How are spectacle lenses manufactured?
From plastic to glass lenses from ZEISS – everything you wanted to know about the production of spectacle lenses

Lenses are the most important part of a pair of glasses and do the most to ensure you enjoy optimum vision. But first the lenses go on quite a journey before ending up in your frames. BETTER VISION explains how both glass and plastic spectacle lenses are made.

What are lenses made of? And what exactly sets individualised lenses apart from those you get "off the shelf"?

It should come as no surprise that the production of spectacle lenses starts with a visit to your optician. They will measure your prescription and create a unique vision profile. Then a suitable spectacle lens is selected and a measurement made to determine how the lens will be positioned in your favourite frames. These are all important factors, and the data must be passed on to the spectacle lens manufacturer so that they can produce a spectacle lens individualised and optimised just for you. But what happens next? How does vision analysis result in a modern, customised lens? First, a semi-finished lens is produced. Here you have a choice between two materials, plastic (also known as organic glass) and "real" glass (also known as mineral glass). These two materials are the foundation for creating spectacle lenses.
There are basically two different processes: no matter the manufacturer, individualised precision lenses – also known as prescription lenses – are almost all created using freeform technology. This is a cutting-edge production technique developed by ZEISS that the entire spectacle lens industry has since licensed.

Unlike prescription lenses, “off-the-shelf” stock lenses are created in a casting process. There is a difference between these two kinds of spectacle lenses: the optician usually selects stock lenses for a simple, cost-effective pair of glasses, i.e. for reading glasses or when the wearer needs replacement lenses quickly. Unlike prescription lenses, these are manufactured in large quantities and not individually. Stock lenses are perfectly well-suited for standard vision correction, but do not offer the same level of performance as individualised precision lenses. To produce the latter, the optician creates a detailed, comprehensive visual profile of the spectacle wearer that serves as the foundation for spectacle lens manufacture.

Creating an individualised lens in just nine steps

1. Preparation

These days, the production process for spectacle lenses is largely automated. Once the optician has sent the patient’s lens order to ZEISS, the first production step begins: the individualised lens is calculated and the data required for manufacturing the lenses is made available. Each production order is assigned a bar code so that the data necessary for processing the lens can be identified at each station in real time and then loaded to the particular processing station.

Depending on the prescription, the semi-finished lenses are selected automatically in the warehouse. The semi-finished lenses for the left and right eye already have an optical power on the front surface. To create the wearer’s prescription, only the back surface is machined with ZEISS freeform technology. The semi-finished lenses – also known as “pucks” because of their shape – are automatically taken from the warehouse and placed in a tray. Then the journey begins: conveyor belts transport the tray from one station to the next until ultimately two spectacle lenses have been created.
2. Blocking

The next step is blocking. Here a protective coating is applied to the surface of the lens. The semi-finished lens is then attached to the so-called "blocker". This step is necessary so that the lenses can be properly clamped and processed in the machines.

3. Generating

Once blocking is complete, the lens is formed to give it the desired shape and prescription. With ZEISS freeform technology, the front surface of the semi-finished lens already has the corrective optical power when taken from the warehouse. Only the back surface still needs to be machined and shaped for the particular wearer. To do this, a 5-axis CNC method is used that creates the right shape and prescription for the wearer in around 90 seconds. Basically, three different steps are performed within a minute and a half: the lenses are roughened, given a general shape and then tens of thousands machining points are defined using a natural diamond. This method enables the manufacturer to freely customise the optical surface, i.e. freeform.

4. Polishing and engraving

During polishing, the surface of each lenses is polished while the optical properties remain unchanged. A perfect surface is important for the application of modern lens coatings that do not separate from the lens. Every ZEISS lens gets its own special signature: a laser is used to engrave a nearly invisible "Z" in the lens. This precisely positioned marking is important for quality assurance and affixing a stamp that later assists with grinding and centring the lenses.
5. De-blocking and cleaning

Now the lens is de-blocked, i.e. carefully removed from the blocker. Since the metal alloy connecting the lens to the blocker melts at just under 50° C, it is simply dipped into hot water. The lens is then cleaned much like a car at the car wash: brushes, different cleaning agents and ultra-pure (i.e. especially well-treated) water is used to remove any traces from the lenses and prepare them for coating. The lenses are then blow-dried. Environmental protection is a matter of course at all production facilities: materials like the metal alloy are treated and reused, and the water required for production is recycled in an environmentally friendly manner.

