Glass lenses in modern dispensing

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Competencies covered:

Dispensing opticians: Optical appliances

Optometrists: Optical appliances

Up until the 1970s, the majority of spectacle lenses were made of glass, but the introduction of high quality CR39 and then the race for higher index plastics led to glass now making up a small percentage of the lenses dispensed in the UK. But glass has not disappeared altogether and still has some uses in dispensing.

Material properties

Refractive index n_d and n_e - the ratio of the velocity of light in a vacuum to the velocity of light in the refractive medium. In the UK it is convention to quote the helium d-line (n_d) which uses a wavelength of 587.56nm. In continental Europe the mercury e-line (n_e) is often used and gives a slightly higher refractive index. This is due to the using a wavelength of 546.07nm.

Specific gravity (density) - the weight in grams of 1cm³ of the material. This normally increases as the refractive index increases. However, as a guide, if the reduction in volume (indicated by the CVF) is greater than the increase in specific gravity, then the lens would be no heavier than if it had been made in crown glass.

CVF (Curvature Variation Factor). This indicates the change in volume and thickness obtained when a material is compared to crown glass (CVF = 1). CVF is calculated by comparing the refractivity of crown glass to that of the other material using $0.523/(n_d-1)$. So a 1.7 glass material results in a CVF of 0.75; so for the same power, a 25% reduction in edge thickness would be expected by using a material with a refractive index of 1.7 instead of 1.523.

Abbe number – The reciprocal of the dispersive power of the material and indicates the degree of transverse chromatic aberration (TCA) the wearer might experience. **Table 1** uses $V_d = (n_d-1)/(n_F-n_C)$ with n_d being the helium d-line, n_F is the index for the

Material	Refractive index		Specific gravity g/cm³	CVF	Abbe o V_d
	n_d	n_e			
Crown Glass	1.523	1.525	2.54	1.000	59
CR39	1.498	1.502	1.32	1.050	58
Polycarbonate	1.586	1.589	1.20	0.892	30
Trivex	1.530	1.526	1.11	0.987	45
1.6 plastic	1.600	1.603	1.36	0.879	36
1.6 glass	1.600	1.604	2.63	0.866	42
1.67 plastic	1.670	1.674	1.40	0.784	32
1.7 Tital glass	1.700	1.705	3.21	0.746	42
1.74 plastic	1.740	1.746	1.40	0.709	33
1.8 Lantal glass	1.802	1.807	3.65	0.652	35
1.9 Lantal glass	1.885	1.893	4.00	0.590	31

Table 1: Shows a selection of lens materials covering both plastic and glass. (Adapted from Jalie[1] and Wilson[2])

abdo|CET

This article has been approved for 1 CET point by the GOC. It is open to all FBDO members, including associate member optometrists. The multiple-choice questions (MCQs) for this month's CET are available on **page 8** and **online**. Insert your answers to the six MCQs on the inserted sheet or online at www.abdo.org.uk. After log-in, go to 'CET Online'. Please ensure that your email address and GOC number are up-to-date. The pass mark is 60 per cent. The answers will appear in the October issue of *Dispensing Optics*. The closing date is 13 September 2013.

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wavelength, hydrogen blue (486.13nm) and n_c is for hydrogen red (656.27nm). The higher the Abbe number, the lower the degree of chromatic aberration that will be experienced.

It can be seen from **Table 1** that there is a wide selection of refractive indexes still available in glass, and that higher refractive indexes are available in glass compared to plastic. Also, for some indexes, glass offers a higher Abbe number; albeit with a far higher specific gravity.

Crown glass (n_d = 1.523) is composed of 70% silica, 15% soda, 12% lime and 3% other ingredients (including arsenic and antimony)[2]. It is the silica which gives glass its superior scratch resistance, so for those patients working in very dusty environments glass will last longer than a plastic lens. Glass is also more resistance to chemical attack and will be advantageous for those patients who work in environments where harsh chemicals may be in use (provided that a Health & Safety assessment has been done to examine the risk of impacts).

To achieve a higher refractive index, the manufacturer reduces the amount of silica in the mix and replaces it with metal oxides, eg, titanium oxide, barium oxide and lead oxide. This results in a higher refractive index, but it increases the cost of manufacture and can give the material a faint yellow colour. High index glass also tends to be less scratch resistant (although still better than uncoated plastics), less impact resistant and not as chemically stable as crown glass.

