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The products we rely on – Part 2
Spectacle frame materials

Frame materials must be light, strong and easily adjusted, but retain their shape well. They should be flexible enough (under easily provided conditions) to insert a lens, inert both to external agents and body fluids, and be cosmetically attractive (e.g. colours, surface finish, retention of surface finish). From the patient's point of view, they must also be relatively inexpensive. For sale in the EEC, all must meet the requirements of BS EN ISO 12870 (1998). No material meets all these requirements perfectly.

It is almost impossible to tell a "good" frame from a "poor" one when they are new, unless there is an obvious flaw. BS EN ISO 12870 is currently undergoing a revision which will probably tighten the rules on frame quality considerably (ISO CD 12870, 2000; ENV 14027, 2001). Price is unfortunately not a good guide (Walsh & Mitchell, 1998).

There are a very limited number of manufacturers of plastics materials, hence, the "quality" of these depends mostly on the construction and finishing methods used.

In the case of metals, it is somewhat different, because although there are a limited number of alloys in use, small changes in composition and manufacturing methods can make a great difference to performance of the finished product.

Plastics

There are two basic types of plastics – those (thermoplastics) which can be re-formed with heat and those which can't be, commonly called thermosetting. Almost all plastic spectacle frames are made from plastics which soften with heat, although they are not all thermoplastic.

Frames are occasionally made from nylons or from composite materials, most of which do not soften properly on heating under realistic circumstances, although they may be thermoplastic. Other plastics which do not soften with heat are also used, but usually only for minor parts (e.g. silicone rubber for nose-pads).

Many plastics, most notably the cellulose plastics and polycarbonate therefore are vulnerable to solvents. Great care should be taken when cleaning lenses, particularly when acetone is being used.

Methods of production

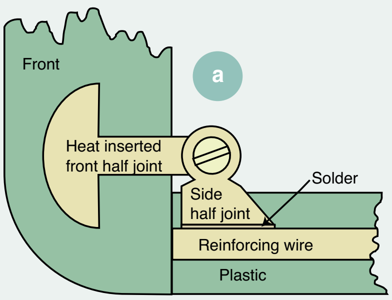
In injection moulding (sometimes called casting) the liquid monomers or liquid polymer are pumped into a mould, forcing the air out. In vacuum moulding (again sometimes called casting), the air is evacuated from the mould and the liquid plastics materials forced in by the pressure of the atmosphere. This process can also be used for composite materials if the fibres are short and thin enough and orientation is not important. Moulding using gravity alone to fill the mould can also be used, but tends to leave air bubbles.

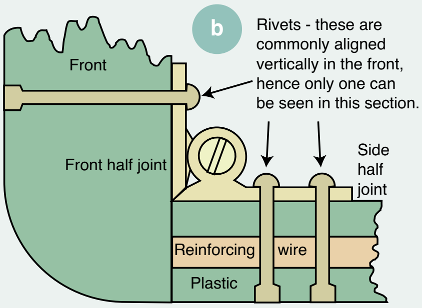
Casting under pressure can also be used for composite materials, which would tend to clog an injection system and may need the fibres aligned. Monomers and fibres are "laid up" correctly in a mould and then pressed into the mould, forcing out the air bubbles. This is often more effective if the mould is evacuated after the monomer is poured in and atmospheric pressure (and more if needed) used to press it to the finished shape. It is not clear how spectacle frames made from composite materials are actually produced.

Pressing the soft, but not molten, plastics (in this case only thermoplastics) to shape using dies is also feasible. The "bumping" of bridges and bending back of lugs are the best known examples.

Plastic half joint

The half joints of plastic frames can be rivetted to, or heat inserted into the front. They can be soldered to the reinforcing wire of the side or attached with rivets. All combinations of methods are possible.

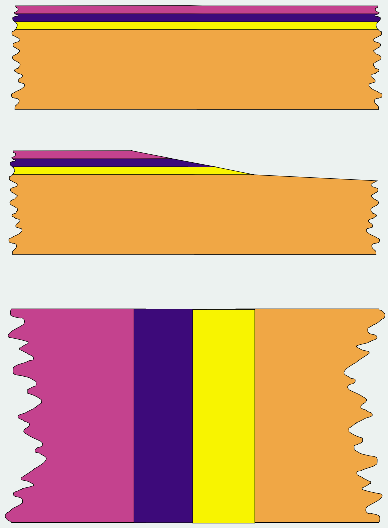




Plastic properties

Material	Typical density g.cm⁻³	Density range g.cm⁻³	Typical adjust °C	Melting point °C
polycarbonate	1.2	1.16-1.45	120?	n/a (amorphous) *6
Cellulose propionate and acetate propionate	1.21	1.19-1.4	60-100 *4	190 (thermoplastic)
Cellulose acetate	1.27	1.26-1.3	50-60	138-230
Kevlar 29 12.1micron fibre	1.44	n/a	n/a	500 (thermoplastic)
Cellulose nitrate	1.4	n/a	65-70	n/a
Cellulose acetate butyrate	1.18	1.16-1.21	n/a	140 (thermoplastic)
Polymethylmethacrylate (extruded sheet) *1	1.18	1.15-1.19	70+	n/a (amorphous)*6
Epoxide resin (optyl)	1.16 *2	n/a	80+	n/a (thermoset)
Other commercial epoxy resins	1.2	1.2-1.88	n/a	n/a (thermoset)
Polyurethane	1.05	1.0-1.3*3	n/a	n/a (amorphous) *6
"pure" Nylons	1.1	1.03-1.18	? *5	180-300 (thermoplastic)
"Co-polyamides"	n/a	n/a	<80	n/a

