General Optical Council Approved CET For Optometrists

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From blank to wearer

In the first of a two-part series on the process of lens manufacture from the original blank to the final spectacle lens, **Andy Hepworth** begins with the production process for semi-finished blanks.

Module C8425, one general point for optometrists and dispensing opticians

When considering the processes involved in creating a modern spectacle lens, there are two separate yet equally vital stages – production and manufacture.

It is of course possible to create a finished lens - such as an uncoated stock single-vision lens - without the need to manufacture. However, this article covers only the processes involved in 'non-stock' prescription lenses. The vast majority of these lenses begin with a semi-finished blank into which the patient's prescription and coating treatments are manufactured in strictly controlled laboratory conditions.

As the demand for mineral (glass) lens material is declining in the UK, this series relates specifically to the production and manufacture of plastic (thermosetting) and polycarbonate (thermoplastic) spectacle lenses.

Production

The majority of plastic lens materials dispensed in the UK fall into the thermosetting plastic category (including CR39, 1.6, 1.67, 1.74). These materials are produced using a casting technique whereby two glass moulds are forced apart with an elastic gasket, creating a cavity and a liquid monomer (for example CR39) plus a chemical catalyst known as an 'initiator' are then poured into the cavity.

These moulds are spring clipped together to secure the liquid mixture and are then placed in an oven (or heated water bath) where heat triggers a chemical reaction known as polymerisation. The liquid monomer is then converted into a solid polymer. The length of time for which the moulds are subjected to heat depends on the refractive index of the monomer being produced; CR39 is heated for approximately 24 hours whereas higher indices such as 1.67 around double that time.

Shrinkage was one of the biggest obstacles faced by the pioneers of CR39 and still poses a real challenge today. Shrinkage of the raw lens material (by approximately 15 per cent) occurs during the polymerisation process. The majority of shrinkage occurs during the earlier phases and can be overcome by the elastic gasket and spring clip that gently squeeze the two moulds together, thus maintaining the required contact with the mix to preserve an accurate optical outcome.

This does, however, become increasingly difficult as the raw lens material continues to solidify and shrink as the glass moulds and the lens need to flex to maintain contact with one another. This issue is even more problematic when the difference between edge and centre thickness increases (ie when producing semi-finished blanks for higher positive or negative lenses) and typically leads to a higher rejection in these higher powers.

Once the polymerisation process is complete the spring clip and elastic gasket are removed and the glass moulds separated to release the lens. It is normal for the glass moulds and spring clip to be used for well over 100 process cycles; however, the elastic gasket is not reusable but is usually recycled.

Polycarbonate production

Although the development of polycarbonate spectacle lenses largely coincided with the introduction of the thermosetting monomers described previously, it was CR39 with its superior scratch resistance that was the eventual conqueror of mineral glass.

Only in the last decade have polycarbonate lenses made a resurgence particularly in the US and Europe. This is partly due to the improvement in durability through the use of more efficient primer layers. A direct result of this is better scratch resistance on a material that provides the perfect solution for protecting patients against projectile impact and harmful UV light.

It could be argued that the seed for change was sown outside the optical community in the late 1970s/early 1980s through the development of compact discs. CD pioneers realised that polycarbonate had the mechanical properties that protected the digital information on each disc, while allowing the laser to read it. They then developed a much more efficient production process.

Injection moulding is used to produce thermoplastic lenses. It is different to the casting process used for thermosetting lenses in many ways, not least because the raw material is in the form of solid polycarbonate pellets (or granules) which look a little like large grains of rice. Steel moulds replace glass in this process and are aligned in a circular formation within the injection moulding machine in what is known as a di-set.

Step one involves the raw polycarbonate pellets being fed into a funnel (hopper) and heated to 300°C which transforms them into a viscous liquid. A screwing device then forces the treacle-like liquid into the cavities within each set of steel moulds. Chilled water is then passed around each of the moulds to cool and solidify the molten polycarbonate. During this process, and as with thermosetting production, shrinkage occurs. This is overcome through compression of the moulds while the chilled water is circulated.

This whole production process from heating to solidifying takes only 20 seconds. An additional step is required following production as the lenses need a temporary 'handling' scratch-resistant coating to protect the surfaces during transportation to the manufacturing site.

The di-set formation consists of five runners (produced by the path that the injected polycarbonate takes) each with a pair of lenses and acts as a great holding device, allowing an automated dip hard coating process to occur.

Variable tint lenses (photochromic)

It is worth highlighting that photochromic properties are added to a lens before the manufacturing process takes place. Because several lens casters now use Transitions photochromic technology as their preferred variable tint, Transitions can be used as an example of the steps required. However, it must be noted that the steps referred to are unique to Transitions lens technology.

Step one involves the front surface of the semi-finished blank being evenly sprayed with the photochromic chemicals. The blank is then transferred to an oven where the thermal action draws the chemicals into the lens monomer to a depth of 15 microns and finally a coating is applied to protect the front surface.