Availability

Crown glass offers all the same combinations as can be found in CR39, such as bifocals, trifocals, PPLs; all with the photochromic option. The availability in the higher refractive indexes does reduce, although PPLs are available up to an index of 1.8. Also, there is the advantage that glass can be bonded; you can order a high index glass lens with a bonded layer (eg, Norbond from Norville). The bonded layer can be tinted, photochromic, or even a segment (usually a round 30) to create a custom-made bifocal[3] and is available even for some 1.9 index lenses.

Figure 1: Broken pieces of toughened glass[5]

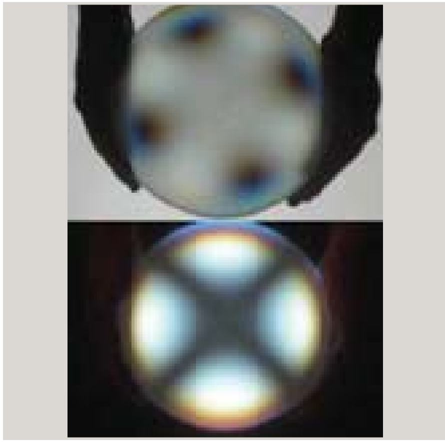

Figure 2: Stress patterns in toughened lenses[5]

Should this option be chosen, then it must be remembered that the bonded shell will be approximately 1.3mm thick and if a bonded segment is ordered then the patient should be advised to take extra care with lens cleaning. It does however mean that even patients with high index lenses can have an even tint on their lenses; rather than the variation in colour due to differences in lens thickness seen with solid tinted glass lenses (the bull's eye or racoon eye effect).

Eye protection

Toughening/tempering

Untreated glass is not acceptable as a means to protect the eyes, but it can be toughened to increase its strength. So if it does break, it will shatter into small granular chunks **(Figure 1)** instead of sharp jagged pieces, and thus less likely to cause injury.

Thermal toughening

The glass lens is placed in a holder, heated to a softening temperature of about 650°C and then cooled quickly with jets of cold air to both sides of the lens. The length of time required for the process is based on the volume of the lens. The sudden cooling causes the outer layer of the material to cool much faster than the centre, resulting in surface compression. It should be noted that the lenses should be edged before being toughened, as edging them afterwards can cause the lens to shatter due to the strain. Thermally toughened glass will meet the British Standards drop ball test.

However thermal toughened glass must be made thicker than a standard stock lens to ensure that it can withstand the final impact test. This process has the advantage that it is fast to complete thus making it ideal for prescription houses that have a low volume of work to toughen. The disadvantages are that there can be a high failure rate before the spectacles are finished, and the heating process can cause some warpage of the lens surface. A thermally toughened lens will show the typical strain patterns when viewed with a strain tester/polariscope **(Figure 2)**.

Chemical toughening

With this method the glass is placed into a bath of potassium nitrate at about 470°C for 16 hours. During this time, the potassium enters the glass and displaces the smaller sodium ions from the material. This substitution of smaller ions for larger ones results in an increased surface compression. Chemically toughened glass is more impact resistant than thermally toughened glass, as well as being more scratch resistant. There is also less strain in the lenses, so there is not a distinctive strain pattern. Other advantages are: not having to use thicker lenses than stock, and the lower temperature does not cause warping of the lens surface. As with thermal toughening, the lenses should be edged before being treated.

Absorptive glass

Let's now look at some special tinted lens options. As these are 'solid' tints the colour density can vary with higher prescriptions, but also there is a need

Continued overleaf

Figure 3: Plano SF-6 lenses from Schott which protect from X-ray radiation

Figure 4: An example of the RayBan G15 tint

Figure 5: Plano protective spectacles for a glass blower

for the lenses to have a minimum thickness across the lens, in order to provide enough protection. This is often 3-4mm and therefore increases the weight, as well as restricting frame choice and causing problems with the position of the bevel[4].

X-rays
X-ray radiation from scattered radiation in areas such as electro physiology, orthopaedic surgery, radiology, catheterisation laboratories, urologic procedures and veterinary surgery, can be blocked by glass lenses. An example is the Schott SF-6 1.8 glass which is a leaded glass (lead oxide) with a light grey colour **(Figure 3)**. It needs a minimum thickness of 3mm to provide protection. Care must be taken as this material has a specific gravity of 5.18 and an Abbe number of only 25.43

Infrared (Short IR 780nm – 1500nm and Long IR 1500nm – 100,000nm)
Problems associated with near IR include clouding of the aqueous and vitreous humours and clouding of the crystalline lens, which results in 'heat cataracts'. Lesions, similar to burns, on the retina and choroids are also a direct result of IR radiation; which would occur if a person were to stare directly at the sun.