*1 Other forms of PMMA can have significantly higher or lower softening temperatures.
*2 Measured by the author: includes lacquer coating.
*3 The lower density is an estimate, as there are some very low density polyurethanes in use for other purposes.
*4 Most CP / CAP materials soften for adjustment 65-75°C, but one form used reportedly for spectacle frames softens at 100°C.
*5 All nylons and co-polyamides shrink with excessive heat. For some this can be as low as 80°C.
*6 Amorphous plastics are not crystalline, and therefore do not have a melting point as such.



Acetate

If thinly laminated acetate is sliced at an angle to the plane of the laminates, an interesting striped effect is achieved. The closer the slice is to being normal to the surface, the narrower the stripes.

Machining ("routing"), is the process in which sheets of material have the excess cut away to form the frame, principally with a "routing" machine. Frames can also be made by initial moulding, followed by machining.

Joints, side reinforcements etc, in plastic frames are usually made from a material like "nickel-silver", but this is not an absolute rule. They can be attached to the front either by rivetting, or by embedding a part of the joint in the plastic during the moulding process or later. Rivet attachment to either front or side is currently rare.

They can be attached to the side either with rivets, or by soldering to the reinforcing wire before it is "shot" or cast into the side.

Polishing with is also usually necessary for plastic frames to get a good finish. This can be done, as it often is in practice, with a rag wheel. On an industrial scale, "barrelling" is often used where the frames are tumbled in a "barrel" containing the abrasive and some hard carrier for it, such as wood chips.

Natural materials

These are not really plastics in the modern sense, although all are to some adjustable with (often wet) heat to a limited extent

Hawksbill turtle ("real shell") is the best known. It was always expensive, and now is very rare. Turtles can no longer be killed, but there are old frames about, and some are still occasionally made from old material. Repairs are possible, but are difficult and are perhaps best left to one of the declining number of specialists.

Bone, horn, ivory, leather and wood have also been used. Although of almost only historical interest, frames are occasionally still produced from them – a wooden fashion frame range was marketed in the UK in the 1990s. If wooden frames are to be used, it should be borne in mind that some woods (yew is the best known British example) may be highly toxic and others quite innocuous – ask for detailed information from the supplier. European Buffalo horn is also occasionally used for frames.

"Additives"

Plastics are usually described purely by the plastic's name, but the literature shows that skin reaction to pure plastic materials is relatively rare. The problems arise from plasticisers, ultra-violet inhibitors, mould release agents, polishes, adhesives and dyestuffs. There is little if any relevant, current information available on these, although it is to be hoped that the industry is eliminating the worst offenders.

Cellulose acetate

Although not ideal, this has long been one of the best compromise materials. It is tolerably light, tolerably strong, mechanically stable at normal temperatures, easily worked and relatively inert. It tends to whiten (this may be additives leaching from it) where in contact with patients' body fluids, particularly at the bridge and temples. This is probably the most common plastic spectacle frame material.

It is attacked by some common solvents, and will dissolve in acetone. Frames are often cut from sheets, although injection/vacuum moulding is becoming increasingly common. Acetate sides usually have full-length wire reinforcement and any colour is usually throughout the material, often as different coloured and/or transparent layers fused together.

There are also high-density (long-chain) acetates, from which comparatively thin frames can be made and which can have significantly higher softening points.

Cellulose nitrate

Nitrate looks very similar to cellulose acetate. It is now banned in the UK (and many other countries) because of its flammability. It is sometimes still seen, either as very old spectacles or as a personal import. It catches fire at a temperature little above that needed to adjust it. If originally clear, it becomes a very distinctive, dark "urine-yellow" colour and very brittle with age.

Cellulose propionate/ cellulose acetate-propionate

These materials are similar to acetate but are stronger (slightly), more flexible and have a slightly lower density. It is often unclear which is used for spectacle frames, as "propionate" appears to be used to describe both. They may need different glazing allowances when edging as they shrink on heating. Frames are usually made by moulding, are surface dyed and are sometimes painted ("enamelled").

There is a longer chain "propionate", softening point about 100°C. Components were joined by ultrasonic or friction welding or with an adhesive. Frames were cut from sheet material. It appears to be no longer made.

Cellulose acetate butyrate (CAB)

This is very rare in spectacles dispensed in the UK. It is occasionally used for safety spectacles. There is little information available on its properties as a spectacle frame material. Some of the plastic side tips of metal frames may be made from it or "hybrids" containing it.

Polymethylmethacrylate (PMMA, "Perspex", "Plexiglass")

Also known as "acrylic" and by many other trade names. This is almost obsolete as a frame material, but "clinical quality" is particularly hypoallergenic. Sides have no reinforcement. Fronts are almost always supra-type, as it can be very difficult to glaze a full rim. Perspex has a slight "memory" when heated to its softening point, but this is lost with further heating (unlike epoxy resins).

