Mitsui Chemicals

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Material makers for the high index revolution

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High index is a phenomenon which has been transforming the face and fortunes of the spectacle lens industry for the past quarter-century. This transformation is ongoing. In retrospect, its effects may be seen to have been as profound as those of the first truly viable ophthalmic lens plastic – ADC (CR-39) – in the 1940s, or, before that, the replacement by standard crown glass of the natural minerals that were the staple lens materials of 100 years ago. The aggregate effect of high refractive index introductions may indeed be greater than the revolutions which went before, changing the lens industry from a virtual monoculture to a new, unprecedented diversity.

MCI researcher with electronic microscope

When the concept was new in the early 1980s, 'high index' signified any refractive index above that of standard crown glass (1.523) or ADC (1.498). Now, as evolution accelerates, the original 1.6 'high' indices are increasingly often being displaced by 1.67 and 1.74, for lenses made in organic – plastic – materials. These are themselves displacing glass, available up to 1.9 refractive index from several sources since the 1980s, in many if not yet all the world's markets.

Thinner, lighter lenses

The reasons for this accelerating evolution? Primarily, that higher index materials enable spectacle lenses to be made thinner and lighter for the same vision-correction value, so offering fresh end-consumer benefits and revenue advantages for optical suppliers and retailers alike, on the lens side of the spectacle equation. These additions to value themselves exist over and above the perceived advantages of organic materials versus glass, in weight and safety terms, which have come increasingly into play since 1971 US legislation on lens impact resistance.

While weight and thickness differentials are undoubtedly one of the factors that has favoured the growth of 'plastic', growth in both glass and plastics high index lenses has boosted demand for anti-reflection coatings to counter the effects of enhanced-index materials' inherently higher reflectance. Given the opportunity to choose them, consumers tend to appreciate AR coatings for their cosmetic and aesthetic properties, if not always in terms of their less well understood functional benefits. So, again, high index lenses and materials have created a 'win:win:win' situation for the industry, optical retailers and consumers, adding both real and perceived value all through the supply chain.

High index lens materials truly have had, and continue to have, a transformative influence on spectacle markets world wide. They are a fairy godmother for a once mundane, commoditised industry sector. Yet while lens forms and designs, coatings and production technologies make the headlines, there is less recognition in the ophthalmic community for specialist materials producers. Yet they it is who provide the building blocks essential to high index lens development.

Wonders of chemistry

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MCI

Mitsui Chemicals Inc (MCI) are a, if not the, world leader in research, development and production of organic high index lens monomers: a well-known name and a valued working partner to lens industry multinationals – think the likes of Carl Zeiss Vision, Essilor, Hoya, Nikon, Rodenstock, Seiko, Shamir – but with perhaps a lower profile beyond this globally influential group than is justified by their vital contribution to progress.

So who are MCI? The corporation dates from 1997, but its operational roots go back as far as the nineteenth century, when products from coal mining in Japan's Kyushu island came under review as sources of chemicals for refinement. MCI's administrative headquarters are located in Tokyo, where the Group has been active for some 60 years; the company was formed 13 years ago from the coming together of Mitsui Toatsu Chemicals and Mitsui Petrochemicals. Along the way, in 1961, MCI opened offices in New York, Düsseldorf and, later, Singapore; today, MCI operate from well over 20 sites across the world. They continue to expand, for example through the purchase in 2008 of California-based lens coating specialists SDC Technologies.

MCI's high index materials R&D and production operations are a main focus of one of their three business sectors, Advanced Chemicals. The others are Basic Chemicals, and Performance Materials. Specialists from MCI's group of research and development scientists, including chemical engineers, began work on materials for higher index spectacles lenses in 1983. What would now be termed 'mid index'materials – between 1.5 and 1.6 index were, of course, already available on the market, as a result of work carried out mainly in Japan. The strategy choice for Mitsui's R&D team was then, as it is now, clear: to

Innovative technologies

create products well differentiated from competitors in terms of characteristics and benefits; their initial campaign was to develop and produce a 1.6 index lens, which was then – a generation ago – the ceiling of lens market demand.

'Epoch making'

In the early 1980s, lens market leaders were already seeking materials to yield lighter and above all thinner lenses, as truly viable alternatives to ADC. Existing higher index materials had been achieved using

Expertise in Fine Chemicals

aromatics, and even bromines; these had downsides at every level of the supply chain. MCI may have been newcomers to the ophthalmic lens sector, but their long history of experience with chemicals had suggested that the lens potential of urethane would be well worth investigating: 'a world first', says Mitsui Chemicals Europe's functional chemicals director based at the firm's Düsseldorf, Germany, location, Julien Buisson. In 1986, the research project bore fruit; MCI launched their first high index product **MR-6**, the first-ever thiourethane ophthalmic lens material: index 1.6, Abbé value 36, weight per cubic gram 1.34.

This new improved 1.6 index compound was, say MCI, an 'epoch-making' innovation, combining as it did a better Abbé value than competitor products of the era with greatly improved strength or mechanical resistance, weight comparable to or better than other contemporary 1.6 index materials, and that vital capacity for use in thinner lens forms. It was a basis on which to build.

At MCI, the process of material refinement continued; the company's background in chemical synthesis prompted them to try replacing hydrocarbon atoms on the molecule they were testing with atoms of sulphur. The result of this approach launched in 1999 was **MR-8**, a thermosetting plastic that has held its place as a high index market leader through to today. Again a 1.6 index material, but with an improved 42 Abbé value, weight just 1.30 and greatly improved heat resistance for easier processing, MR-8 ranks No 1 in the world (as in MCI's quality-orientated home-market, Japan, and indeed across Asia as a whole) among 1.6 index materials.