6. Tinting

At this stage, the lenses are tinted if requested. Plastic lenses are placed in a dip dye batch, while glass lens tints are applied in metal oxide layers.

Textile colours that do not pose any risk to human health or the environment are used for plastic lenses. This process requires great dexterity: since each lens is manufactured individually and ZEISS offers tints in any colour, a lot of experience is necessary to achieve the "right" tint.
7. Coating

Now comes the final step in the production process, which is the most demanding technologically: the application of a spectacle lens coating. Coatings make the lens scratch-resistant and durable, help ensure crystal clear vision when it’s windy or in inclement weather, repel dirt, reduce irritating reflections and offer many functional benefits, such as when a person is driving or working at the computer. Unlike their glass counterparts, plastic lenses are not adequately scratch resistant on their own. Thus a suitable hard coating to protect against scratches is always a must for ZEISS plastic lenses. This is applied as a lacquer to the plastic lens in the dipping process, hardening it. Which of the various specially customised lacquers are used depends on the plastic and thickness of the lens.

After ultrasonic cleaning, the next coating is added by applying anti-reflective layers in a vacuum deposition process – and we do mean layers, because a modern lens can have up to nine. The final layer of coating gives the lens its extremely smooth surface, making it particularly resistant to both dirt and water. You can read more about spectacle lens coatings here.

8. Quality assurance

The lenses are almost done. But do they meet ZEISS’ strict quality assurance requirements? To ensure they do, each lens is thoroughly inspected before delivery. A visual inspection is performed to check for dust or damage, as well as a mechanical one to ensure that each lens meets the necessary specifications. Are the dioptries, the axis, cylinder, thickness, design and diameter correct? If the lens is flawless, then it is “stamped” in the final step. This orientation stamp is used to align the lens and assists the optician with inserting it into the frames precisely. It is removed before the final pair of glasses is dispensed to the wearer.

The Z for ZEISS is only engraved once all the quality assurance steps have been successfully completed and the lens really does feature ZEISS quality. The Z is our signature – our quality promise inscribed into every individual lens.

And anyone who wants a unique label in the spectacle lens can have their initials engraved!

Fun fact: did you know that only women work in the ZEISS tinting department? The reason: women tend to have better colour vision than men, making them extremely good at identifying slight deviations from the norm.
9. Glazing

Usually the optician glazes the lenses – the term used to describe the insertion of the lenses into the frames. However, ZEISS will do it upon request. This process requires micrometre precision, because only optimally fitted lenses provide perfect vision correction.

The ZEISS Online Vision Check

How well do you see contrast and color? Check your vision quickly and simply here!

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How are stock lenses and semi-finished lenses made?

Stock lenses and semi-finished lenses made of plastic are created in a casting process: special ingredients, such as for improving UV absorption, are added to the liquid materials called monomers. This mixture is poured into moulds, hardened and then processed to reduce residual
stress. Then the semi-finished lens is ready for use. If it will serve as a stock lens, then a hard coating is applied and, if requested, additional coatings.

The process is slightly different for semi-finished lenses made of glass: first, natural materials such as quartz, potassium carbonate, soda and oxide are melted at 1400° to 1500° C to form a glass mixture. Then this is pressed to form a round glass block that is one to three centimetres thick called a pressing. The front surface is processed in the next step. A diamond grinding tool is used to give the lens its exactly prescribed shape, while polishing gives it the necessary transparency. Now we have a transparent semi-finished lens that has already been ground on the one side.