Epoxy (or epoxide) resins

Optyl was the name of the principal company to manufacture frames from this thermosetting material and is still the name usually attached to it. The polymerisation takes place in the mould, in a process akin to vacuum moulding. Frames are coloured by surface dyeing.

Historically, epoxy frames could be recognised by the short reinforcement in the sides. However, all sides fitted to epoxy fronts now have full-length wire reinforcement or are metal. It needs a lot of heat, then it suddenly goes very soft. If heated and allowed to cool without holding it, it returns to the original shape in which it was made ("memory"). This effect can also annoyingly occur if, eg the frames are left in sunshine (commonly in a car window). Epoxy frames are usually translucent, but opaque colours have also been available (in this case the body of the material is usually white, and is again coloured with a surface dye).

Optyl frames have been claimed to be hypoallergenic, but there is no evidence that it is any more so than any other spectacle frame material. They are usually coated with a transparent lacquer (polyurethane?) both to protect them and reduce their allergenic potential

Polyamides (Nylons)

These are very rarely called "Nylons" in the prescription spectacle context. The materials are used in sunglasses, sports spectacles, safety spectacles and temporary aphakic spectacles. They are very strong, but have a very soft surface, can be very flexible and often cannot be adjusted with ordinary frame heaters.

Frames sometimes have reinforced sides to allow them to retain their shape with cold adjustment (sometimes just close to the bend), or sides with a sliding end section. Sometimes (rarely) the lenses are held in place by screwing rims together (like a metal frame). Nylon frames are usually made by moulding. They are resistant to most common solvents other than phenols. All nylons shrink with excessive heat.

"Co-polyamides" may be either mixtures/co-polymers of different polyamides or co-polymers with other plastics materials. Little information is available on them, although most appear to be coated with a lacquer and to be adjustable with heat to some degree.

The name of one product (SPX) has become almost a generic name for this type of material, although there are now many others on the market. SPX shrinks at 80°C and therefore should not be heated to this temperature. The properties of other co-polyamides appear to be similar, although some shrink only at higher temperatures.

Although historically opaque or at best translucent, some polyamides are now made clear. This makes them annoyingly difficult to distinguish from acetate and propionate.

Polycarbonate

This is best known as a lens material and is very strong. Its use as a frame material is uncommon, other than for sports and safety spectacles. Difficult to adjust, it is commonly used for the side shields of safety spectacles and for one-piece, moulded, plano safety spectacles, which can make fitting them difficult.

Silicone rubbers

These are soft, flexible materials, used for bridges, side-tips, rim-liners, etc. They are extremely stable and typically retain their elastic properties from -50 to 200°C. Oxygen permeates them relatively well, although there is no evidence that this is of importance in spectacle frames. Little information is available on the specific polymers used in the spectacle industry.

Chemically, silicone rubbers are distinct from carbon-based polymers, as they have a silicon-oxygen backbone with organic (carbon) groups attached to it.

Many silicone rubbers are very permeable to oxygen, but there is no evidence of this being advantageous in a spectacle frame component such as a pad. Exotic hybrid with more conventional carbon-based polymers are used in the contact lens industry, but there is no evidence of them in spectacle frames – although they may be used for some nose-pads. It is common for a soft silicone rubber pad to have a hard plastics (acetate?) centre to support it.

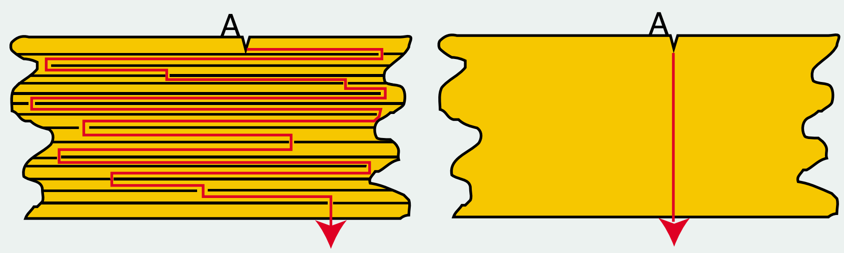
Composite materials

As the term is used here, these consist of two distinct elements: very fine, strong fibres, and the plastic in which they are set. The plastics can be any of those described above, or may be others. This information is often not readily available.

The strength of the finished object is very dependent on the orientation of the fibres, but it is unclear what would be the ideal fibre arrangement, or if frame producers have any control over this. Although those selling these materials to us may make extravagant claims for the performance, there is no evidence to support these other than inference from other uses.

It is not clear what production methods are used for composite materials at present. To a large extent the methods which are suitable are dependent on the length and flexibility of the fibres themselves and on the orientation (if any) required of those fibres. Composites are usually only used for fronts, sides being made from another material.