Manufacturing

Taking only semi-finished lenses into account and following the production processes already highlighted, we now have a semi-finished lens with an optically finished front surface. Our first step in the manufacturing process is to apply tape to the front surface.

Taping

There are two reasons why the front surface of the lens must be taped. Firstly it needs to be protected throughout the manufacturing process, and secondly the tape provides adhesion to a blocking alloy that will stay with the lens throughout the surfacing process. It should be noted that even though a temporary 'handling' hard coat was applied to polycarbonate lenses, this is simply to protect the front surface during transportation and would not provide enough protection to withstand manufacturing, hence the need for tape even on this material.

There are several techniques for lens taping, the most common being semi-automatic. This means the lens is placed in a holding device while the tape is wrapped over the front surface. Alternatively, there is a manual process where tape is applied directly to the semi-finished lens by the operator.

Blocking

The first step is to place an aluminium insert into the blocking device. This insert has several uses; it reduces the amount of metal alloy that needs to be used, hence reducing the amount of heat the lens is exposed to. It also has machined grooves, which allows the block to be positioned correctly in subsequent machines.

Once taped, a block is applied to the front surface of the semi-finished lens (Figure 1). To ensure that surfacing details on the rear of the lens are accurate, optical centration must be precise. It is vital that the blocking position is correct. It is at this point during the manufacturing process that any prescribed prism can be added to the lens. The amount of tilt and orientation then dictates the amount and the direction of the prism base.

A blocking ring selected from a 65 add/base combination is added above the insert and can be tilted to cancel any cosmetic prism thinning that would have been worked into a semi-finished varifocal lens during production. This is only done at the request of the practitioner; systematically, the blocking ring is laid flat to ensure the cosmetic benefit generated by the prism thinning is present in the final product.

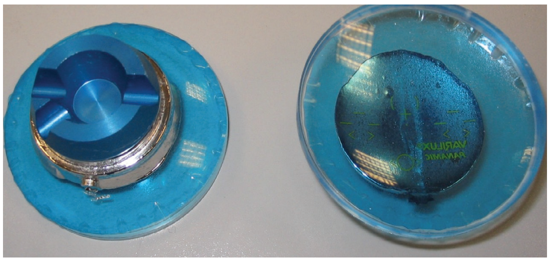

Figure 1 A block is applied to the front surface of the semi-finished lens

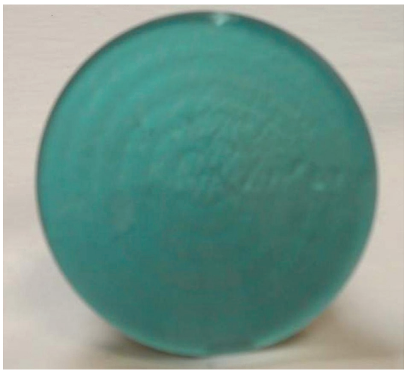

Figure 3 The rear surface has to be smoothed

Next, the front surface of the semi-finished lens is accurately positioned onto the blocking ring, and clamped before molten metal alloy is poured into the cavity (the cavity created by the blocking ring) between the lens and the aluminium insert. As soon as the cavity is full, chilled water is circulated around the block to assist solidification. The blocked semi-finished lens is then held back for a short period to allow for the full contraction. Thermosetting and thermoplastic lens materials have a fairly high coefficient of expansion and expand in the presence of heat. It is therefore essential to allow the blocked semi-finished lens time to return to its room temperature volume before any additional process takes place.

Cribbing

Nearly all semi-finished lenses are produced as 80mm diameter blanks, regardless of power or design and in nearly all cases the practitioner and glazer need a smaller diameter. Not only would many hypermetropic patients be unhappy with the cosmetic appearance if their spectacles were cut into their chosen frame using a blank of this diameter, technicians would be unhappy with the unnecessary wear and tear that their edging instruments would endure in order to cut the lenses into the frame shape. The reality is that

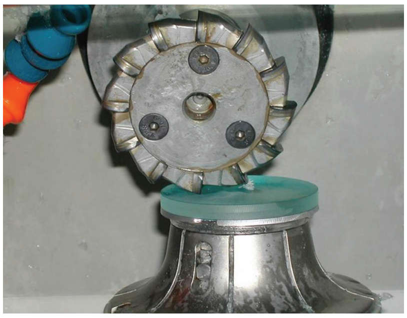

Figure 2 A rotating cutting wheel

the blanks are reduced in size through the cribbing process. The blocked semi-finished lens is placed in a surfacing generator (almost all modern generators have a cribbing function) and is rotated while a cutting tool shapes to the required diameter. Modern cribbing machines are now accurate to 0.03mm and can shape diameters to the nearest 3mm if necessary (eg 62/67 varifocal blank is possible).

Surface generation

To enable manufacturers to achieve the required curvature on the rear surface of a semi-finished lens, a number of variations of the main techniques have been implemented in recent years. The following is an overview of the three main methods used for the majority of lens designs/materials.

Rough cut, smooth and polish

This is the oldest technique in use today and, as the title suggests, is a three-step process. Before the process can start the lens curvature needs to be calculated using information about the material's refractive index, semi-finished curvature and the required lens power.