Since exposure to infrared is usually accompanied by a sensation of heat, there is an immediate awareness of the hazard and an immediate reaction occurs. However, high dosages of IR radiation can be present in excessive amounts in tropical countries and in industry when welding and furnaces are used; or for specialist professions such as glass blowers.

IR is more difficult to block than UV due to its very long wavelength and plastic lens materials generally do not provide IR protection. But IR can be effectively blocked by a glass lens with a solid tint that contains ferrous (iron) oxide. This gives the lens a characteristic dark green colour (eg, the RayBan G15 – **Figure 4**).

Didymium lenses
When a glassblower or other glass worker heats glass directly in a flame, the flame surrounding the glass emits a yellow light termed sodium flare. Didymium is a mineral which is added to the glass melt to create a high luminous transmittance filter specifically designed to absorb bright yellow sodium flare (589nm), making it easier for the glass worker to view his or her work **(Figure 5)**. The luminous transmittance of didymium glass is approximately 50%, depending on lens thickness, and didymium lenses can be worn indoors under normal lighting conditions with little effect on visual acuity. However, didymium glass does not provide a high level of protection from UV or IR radiation. It should only be worn in lower-temperature industrial applications, where radiation levels are low. The transmittance curve for a didymium lens is shown in **Figure 6**. It is also worth noting that didymium is now harder to find and that plastic options are now starting to emerge to help protect against sodium flare[6].

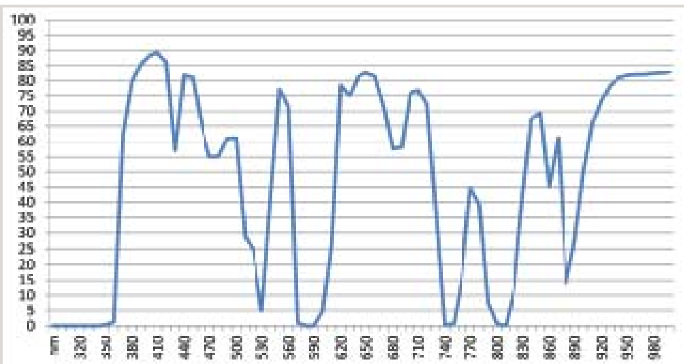

Figure 6: The transmittance curve for a didymium lens[6]

Conclusion
Glass is not the lens material of choice for most of the patients seen in practice, but there are still times when it will meet the patient's requirements better than a plastic lens. This might be due to prescription, patient demands for cosmesis, or due to lifestyle requirements for a separate work or hobby pair of glasses. Provided that the dispensing optician covers the advantages and disadvantages, the patient can make an informed choice.

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6. Phillips Safety website http://www.phillips-safety.com/glassworking/glassworking-eyewear/shop-by-glass-filter/sodium-flare.html [accessed 12 May 2013].

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MCQs overleaf

Multiple choice questions (MCQs)

Glass lenses in modern dispensing

1. If a glass spectacle lens has a curve variation factor of 0.80, its refractive index (n_d) will be

a. 1.604 b. 1.637 c. 1.654 d. 1.670

2. A lens has the following parameters: mean dispersion 0.01743, n_d 1.523. Its Abbe number will be

a. 30 b. 42 c. 48 d. 35

3. Which statement is true?

a. A high refractive index glass can be produced by reducing various metal oxides and replacing them with silica
b. Chemically toughened lenses show no strain pattern
c. If a glass lens appears to have exactly the same colour tint as a CR39 lens, their transmission curves will be the same
d. Glass of refractive index 1.7 is less chemically stable than glass of refractive index 1.523

4. Glass lenses are preferred in a dusty environment because

a. sodium ions have been replaced by potassium ions
b. they provide more protection when thermally toughened
c. silica provides abrasion resistance
d. they are easier to clean

5. Which of these statements is false?

a. Refractive index is the ratio of the velocity of light in a vacuum to the velocity of light in the refractive medium
b. Specific gravity is the weight in grams of $1mm^3$ of material
c. Trifocal lenses are available in glass
d. The time taken to thermally toughen a lens depends on its volume

6. If a CVF is quoted as 0.85, this means

a. there will be a reduction in thickness of 15%
b. the lens material must be glass
c. the Abbe number must be over 45
d. a glass lens will be heavier than the equivalent plastics lens

The deadline for posted or faxed response is 13 September 2013 to the address on page 4.
The module code is C-30544

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