Composite materials



A fracture normally starts with a small crack (A). It will propagate through the material along the path of least resistance. If the fibres in the composite (left) are strong (relatively free from surface flaws), then the crack will travel along the fibres until it finds a point where they are weak or a gap is present. This makes the crack length much greater and the energy to produce it is therefore much greater than in the main material. In three dimensions, the ends of faults in fibres will seldom correspond at any point and the crack length will be even greater. For aligned fibres, the material will tend to split along the direction of alignment, whilst for woven or random fibre arrangement, the path will be much more complex. In a non-composite material, the path length is a lot shorter hence, although the material may be intrinsically "stronger", breakage will occur more catastrophically and often more easily.

Carbon-fibre

This is always opaque. A lacquer coating is usually applied if a gloss finish is wanted. Lenses are often retained by a glazing screw. Nylon may be the commonest plastic in which the fibres are set. There is little information on this and there are other, equally suitable, plastics including thermosetting ones.

Fibreglass

This is an unusual frame material, again with little information available, but a few fronts are made from it. It consists of very fine strands of glass in set in (a seldom named) plastic. Lenses are inserted cold, but in this case there is usually no glazing screw. Fibreglass frames are opaque or translucent.

Kevlar

This is another material now in occasional use. It is what "bullet-proof vests" are made from. Kevlar is not in itself a composite, but is a cousin of the nylons (a "polyaramide"). Very fine, very strong fibres can be made from it. Whilst it is almost certainly a composite that is used in spectacle frames, as it softens in an ordinary frame heater, again little information is available. Some other polyamides and polyaramides can be treated similarly, but do not appear to be used in spectacle frames.

Metals

Metal frames usually consist of a number of different materials: base metals (i.e. the structural metal of the frame), plating (often several different layers), frequently an organic lacquer or coating, and the plastic side tips and nose-pads. These are usually cellulose acetate or a closely related plastic or silicone rubber. Before coating (except for rolled gold), the wire is "drawn" through rollers to reduce it to the required section. This "work hardens" most alloys.

Joints between the components of most metal frames can either be made by soldering (using a "hard" solder – e.g. silver solder) or by welding. Both soldering and welding destroy the work hardening of the wire in the heated area.

Many alloys cannot be soldered or welded satisfactorily with the simple brazing torches used in practice, as an oxide layer forms very rapidly and prevents adhesion.

Many metals are toxic and great care should be taken not to inhale any dust from these alloys if grinding/polishing them. Even "safe" metals such as titanium and aluminium can be dangerous if the particle size is such as to cause lung damage (COSHH, 1997).

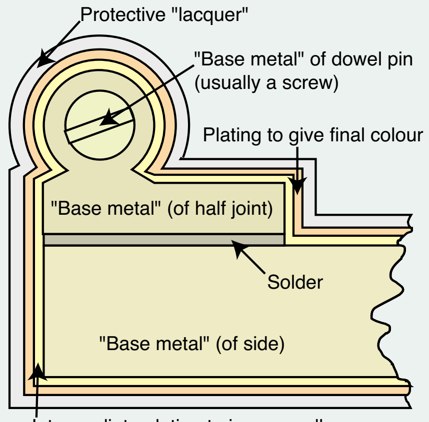
Base metal

This is a term used both to describe "non-precious" metals, as in the alchemist's desire to turn base metals into gold, or the metals which are under a "precious" metal coating. For spectacle frames there is usually little difference in meaning.

Material	Symbol	Density g.cm^{-3}
Beryllium	Be	1.8
Cobalt	Co	8.8
Chromium	Cr	7.2
Palladium	Pd	12
Silver	Ag	10.5
Aluminium	Al	2.7
Gold	Au	19.3
Copper	Cu	9
Iron	Fe	7.9
Iridium	Ir	22.7
Magnesium	Mg	1.7
Manganese	Mn	7.44
Nickel	Ni	8.9
Platinum	Pt	21.5
Rhodium	Rh	12.4
Ruthenium	Ru	12.3
Antimony	Sb	6.6
Lead	Pb	11.3
Tin	Sn	5.8-7.3 *1
Vanadium	V	6.1
Titanium	Ti	4.5
Zinc	Zn	7.1
Zirconium	Zr	6.5
Molybdenum	Mo	10.2
Niobium	Nb	8.6
Silicon	Si	2.3
Carbon (graphite)	C	1.7-2.3
Carbon (fibre)	C	1.8

The metals reported as being present in spectacle frames, or in alloys bearing the same names as those used for spectacle frames. If the proportion of each metal present in the alloy is known, the density of the alloy can usually be estimated – although it will seldom be exactly what is predicted. The weight of the finished spectacles is much less predictable, as the design and minimum amount of material needed for adequate strength are often of greater importance in determining this.

*1Tin can exist in three forms: α (5.8 g.cm^{-3}), β (7.3g.cm^{-3}), γ (6.5 g.cm^{-3}).



Typical structure around the half joint of a metal frame. There are often more than two plating layers. The layers of plating are typically only a few microns thick, with the lacquer and solder both a little thicker. If the half joint is welded to the side, there is no solder and the "base metal" alloys of the half joint and side fuse with each other.

Nickel and copper-nickel alloys

These are commonly used in spectacle frames. Amongst these are German silver (copper-nickel-zinc), Blanka-Z (copper-nickel-zinc-tin) and nickel-manganese (mostly nickel). The best known however are "Nickel-silver" and "Monel".

