lot of new types of molecules with calculating refractive index by using original calculating systems, and tried to synthesize each molecule that has high contents of sulfur atoms by replacing carbon and/or oxygen atoms. Finally, we managed to successfully produce new molecular structures with one having best ophthalmic properties: a poly thiol monomer that has a lot of sulfur atoms in the molecule.

The result was MR-8 with 1.60 refractive index, high abbe number and high heat resistance.

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Thanks to our customers, we believe that MR-8 has the world-wide top share in the 1.60 material field and was followed by MR-7 with 1.67 refractive index. This is the first material that was launched in the super high index field. It also has top share in the super high index material field with an excellent property for tinting. Additionally, MR-10 with 1.67 refractive index and slightly higher heat resistance was launched.

All these monomers are based on the thiourethane technology. They have not only high optical properties but also flexible processability such as drilling or high curved shapes by using appropriate glass molds.

LORENTZ-LORENZ EQUATION

We are now trying to further increase the sulfur content into the new MR-series. To make it easier to understand the theory, we are showing the Lorentz-Lorenz equation.

As already well-known, atomic refraction is the key factor of high refractive index. Sulfur has higher atomic refraction. Figure 3 shows

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the sulfur content of MR-series polymer. The sulfur content of MR-7 is approximately 30%, MR-170 is 40%, and MR-174 is 60%. If one can introduce more and more sulfur atoms in the molecule, one could achieve 1.80 index, but

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we can't design a molecule by using sulfur atoms only. It needs carbon atoms or other similar atoms to make multifunctional monomer molecule contents. So, as far as using sulfur atoms only, we believe it will be very hard to design the molecule that has a higher refractive index than 1.74. And then, we need to pay attention to higher atomic refraction like metal atoms.

Figure 4 shows some of metal atoms that have higher atomic refraction which is calculated on some original method.

ACHIEVING 1.80 INDEX AND HIGHER

As a result of simple calculation of refractive index, it will be possible to achieve over 1.80.

In figure 4 you can see the image of the monomer and polymer that have metals in the molecule or polymer. By introducing Sn (tin atom) in the molecule, it could be possible to achieve 1.80 index. If we can introduce some metal atoms that have higher atomic refraction, we could achieve a index higher than 1.85. And even achieve 1.90 by the similar ways.

But the problem is, as you already noticed, that the specific gravity is far higher than current polymer. It will be close to mineral glass that has metal atoms to increase the refractive index.

MCI will challenge to produce and launch the over 1.80 polymer in the near future.

Is the sky the limit?