FRAME MATERIALS

There are many materials used in spectacle frame manufacture both from natural and man-made sources. These may be used alone or in combination, explains Stephen Golding

Frame materials must meet certain criteria to enable them to be used successfully in the manufacture of frames. They must be lightweight, yet strong, easily adjustable yet maintain their shape, be machined in such a way as to allow easy glazing, be inert to both body fluids and external chemicals and colour fast.

There are two types of plastics materials available, thermoplastic and thermosetting. The materials which frame manufacturers generally use are thermoplastic. These are capable of being reformed under heat. Thermosetting plastics set or harden in the final stages of adjustment, fixing their shape. Such frames will not soften when reheated, but will burn or melt. This makes them unsuitable for frame manufacture, as dispensing opticians will have to make adjustments to the frames.

Production of plastics frames can be carried out in a number of ways:

Injection moulding, where the liquid monomer or polymer is pumped into a mould, Here joints are usually placed into the mould prior to moulding.

Machining or routing is where the eye shape is cut from sheet material. Joints are either heat sunk or riveted. Frames can also be made by moulding, followed by machining.

Cellulose acetate

Cellulose acetate is the most common material used since being developed in 1894. It is produced from cotton linters and acetic acid. It is usually made into sheet form, although it may be made from extruded strips. Colour is generally applied by laminating colours on base materials, fusing them together forming sheet acetate. This is then machined into shape, before being barrel polished. Acetate is reasonably lightweight and mechanically stable at room temperature, non-flammable, softening at 57°C. It will, however, warp easily above this. Acetate has poor resistance to common solvents. Acetone is used as a solvent to repair acetate frames (also found in nail varnish remover). Frames when in contact with the skin can whiten especially at the bridge and temple areas. Sides are reinforced. Joints are generally heat inserted or they may be riveted.

Cellulose propionate

Cellulose propionate is made from cellulose flakes and proprionic acid. In its raw state it comes in clear granules. These are liquified and injected into heated moulds. Joints are usually pre-inserted in the moulds. Finished frames are then barrel polished. Colour is applied by dying, transfer printing or by hand painting. The finished frame is then lacquered to maintain the polished appearance. The softening temperate is 67°C. Excessive heat above this causes shrinkage. Propionate has good elasticity but stretching the frame will cause it to cleave.

Cellulose nitrate

Cellulose nitrate is made from cotton linters and nitric acid with camphor used as a plasticiser, which give it its characteristic mothball smell. Old frames have a typical dark urine yellow colour. Nitrate frames were more robust than acetate although they became very brittle with age. Nitrate frames are no longer made in the UK due to its flammability **(Figure 1)**. Its flash point is at 70°C, which is just above the softening point, 65°C.

SPX

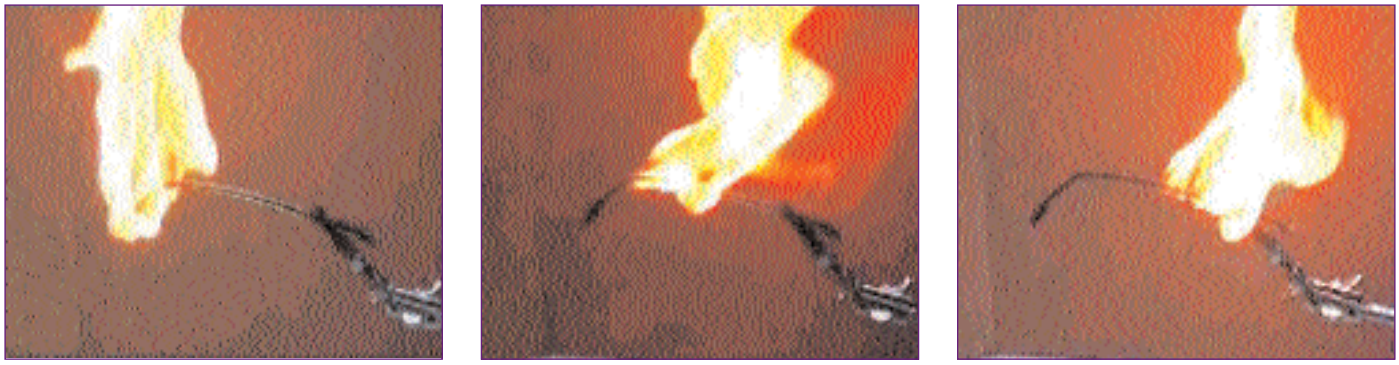
SPX is a co-polyamide, which is a lightweight, strong and mouldable nylon derivative. Co-polyamides are derived from two different monomers joined in the same polymer chain. It is easily coloured then lacquered to give a high polish. It is highly elastic and impact-resistant and has a harder surface than acetate therefore resistance to abrasion is greater. It is classed as a hypoallergenic material. SPX is resistant to most solvents, cosmetics and oils. It softens at 95°C; excessive heat will cause it to shrink, therefore it is recommended that it be accurately cold glazed. Over-glazing of SPX will cause it to craze and/or crack. However, should the lenses be under-glazed, unlike acetate, it is not possible to shrink the rim in a controlled fashion. SPX has a disadvantage in that it is more susceptible to temperature shock. Due to this most of the breakages occur in the winter months. In the search for thinner frames SPX used to be inline glazed. Inline glazing was a process where the frame had a bevel in the rim. The lens had a supra groove running around it. This is generally only found on the older styles. Sides are reinforced.