The lens is held within the generator by the aluminium block (placed onto the lens during the aforementioned blocking process). A rotating cutting wheel (Figure 2), which is mounted on a swing arm, then sweeps across the rear surface. To generate a toroidal surface (if required) the cutter is tilted and it is the combination of swing motion along with tilting that facilitates this.

Following the rough cut, the rear surface has a striated irregular finish (Figure 3) which has to be smoothed. This smoothing process is performed by a lap, also known as the tool (Figure 4) which carries the required curvature. To manufacture a significant Rx range, a vast number of laps are required. Manufacturers must also cater for a ▶

range of different refractive indices. As a result many of the bigger, more modern laboratories have invested in automation to pick and subsequently replace the required tool.

Once the correct lap has been selected an abrasive pad is placed on top and water is introduced to lubricate the mechanical process of oscillating the semi-finished lens over the tool. This process removes a small amount of the semi-finished lens material. In its smoothed state, the lens surface is still not wholly transparent, so to achieve this a final polishing process is performed using the same lap. However, the abrasive (smoothing pad) is replaced with a finer felt pad. Rather than simply a mechanical process, polishing also involves a chemical reaction triggered by using slurry (AlO_2) rather than water as the lubricant.

Cut to polishing

Today's advanced technology provides an alternative to a traditional rough cutting wheel with a single point cutter (Figure 5). The point cutter delivers a more refined surface and eliminates the need for smoothing so the lens can move straight onto the polishing phase. In relation to the polishing this is exactly the same as mentioned before with the required lap and slurry being used to lubricate and drive a chemical reaction.

Digital surfacing

This technique is also referred to as free-form and considers the rear surface as a series of individual points. These points are then cut directly onto the lens surface – front, rear or both.

Digital surfacing has enabled lens designers to generate new lens designs that were previously not workable. It is important to note that just because a lens is digitally or free-form surfaced it will not automatically guarantee an improved optical performance. It is, however, an excellent manufacturing technique.

Digital surfacing used to generate an average lens design will result in a very accurately made average lens. In the end, a lens is only as good as the features that have been designed into it, which in turn is a reflection of the quality of the research and development that created the design. It is important to ask the manufacturer what features, and therefore wearer benefits, have been designed into the lens which required it to be manufactured in this way.

Firstly, the surface design information relating to the required cutting depth (sag value) at each individual point on the rear surface is entered into a CNC (computer numeric controlled) generator. While the semi-finished lens rotates, a single point diamond cutter individually cuts points across the surface to an accuracy of around 0.1 micron (0.0001mm).

Even though the cutting phase is far more accurate than the more traditional methods and lens smoothing is certainly not needed, the polishing phase is still required. It would, however, render this accurate cutting technique pointless if traditional lapping tools were used to polish the surface as these would simply return the surface to a spherical or toroidal curvature, effectively 'rubbing' out all the individual points.

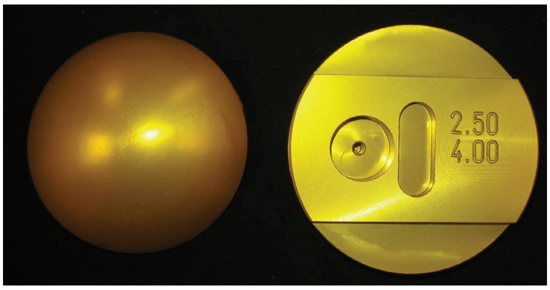

Figure 4 A lap or tool is used in the smoothing process

Figure 5 A single point cutter

To overcome this, several methods have been employed, including a computer controlled self-adjusting pad (used by Essilor), which accurately follows the topography of the surface ensuring optimal clarity while maintaining the integrity of the surface and therefore design.

Part 2 will look at the glazing and final checking of the lens.

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MULTIPLE-CHOICE QUESTIONS

1 What might be the expected approximate duration of polymerisation with heat of a mould containing material of index 1.67?
A No time as the monomer is unstable
B 24 hours
C 48 hours
D 1 hour

2 Which of the following statements about polymerisation is true?
A Heating results in an expanded material of around 15 per cent increased size
B Shrinkage occurs towards the end of the process
C Shrinkage is a particular problem for lower power lenses
D Moulds and clips are reusable, elastic gaskets are not

3 Which of the following statements about polycarbonate production is true?
A The complete process of pellet heating and solidification can be done in around 20 seconds
B Pellets need to be heated to 200°C
C Production uses a casting process
D Shrinkage is not a problem for polycarbonate during production

4 Which of the following statements is true about taping?
A It is only necessary on fragile materials so not used for polycarbonate
B It is synonymous with cribbing
C It helps secure the lens to a blocking alloy
D Tape is applied to the back surface of the lens

5 What is the most likely diameter of blank for semi-finished lenses?
A 65mm
B 70mm
C 75mm
D 80mm

6 Which of the following is integral to lens polishing?
A Aluminum sulphide
B Aluminium oxide
C Aluminium carbonate
D Zinc oxide

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