Nickel is very rarely used in its pure or nearly pure form. Allergies to nickel and its alloys are common. Fortunately, they only present a problem where the metal is in contact with the skin, which is seldom the case with modern spectacle frames with their plastic side-tips and bridges and inert metal or polymer coatings.

There is a European Community directive to control the use of nickel in contact with the skin (European Parliament, 1994). This is being incorporated in the new BS EN ISO 12870, including the first ever indication that the surface protection (and by inference the frame) should survive two years of normal use (BS EN 1811; ISO/CD 12870, 2000; ENV 14027, 2001). This will control the leaching of nickel from the surface of such products, but will not stop the use of the metal. Nickel allergy is more common in women than men, apparently due to the historical use of the metal in bra clips and jeans studs in contact with the skin, and in hairdressing products.

An interesting historical point about the use of nickel in spectacle frames is that copper-nickel alloys were specifically required for NHS metal frames. The only traceable reason for this is anecdotal; one of the leading ophthalmologists of the time may have said (without supporting evidence and unofficially) that he had seen fewer allergic reactions with high nickel content materials to someone on the original committees. If this is true, then he had an awful lot to answer for!

Nickel silver

This is 12-25% nickel, but mostly copper. It is mechanically quite a good material for spectacle frames, although it goes dull very quickly if not plated/coated, and rapidly turns green in contact with body fluids. It is easily worked and soldered and used to be the most common material for spectacle frames, and probably it (or a very similar alloy) still is. The term is often used to describe any copper-nickel alloy.

Nickel silver is commonly used for the joints and side reinforcement of plastic frames. There are no reports of nickel leaching from reinforcing wire of plastic sides so long as the plastic is intact, but sensitive patients may react to unplated half joints when touched with their fingers.

Monel

This is similar to nickel silver, but is 68% (BS 3072, 1989; 3076, 1989). The higher nickel content than nickel silver reduces the rate of corrosion. It has recently been marketed as hypoallergenic, but there is no evidence to support any such (almost certainly false) claims. Monel is often used outside the UK to describe lower nickel content alloys and this "abuse use" may be continued into the UK with imported frames.

Bronzes

These are copper-tin alloys and are often chosen for specific properties (e.g. springy sides) given by other alloying materials such as phosphorous and beryllium.

Stainless steel

This is relatively difficult to work and to plate. It is relatively uncommon as a spectacle frame material, although its use is increasing. Information is not readily available on the type used in most spectacle frames, although many "stainless" alloys also can have quite a high nickel content. The surface leaching of nickel from some of the nickel-containing alloys is minimal even when unplated, but not all have been tested.

Titanium

This is probably close to the ideal spectacle frame material. It is particularly light, strong, inert and (in its pure form) hypoallergenic. It is currently very expensive for spectacle frames, nominally due to extraction and manufacturing costs, but the current level of this premium may, as with "designer" frames, not be directly related to manufacturing costs.

It is relatively difficult to plate with more "attractive" metals such as gold, although this is now quite common. Unfortunately, some of the coating processes involve the use of a nickel inter layer. It is also sometimes coloured by a process very similar to vacuum coating lenses ("ion plating").

One point of particular importance to our patients with allergies – "titanium" seldom (if ever) means pure titanium, even when the sales literature says titanium (Bridle, 2000). Screws, nose-pads and side-tips are very frequently excluded – although this is frequently not clearly indicated by the suppliers. Pure is usually taken to mean that 98% or more of the putatively titanium parts is titanium (not of the whole frame). There are other common descriptors, such as "β titanium" in which only about 75-80% is titanium, the rest being a selection from aluminium, chromium, iron, molybdenum, niobium, silicon, tin, vanadium and zirconium. Nickel and cobalt are also common additives to "titanium alloys".

Aluminium

Aluminium is light and soft. It is usually "anodised" (an electrolytic colouring process), plated or coated. Joints are usually rivetted to the front and sides, although occasionally they may be welded on or even cast as a part of the side. Aluminium parts are always quite thick for a metal frame, due to the softness of the material. In common with titanium, pure aluminium is hypoallergenic. Many alloys of aluminium have probably been used in spectacle frames as these can have much better mechanical properties than the pure metal, but there is no information available on which ones these are.

Memory metals

This is a group of unrelated alloys which have the common property of being able to return to their original shape after considerable distortion. They have been intensively marketed for a number of years. Apparently (and not surprisingly), they do snap if repeatedly flexed through sharp angles, but this is only a problem for those who insist on demonstrating them to patients this way.

Frames are seldom made from memory metals alone. These materials are commonly used for temples and bridges, with more conventional materials used for the eyewire, screws and other parts. This may either be because of cost or because they are so flexible that they cannot be adjusted satisfactorily. The memory metal parts are often attached to other materials by inserting them into a ferrule which is soldered to the conventional material and retaining them with cyanoacrylate glue (Bridle, 2000).

The best known memory metal is nickel-titanium but it is often sold as a "titanium alloy" with no mention of the nickel. There are also other "memory effect brasses/memory metals" which are free of nickel, titanium or both. These include copper–aluminium, titanium-cobalt and aluminium-vanadium-titanium.