Epoxy resin

Epoxy resin or Optyl is a thermo-setting plastic, softening at 80°C, with a thermoplastic memory, enabling it to set into any new shape, but return to its original form when heat is applied. It is brittle when cold. Colour is applied by dying with a top layer of varnish. It is resistant to burning and cannot be shrunk. The resin is vacuum injection moulded with the joints inserted in the mould. It is approximately 30 per cent lighter than acetate. The sides can either have a short reinforced side or a light coated metal side (LCM). LCM sides were introduced to allow the sides to be adjusted easily without the need for heat. The short reinforced sides required enough heat to make them soften, then they had to be held in shape whilst cooling. They used to be supplied with a cloth cover to stop the dispensing optician from burning their fingers.

Polymethylmethacrylate

Polymethylmethacrylate (Perspex) is a stable, lightweight (specific gravity 1.2g/cm^3)[1] acrylic resin with a refractive index of 1.49 giving it its crystal properties. It is a hard, rigid material, but brittle. Frames made of acrylic are often of a supra, design due to the high temperature required to spring in lenses and the rigidity of the material **(Figure 2)**. The sides are usually sinuous and non-reinforced. Colour is laminated onto a clear base. The joints are often fixed by



▲ Figure 1: Three frames at approximately 5, 10 and 20 seconds after ignition.

mushroom pinning. It is dermatologically inert.

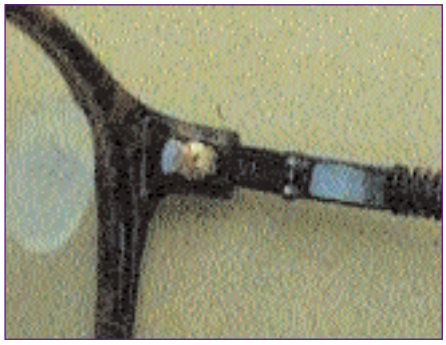
Carbon fibre

Carbon Fibre is a misnomer, as pure carbon fibre is not used for frame manufacturing. What is called carbon fibre is a composite material of nylon impregnated with carbon fibres. The typical composition is 80 per cent nylon and 20 per cent carbon fibre. They are naturally a dark grey colour with the colour being applied by lacquer; because of this the colours tend to be dark, bold shades. Some of the frames have closing blocks whilst others have full rims, which require cold accurate glazing. The sides are usually of another material, which is typically of a metal composition. The sides are usually attached by a screw fitting **(Figure 3)**.

Kevlar

Kevlar is a polyaromatic amide, a nylon-based derivative, developed in 1965. It is occasionally used in spectacle frame manufacture. It is lightweight and flexible, being twice as strong as nylon and five times stronger than steel. It is thermally stable and self-extinguishing. It is resistant to solvents but its external surface is affected by ultra violet light.

▲ Figure 2: Perspex supra design.



▲ Figure 3: Side attachment on a carbon fibre frame.

Nickel silver

Nickel silver is an alloy of copper, nickel and zinc, its nickel content being between 12 -25 per cent. It is an easily worked, flexible material, which requires plating to prevent it discolouring. Where there is contact with the skin it goes green. It is often used as a core material for rolled gold. Nickel is, however, one of the most common materials to cause an allergic reaction. Experience has shown this to be more of a problem with females, possibly due to the fact they have had more sensitising contact with other nickel-based products, such as jewellery and clothes fastenings[2]. There is now a European Directive (94/27/EC), which specifies the upper limit for nickel release in articles, which have direct and prolonged contact with the skin.

Monel

Monel is another nickel-based alloy, developed in 1905. It has much higher nickel content than nickel silver. It is made up from 66 per cent nickel, 31.5 per cent copper plus iron, manganese and silicon. It is corrosion-resistant and is capable of being left in seawater for 24 hours without degradation. However due to the high nickel content there can be a higher incidence of allergic reaction. It is commonly used as rims with the bridges being a memory metal.

Titanium

Titanium is one of the most expensive frame materials to produce due to its extraction costs and manufacture. It is generally considered to be hypo allergenic, particularly in its pure form, although when it is clad a layer of nickel is used. It has low electrical and thermal conductivity. Weight for weight it is approximately half that of nickel silver. It is common for titanium frames to be an alloy of titanium, vanadium, aluminium and manganese. This is known as Beta titanium. The surface hardness is about three times that of gold plating making it abrasion resistant. Titanium is very flexible, being 20 per cent more elastic than nickel silver.

In general, welding of titanium and its alloys can be readily performed, but it is necessary to exclude reactive gases, including oxygen and nitrogen from the air, and to maintain cleanliness. Titanium oxide, which is formed when titanium is heated to high temperatures, is brittle. Argon gas is used during the welding process.