**Producing plastic and glass bifocal lenses**

Bifocal lenses are a type of spectacle lens that have one field-of-vision for viewing objects up close, and another for distance vision. Bifocal lenses can be made of either glass or plastic. However, the production process varies enormously depending on the material. With glass bifocal lenses, an additional lens is integrated into the semi-finished lens, the upper half of which has the same power as the main lens while the lower near-vision area is stronger. First, the back surface of the additional lens is ground and polished. Then, the curved side is placed in the existing indentation of the main lens. Now the additional lens is melted and ground together with the main lens until only a single lens is visible. The bifocal semi-finished lens is then further processed by grinding and polishing the front and back surfaces.

Manufacturing bifocal lenses made of plastic is significantly less complicated. Unlike bifocal lenses made of glass, the power of the near vision area does not require an additional lens. Instead, the relevant area is more strongly curved. This curvature is achieved by using a suitable mould into which the semi-finished lens is poured.

**How varifocal lenses are produced**

The decisive factor when developing varifocal (also known as progressive) lenses is knowing what they’ll be used for: Will the wearer place special demands on their lenses, such as by working at the computer screen? Or will the lenses be worn while performing standard day-to-day activities? A large number of factors comes into play when calculating a lens design, much like a math equation with hundreds of unknown variables. Thus it should come as no surprise that producing the lens is a complex task. Here a special grinding machine gives the semi-finished spectacle lens the calculated design. A varifocal lens is optimised in multiple test phases before it is rolled out and batch production begins. The varifocal lens design is repeatedly modified and fine adjustments are made until the first lens prototypes are available. Test wearers put the lenses through the paces to ensure wearer tolerability. Batch production and marketing only begin once the test wearers are satisfied with the particular lens design.

**An individualised fit: lenses as unique as you**

At night, our eyes switch from daytime vision (photopic vision) to nighttime vision (scotopic vision). Healthy eyes need around 25 minutes to adapt to the dark. The less light that is available, the more active the eye’s sensory cells will become: they’re responsible for our light-to-dark vision and are known as rods. At the same time, the pupils widen to “let in” as much light as possible. Healthy eyes have no trouble adapting to changing light conditions. Hereditary diseases, certain medication, injuries and a vitamin A deficiency can all result in limited vision at night or dusk. This is a problem that affects many people who wear glasses. Pupils need to dilate more in reduced lighting conditions. As a result, depth of field is lost and spatial vision limited, while reflections and poor contrast tire the eyes. The ® Technology from ZEISS takes into consideration the wearer’s dilated pupils at night in the lens design, helping to considerably improve visual performance in low light conditions.

And did you know that our light-and-dark vision also plays a role when it comes to safety on a plane? During takeoff and landing, the cabin lights are dimmed so that passengers’ and crew members’ eyes can adapt immediately to the new light conditions in the event of a crash. This can save precious seconds in an emergency.

**Vision problems and eye diseases – what to do if your vision is restricted**

To be sure, “off the shelf” lenses are more than adequate for many different activities and visual defects. However, a perfectly customised pair of glasses can do a lot more. For example: while stock lenses accommodate the visual point of each eye, the actual fit of the spectacle lenses in front of the eye – no matter the frames – are not considered during fitting. The more lens production
incorporates how a spectacle wearer looks through their frames, the more precise the manufacture, ensuring the wearer enjoys optimum, natural vision. To achieve this, the optician needs to identify many other important facial parameters in addition to the visual point – and all with an accuracy of a tenth of a millimetre. The more the optician knows about the wearer, the more precisely the ZEISS lens design can be optimised. It also doesn’t hurt if the optician works with ZEISS measuring equipment, because this helps prevent “data transfer errors”.

Unless you attain perfect harmony between the frames, lenses, individual visual needs and the shape of the wearer’s face, then relaxed and natural vision is simply not possible, especially for people with older eyes or less common visual defects. ZEISS freeform technology accommodates a large number of personal data for the spectacle lens wearer and, thanks to complicated mathematical calculations, produces lenses featuring such precise manufacture and fit that the wearer enjoys optimum vision with their chosen frames. This is how you enjoy clear vision across the largest possible visual field for different distances as well as outstanding wearer tolerance. The more complex and unique the situation, the more significant the differences are between individualised and stock lenses.

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