Brass

This is usually a copper-zinc alloy, but the term is often used to describe other "yellow", high copper content alloys. There is little evidence of anything called "brass" being used in spectacle frames, although some modern frames look and feel "brassy". Aluminium brass (10% aluminium/90% copper) has been used with some success in the past (Phillips, 1909) and may have returned to use.

Cobalt

This is probably not used for spectacle frames in its pure form. It is mechanically, chemically and allergenically very similar to nickel. Despite this, it is currently being marketed as a component of some "nickel-free" frames.

Antimony

This should no longer be used in spectacle frames, but may be present in "white metal" antique frames should a patient wish to have one glazed. It was a common irritant when it was in use (Taylor, 1907).

Lead

Lead may be a constituent of some solders and is present in some "spring bronzes", although there is no evidence of its recent use in spectacles.

Plating of frames

Metal frames are often plated with another metal both to improve their cosmetic appearance and to reduce corrosion. Mechanically, plating is problematic as the rates of thermal expansion and elasticities of the metals used can make the plating liable to crack in something as flexible as a spectacle frame.

Electrolytic plating

This is the method by which the majority of metal frames are plated with gold and other metals. The pure metal or alloy is deposited onto the surface from solution. Both the thickness and porosity are dramatically affected by the exact manufacturing details – varying from comparable with mechanical plating to downright awful. There is no satisfactory way of distinguishing these clinically other than in use – the reputation of your supplier is all you have to go on.

Mechanical plating

This is best known for the production of "rolled gold" frames. A relatively hard, impermeable "work-hardened" gold layer is produced by the process, as the gold is applied to the wire used before it is drawn. Cutting obviously penetrates the wire and soldering can locally disrupt the work hardening (although such frames often are able to tolerate solder repairs with no cosmetic changes in appearance).

Chemical plating

Historically, this was derogatorily called "gold washing". The process can, in principle, be as good as electroplating. If it is used on spectacle frames, manufacturers do not publicise it.

METALS FOR PLATING METAL FRAMES

Gold

Gold is usually used as an alloy, frequently with silver and copper, but occasionally with zinc or nickel. Modern white gold can have a significant nickel content, although this may not be the case for antique white gold. Carats are the proportion of the alloy by weight which is pure gold: 12 carat is 50% gold, 18 carat is 75% gold etc. The colour of gold gives no indication of its gold content, although 24 carat gold can only be the colour of pure gold, despite frames recently having been marketed as "24 carat red gold".

Gold or not gold?

Strictly, the only frames which can be called "gold" are those made from gold and high gold content alloys and hallmarked, (Hallmarking Act, 1973; Obstfeld, 1997). The term "rolled gold" is also acceptable (although the often used alternative "gold filled" is not permitted in the UK). Otherwise, frames should be called by a name which makes it clear they are not made from gold, such as gold plated, gold coloured or similar. European legislation is in the process of changing this situation. Anything less than 12 carat cannot be called "gold".

Occasionally real gold frames are imported and sold which are not hallmarked. The legality of this is questionable, although European free trade rules make it harder to be certain of the situation.

Unquestionably not gold

Frames have been marketed in the past – and undoubtedly will again – which are gold coloured, but contain no gold whatsoever. Sometimes these have an opaque gold lacquer on the surface, sometimes a clear lacquer over a yellow metal, sometimes a transparent yellow lacquer over a silver metal or sometimes are plated with a less expensive yellow alloy. There is no reason why this should be any worse that the common coloured decorative lacquer finishes. A clear lacquer over a polished "silver" frame would give the appearance of a silver-coloured plating.

Palladium, rhodium, ruthenium

These "platinum group" metals are very expensive, hard, silvery metals. Palladium allergy is on the increase, and may be approaching problems numbers in some parts of the world (Aberer et al, 1993; Kanerva et al, 1996).

Chromium

This is hard silvery metal. It is quite reactive, but quickly forms a thin, hard, transparent, protective oxide layer.

Nickel, silver, copper

These are very rarely used as a surface plating, but are quite often used as an intermediate layer to improve adherence and elasticity and because they have a different crystal structure to the top plating layer – hence imperfections in the layers are not aligned – reducing corrosion. Nickel plated steel was common in frames circa 1900 (Taylor, 1907) and may therefore occasionally be seen when antique frames are presented for glazing.

Electrochemical series and corrosion

Corrosion of a metal spectacle frame is often probably electrolytic. Some metals are more electropositive than others. This means that in the presence of sweat (an "electrolyte") and a fault in the plating, a "battery" is set up. The base metal corrodes to produce the familiar green "verdigris" colour (or other colour if not cupro-nickel). This consists of hydrated salts of the base metals, and occupies considerably more space than the sweat or original metal, hence the plating is forced off still further.

Lacquering of frames

The majority of metal frames and some plastic frames are now covered with an organic material either to reduce surface corrosion or for cosmetic effect. These lacquers can be either applied as a liquid or as a powder which (on metal frames) is then heated until it liquefies. They may either be polymerised before application or during any heating process.

Common coating polymers include polyurethanes, polymethylmethacrylate and epoxy resins. Rubbers (silicone?) have also been used and are sometimes also used in the groove to protect the lenses. Information on which process and which material is used on which frame can be very difficult to obtain.