TIG welding, also known as Gas Tungsten Arc Welding (GTAW), is used to produce high quality welds. In TIG welding an arc is formed between a non-consumable tungsten electrode and the metal being welded. Gas is fed through the torch to shield the electrode and molten weld pool.

Memory metals

Memory metals are made of various alloys, typically 40 per cent nickel and 60 per cent titanium. Cobalt and titanium are also used. Due to the flexibility they are difficult to adjust. The flexibility is about 8x that of spring steel. It is corrosion and tarnish-resistant. Most commonly the bridges and sides are made of the alloy with the rims being of a more rigid material, typically Monel. They are usually attached together by means of a cup soldered to the rim and the bridge fitting into the cup, being made secure with a superglue[3]. Memory metals are not new having been developed for the US military in 1961.

Aluminium

Aluminium is a lightweight material, which is cold to touch. The colour is applied by anodising the surface, then dying. The anodising process is where an electric current is passed through the aluminium (anode), which is suspended in a sulphuric acid bath. The aluminium is oxidised. The length of time the aluminium is in the bath determines the thickness of the oxide layer. The oxidised layer can then be dyed with a water-based dye. It is stain and tarnish-resistant. As it cannot be soldered or brazed, joints have to be pinned. Some joints are milled from a solid block giving the appearance

of a soldered joint. It was traditionally used for sides on plastics frames, but is now used as in full frames or fronts with, for example, titanium sides.

Stainless steel

Stainless steel is an alloy of iron, chromium and nickel. It is a strong, lightweight, non -corrosive metal, hence the name. It is produced either from wire or plates depending on the design. It is easy to adjust and not easily damaged. It rarely causes skin irritation. It discolours easily when heated.

Rolled gold

Rolled gold is produced by bonding a skin of gold onto base metal, usually that of nickel silver. It has good resistance to corrosion. Rolled gold maintains its appearance even after repair and is unlikely to cause skin problems unless constantly touching, or if the integrity of the gold is compromised. The gold blocks are cold hammered and rolled to a suitable size for drawing into frame-making wire, which is then sold already profiled to manufacturers. Rolled gold will be stamped with the gold content, eg, $^{1}/_{20}$ 14kt, which denotes 20 parts per thousand of 14-carat rolled gold.

Electroplating

A number of frames are electroplated to give them their final finish. The base material is usually that of nickel silver. A number of materials have been used gold, palladium, rhodium and ruthenium (all members of the platinum group) and chromium. If the plating is damaged then perspiration can act as an electrolyte between the base (+ve) and the plating (-ve) like a battery. The small current causes copper salts in the nickel silver to form 'verdigris' which forces off more plating as it occupies a greater space. To protect the frames further they are often treated with a lacquer, which may be applied as a liquid or as a powder, which is then heated until it liquifies. Common plastic polymers used for covering frames include polyurethanes, polymethylmethacrylate, and epoxy resins. Polymerisation can be before the heating process or as a result of it.

Other materials

Some naturally occurring products have been, and still are being used in spectacle manufacture. These include shell, horn and wood.

Tortoise shell

Tortoise shell frames are formed from the belly plates of the hawksbill turtle. As it is an endangered species it is no longer allowed to be killed for the shell. However, there are still supplies in the world and old frames still surface. It is manufactured by forging the plates together, under heat and pressure. It displays thermoplastic characteristics. Due to the risk of erosion where the sides meet the front, metal-to-metal joints will be used. As it is a natural product the colouring will vary from frame to frame with the rarer lighter colours being the most expensive. It is also identifiable by the green mottled patches. Shell adjustment needs to be done over a steam bath at 75°C, but should an accident happen, it is possible to repair shell by splicing together the pieces, placing in a saline bath and leaving for 24 hours.

Another natural material often confused with shell is horn due to the metal-to-metal joints. This is commonly sourced from buffalo horn. Its warm natural colours range from cream to black. Like shell it is lightweight and also hypoallergenic, not reacting to skin secretions. It expands under heat without warping. It has a hard surface, which takes a good polish but it can flake easily and will become brittle if left to dry out.

Wood

Wood is used in frame manufacture typically in sides covering a metal core, but fronts have also been made. Woods used include boxwood, beech, lime, cedar, bamboo and yew. The patient needs to be warned, that some woods, such as yew, can be toxic if eaten. Wood is a fibrous material that is hard and lightweight. It often has a yellow tinge. Wood will alter in size depending on the humidity, so no good for the sauna!

Dispensing opticians are often guilty of concentrating on the advances in lens technology to the detriment of frame materials. A good working knowledge of frames and their properties is an essential part of the dispensing optician's role, especially now that more patients are experiencing or are becoming aware of allergic responses to external elements.

References

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2 Bridle D, Titanium - truth and fiction. *Dispensing Optics,* November 2000
3 Various internet sites
4 Further Reading : Obstfeld: Spectacle frames and their dispensing

Photographs by the author with assistance of Ben Turley (Digital imaging, Manchester Royal Eye Hospital) for the Nitrate stills.

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