MR-8 has been widely used in progressive as well as single vision lens designs; its coatability and tintability made it versatile for use in photochromic and in prescription polarising lenses. It is, adds Julien Buisson, a lens material also perfectly adapted for the free-form era.

Fresh advances

Research and development did not stop with **MR-8**. In the 1990s, with the overall lens market trend moving fast in favour of organics, demand was accelerating for plastic materials with even higher index 'thin and light' benefits. Mitsui

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introduced a choice of 1.67 index materials, **MR-7** and **MR-10**, each a thermosetting thiourethane compound with high concentrate of sulphur atoms in the molecule, **MR-10** with higher heat resistance, **MR-7** with higher tintability. Both these materials (Abbé value 31 in each case) have superior tensile strength; it goes without saying that they are AR coating compatible and, along with others in MCI's MR series, can be hard coated by either the dip-or the spin-method. Both can be used in the increasingly important role of high base curve lenses when cast using appropriate glass moulds. This has opened up new opportunities for lens makers in the lucrative, rapidly expanding sports eyewear sector.

Among the most recent additions to the MR materials series is **MR-174**, designed to satisfy the 21st century appetite for what have been termed 'ultra high index' lenses. The rise in index is consonant with Mitsui Chemicals' policy of moving their materials up the refractive index ladder by clearly differentiated step changes.

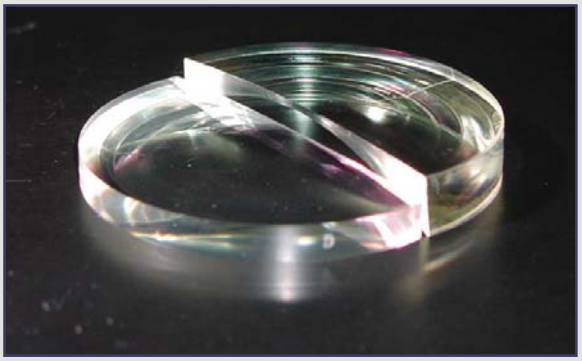
Where next?

All lenses presently available in 1.74 index materials exhibit characteristics, according to some lens industry experts, which suggest that this current line of development may have gone about as far as it can go. Tintability has been lost, and impact resistance, though remaining acceptable for MCI's product, is less than for lower indices.

Is 1.74 the end of the practicable road for MCI, given that the sulphur atom percentage required for a major rise in index might make the material non-viable? Not so. The acquisition of hard coating specialists SDC Technologies is proving helpful over the whole MR series by making it possible to integrate materials R&D with the development of index-matched coatings. Beyond this, 'if we can introduce metal atoms in the molecule', the firm says, 'it will be possible to achieve 1.80 index lenses'.

Initially, for this evolutionary step, the atom of choice would be tin, but 'if we can introduce metal atoms that have higher atomic refraction it would be possible to achieve an index higher than 1.85… even 1.9'. This would put organic lens materials fully on a par with glass, in refractive index terms.

The problem, MCI acknowledge, is the increase in specific gravity – weight – that would accompany the addition of metal atoms to the polymer. This effect might not prove insurmountable in the market, given the relative success of ultra-thin 1.9 index mineral lenses in their day. A 1.8 index polymer from Mitsui 'in the near future' is an avowed part of this firm's global strategy.



Thickness difference between MR Series (left) and 1.50 index lens (right)

Where will the market for high index lens materials be found? As Optical World consultant editor Dick Chaffin wrote in a recent issue, the 80:20 formula for organic lens supply is well established; 80 per cent of spectacle users need and wear low-to-moderate powers, for which ADC remains an acceptable, and affordable, choice (with polycarbonate as high impact resistance alternative. The properties are 'good enough' says one of those lens industry experts. Do the remaining world 20 per cent of higher power corrections, especially high minus, represent the only market for high index, and a sufficient global incentive for continuing investment and research?

Is there evidence not only that the incidence of ametropia, specifically myopia, is increasing – as it certainly seems to be, especially in many Asian markets – but that more myopes are leaving the 'moderate majority' to become higher power wearers? Not that your reporter is aware.

There are, however, suggestions from lens market 'big names' that more myopes towards the higher end of the 'moderate majority' would welcome the opportunity to wear thinner, lighter lenses. (Using 1.74 lenses can save up to 40 per cent on edge thickness.) As higher index lenses become a more frequently offered, more visible, better understood dispensing option, as labs worldwide accept higher index lens processing as a routine element in the order mix, it seems reasonable to presume that these lenses' appeal will widen. The high index sector may gain more from ADC materials than from polycarbonate. This is a proposition agreed by MCE's Julien Buisson.

As a specialist supplier of high index spectacle lens materials, MCI in the ophthalmic context is both the creation of, and a major contributor to, a fast-changing world lens market. Their three business sectors, of course, supply the world with a host of other products for a huge range of industries. The firm's aims, throughout the development of the MR series, have been to focus first on materials for thinner lenses, but to couple this with ensuring well-balanced materials featuring the best achievable combinations also of Abbé value, strength, hardness, lightness and versatility for any given index – and always to work closely with their lens caster customers. This is a story that clearly has more chapters yet to be written.