Combination of materials

British Standards (B.S.3521: 2, 1991) defines combination spectacles as "Spectacles in which the principal parts of the front of the frame or mount are made of two distinct materials, for example metals and plastics".

This does not include, eg a plastic front with metal joints, or a metal front with plastic nose-pads. It also does not include composites.

In practice, almost all frames are made from combinations of materials – plastic fronts commonly have metal sides and vice versa. Similarly, plastic sides usually have metal reinforcement, whilst metal sides usually have plastic tips. Metal fronts have plastic nose pieces, plastic frames have metal joints and the term is usually reserved for frames with a metal eye-wire and plastic top section or (rarely) a thick plastic liner inside a metal eye-wire.

Safety and allergenicity of frame materials

There is little published information on the safety of the metals used in spectacle frames, however many of them are potentially quite nasty (Walsh, 1998). These "nasties" include some of the most common materials. Although the majority of problems are with allergic contact dermatitis, some of the materials are potentially toxic or carcinogenic. However, it must be emphasised that there is no published evidence of toxic/carcinogenic effects in relation to spectacle frames and that the majority now have a relatively safe protective coating. Unfortunately, there is no published evidence of how long such coatings last.

It is very rare to find metals used in their pure form; the other metals in the alloys must also be taken into consideration. Individual mixtures and even variations of metal crystal structure can make big differences – e.g. almost no nickel comes out of some nickel containing stainless steels.

Conclusion

Spectacle frames have long been dismissed as a minor element in ophthalmic dispensing, almost all scientific effort having been concentrated on lenses. This is somewhat anachronistic, as a considerable proportion of the problems encountered in any practice are due to the frames. These are usually fitting problems, but skin reactions are common with an expected prevalence somewhat higher than that of our profession's great worry, glaucoma (Walsh, 1998). A little knowledge of frame materials not only reduces such problems, but can greatly enhance our reputation with our patients.

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Multiple choice questions

The products we rely on – Part 2
Spectacle frame materials

1. Which of the following is incorrect of cellulose acetate?
a. Frames are commonly made by machining
b. Frames are commonly made by moulding
c. It is commonly used for parts of metal frames
d. Its softening point is typically about 87°C

2. Which of the following is incorrect of polyamides?
a. They are commonly used in carbon-fibre spectacle frames
b. They are thermosetting plastics
c. Frames are usually made by moulding
d. Have a relatively soft surface

3. Which of the following materials is most likely to elicit an allergic reaction from a patient?
a. Monel
b. Aluminium
c. Bronze
d. Brass

4. Which of the following materials is not commonly used for coating metal frames?
a. Polymethylmethacrylate
b. Epoxy resins
c. Polycarbonate
d. Polyurethanes

5. Which of the following materials would you not expect to find in a modern spectacle frame?
a. Copper
b. Nickel
c. Cobalt
d. Antimony

6. Which of the following is incorrect?
a. Blanka-Z is an alloy principally of copper and aluminium
b. Monel is an alloy principally of copper and nickel
c. Nickel silver is an alloy principally of copper and nickel
d. Brass is an alloy principally of copper and zinc

Questions 7-12 continued over

Multiple choice questions

The products we rely on – Part 2

Spectacle frame materials

7. Which of the above materials is the MOST DIFFICULT to soften for adjustment in a hot-air frame heater?
a. Cellulose propionate
b. Polycarbonate
c. Optyl
d. Polymethylmethacrylate

8. Which of the following materials CANNOT be obtained in a transparent form?
a. Carbon fibre
b. Co-polyamide
c. Cellulose acetate
d. Polycarbonate

9. Which of the following materials is usually a "composite" material in spectacle frames?
a. Polycarbonate
b. Optyl
c. Kevlar
d. Monel

10. Which description of a frame material is of questionable legality in the UK?
a. Rolled gold
b. Gold filled
c. Gold plated
d. Gold

11. Which material should no longer be supplied (almost) anywhere as a spectacle frame?
a. Cellulose acetate butyrate
b. Polymethylmethacrate
c. Cellulose acetate propionate
d. Cellulose nitrate

12. Which of the following statements is correct?
a. A spectacle frame described as being "gold" must be at least 50% by weight gold
b. A frame marked 100% titanium will always be over 98% titanium
c. Price is usually a good guide to the quality of a spectacle frame
d. Vanadium is a hard, white shiny metal which is often used to plate spectacle frames

The answers will appear with – Tints and coatings – to be published on October 5.

Multiple choice answers - The products we rely on Part 1

Here are the correct answers to the questions in the article which appeared in our July 27 issue

1. Which of the following is INCORRECT?
a. The dispersion of a material is the reciprocal of its Abbé number
b. A lens with a high Abbé number is preferable to one with a low Abbé number
c. The "equivalent index" of a material is lower than its actual refractive index
d. The reflection proportion of light reflected from a lens increases with the refractive index

The correct answer is c
The "equivalent index" is the refractive index that a best form lens with spherical or toric surfaces would have to be made from to be the same thickness as an aspheric lens on a low base curve. It is therefore always higher than the true index.

2. Which of the following is INCORRECT?
a. Flint glass is used in fused bifocal lenses
b. Lenses made from polymethylmethacrylate are heavier than those made from CR39
c. The Abbé number of allyl diglycol carbonate is comparable clinically to that of crown glass
d. Polycarbonate is a thermoplastic material

The correct answer is b
Polymethylmethacrylate, despite its many failings as a lens material has a density of about 1.2 gm.cm-3, compared with 1.32 gm.cm-3 for unmodified CR39. Allyl diglycol carbonate is another name for CR39.

3. Which of the following is INCORRECT for the same lens power, size and minimum substance?
a. An optically optimised equiconvex aspheric lens would be thicker than a similarly optimised plano-convex aspheric lens
b. A "best form" lens would normally be thicker than an aspheric lens
c. A "best form" lens would normally be thicker than a plano-convex lens
d. The thickness of the lens increases approximately linearly with (refractive index - 1) for most common lens powers

The correct answer is a
The thinnest form of any lens is the symmetrical (equiconvex or equiconcave) form, although this form is not used for commercial aspheric lenses. In general, flattening the base curve makes a lens thinner.

4. Which of the following lens material is most susceptible to attack by common solvents?
a. Allyl diglycol carbonate
b. CR39
c. Polycarbonate
d. Polyurethane

The correct answer is c
Polycarbonate lenses, despite their remarkable impact resistance, are easily damaged by acetone and other common solvents.

5. Which of the following is INCORRECT?
a. It is difficult to produce a stable coating on plastics that is comparable in hardness to crown glass
b. "Relative curvature" can be used alone to accurately estimate the thickness of a lens
c. There is no accepted test of lens surface hardness for everyday prescription lenses
d. Polycarbonate has one of the highest dispersions of any current spectacle lens material

The correct answer is b
Although relative curvature is useful in predicting relative thickness, lens form and minimum acceptable substance also play significant roles. There are BS EN standard tests for comparison of surface hardness, but these are not applied to prescription spectacles.

6. Which of the following is INCORRECT?
a. 1.6 (±0.02) index plastics with densities from 1.2 to 1.48 are commercially available
b. 1.6 (±0.02) index plastics with Abbé numbers from 28 to 42 are commercially available
c. For a given refractive index plastics material, high density and high density normally go together
d. The publicised Abbé number of many apparently identical materials often differs depending on the sources from which they are obtained

The correct answer is c
There is no real link between refractive index and density for current materials. However, the large numbers of identical or nearly identical materials marketed tends to give this impression.

7. Which of the following is INCORRECT?
a. "High index" lenses are often heavier than "normal index" ones which are identical in prescription, centration and shape
b. Chromatic aberration, in prism dioptres, increases linearly with decreasing Abbé number

c. The refractive index of the segment of a fused bifocal is higher than that of the main lens
d. Relative to CR39, a negative lens of similar form, made from a 1.6 refractive index material is about 18% thinner, excluding the effect of the minimum thickness

The correct answer is b
Chromatic aberration is proportional to the reciprocal of the Abbé number.

8. Which of the following is INCORRECT of the amount of chromatic aberration perceived by a spectacle wearer?
a. It increases with the distance from the optical centre through which he is looking
b. It increases with the dispersion of the material
c. It is higher for polymethymethacrylate than for allyl diglycol carbonate lenses
d. It increases with the power of the lenses

The correct answer is c
Both CR39 (allyl diglycol carbonate) and PMMA (Perspex, Igard, polymethylmethacrylate) lenses have Abbé numbers of about 58.

9. Which of the following is INCORRECT according to BS EN ISO 13666 (1999)?
a. "Blended lenticular" lenses can legitimately be described as "aspheric"
b. "Polynomial aspheric" lenses can legitimately be described as "aspheric
c. A "toric" lens can be made in biconcave form
d. The area around the optical zone of a lenticular lens is called the "carrier"

The correct answer is d
There are many changes in the definitions from earlier standards (e.g. a, b, c), but the non-optical zone of a lenticular lens is still called the "margin".

10. Which of the following is INCORRECT?
a. A best form has it surfaces designed to minimise lens thickness
b. An aspheric lens has at least one aspherical surface
c. High plus lenticulars are less commonly seen than they were 20 years ago
d. An atoric lens has at least one atoroidal surface

The correct answer is a
Best form lenses are designed to reduce the effects of the aberration oblique astigmatism.

11.From which of the following materials have ophthalmic prescription lenses NOT been commercially produced?
a. Polyvinylchloride
b. Polycarbonate
c. Polypropylene
d. Polyurethane

The correct answer is c
Polycarbonate and polyurethanes are commonly used for spectacles lenses. PVC (polyvinylchloride) has been used, although it is very rare as a main lens component.

12.Which of the following is INCORRECT according to BS 7394; 1994?
a. A glass lens of refractive index of 1.76 is "very high index"
b. A glass lens of refractive index of 1.70 is " high index"
c. A plastics lens of refractive index of 1.63 is "high index"
d. A plastics lens of refractive index of 1.61 is "mid index"

The correct answer is c
Although plastics of index over 1.6 are often referred to in practice as "high index", there is no differentiation between glass and plastics in this standard.