

Materials and allergens within spectacle frames: a review

GLYN WALSH¹ AND S. MARK WILKINSON²

¹Department of Vision Sciences, Glasgow Caledonian University, Glasgow G4 0BA, and ²Department of Dermatology, General Infirmary, Leeds LS1 3EX, UK

The materials that have been reported as causing allergic contact dermatitis within spectacle frames are identified, and their most likely location on the frame is highlighted. The lack of any real control over spectacle frame quality and content is indicated to be a problem, as is the difficulty in determining the true source of many frames. Much of the information must be obtained from anonymous sources in the industry, historical 'common knowledge' of indeterminate source or reports of dermatological problems.

Key words: allergic contact dermatitis; glasses; metals; plastics; spectacles. © Blackwell Munksgaard, 2006.

Accepted for publication 29 November 2005

Since the review of Smith and Calnan (1), there has been no equivalent review of the potential causes of dermatological problems from spectacle frames, although a short review was given by Nakada and Maibach (2). The aim of this article is to bring the established, unfortunately often unsourced, information which is available to those closely involved with the products to the attention of the dermatological community, as there does not appear to be any extensive listing currently available. The materials included are only those for which the authors have found either past or current evidence and do not purport to be complete. It will also indicate where the material is likely to be found on the frame. Smith and Calnan (1) gave a comprehensive review of papers relating to spectacle frame allergy up to that date, and these earlier papers will not be cited individually. Where no references are given, the information has been provided by sources in confidence for reasons of industrial secrecy or it is information from advertising material that has been confirmed by the manufacturers/importers orally. The majority of frame importers/manufacturers are unwilling to commit themselves in writing. This is perhaps not surprising given the inaccuracy of that which is provided (3).

The significant nickel content of many frames is an established truth. However, unlike most other objects placed in contact with the skin, spectacle frames in the UK are classed as medical

devices (4). They are therefore subject to some degree of legal restraint over their quality and content, yet there does not appear to be any real control over them by the Medicines and Healthcare Products Regulatory Agency (formerly the Medical Devices Agency). Indeed, since registering as a frame manufacturer at the introduction of such control, one of the authors (GW) has not received any unsolicited communication from the agency.

For a spectacle frame to be marketed in the UK, it must be 'CE marked'. This CE marking should indicate conformance with both the EC Nickel Directive (5, 6) and any relevant British and European standards (7–12). However, the testing of conformance is destructive (10–12), and therefore, only batch testing can be carried out. Of interest is the statement (8) that: 'The manufacturer of spectacle frames shall exclude from contact with the skin, any materials that, amongst a significant proportion of users, during wear are known to cause irritation, allergic or toxic reaction to skin in a normal state of health. NOTE Rare or idiosyncratic reaction to any material may occur and may indicate the need for the individual to avoid particular types of material'. The current interpretation of this appears to be that the article should merely conform with the EC Nickel Directive (5).

It is concerning that many spectacle frames marketed to the optical professions as 'hypoallergenic' are potentially far from it. Recent glaring

examples include both Monel, which consists principally of nickel, and some of the 'titanium memory alloys', which can also have a nickel content of 40% or more. Since the introduction of the EC Nickel Directive (5), there have been several reports of a high level of non-conformance (13–15). Furthermore, almost all current-plated metal frames are electroplated then coated with a polymer. Much less commonly, particularly for aluminium and titanium alloys, they are 'anodized' and dyed or 'ion plated' with a coloured salt. Electroplating alone gives a surface with microscopic imperfections through which nickel can penetrate when dissolved in sweat (16). Gross imperfections have been shown to be present in both electroplated and 'rolled gold' spectacle frames, to the extent that any plating should be considered faulty if not coated by a polymer (17–19).

At present, there is only a small UK plastic spectacle frame industry and, so far as spectacle frames are concerned, no UK plastic industry. A small number of metal frames are assembled in the UK from imported parts, and a small number of plastic frames made from imported polymers. The situation is little different in most other Western countries, with most of the frames on the market being made in the Far East, particularly southern China. The long supply chain makes obtaining information on many products particularly difficult. Many of the principal polymer constituents of spectacle frames are well known in general terms, although data on their specific nature such as molecular weight, the presence of residual monomers and 'additives' are not available (20). Some suppliers will give information on the mechanical properties of their polymers – sometimes incorrectly (21).

Materials and Allergens

Metal

Copper. Nickel alloys were by far the commonest metal frame materials until recently and may still be such, but they are often hidden by alloy names such as 'nickel–silver' and 'Monel'. Their use appears to be declining, but it is difficult to know to what degree, as information on the metal used can be difficult to come by. This applies particularly at the bottom end of the market, where these alloys are likely to continue in significant quantities. Spectacle frames must now meet the requirements of the EC Nickel Directive (5). This effectively means there should be no significant free surface nickel for 2 years of use. In principle, this should overcome the main

objections to the alloys, although it relies entirely on any protective coating remaining intact. The normal material for plastic frames' half joints and side-reinforcing wires continues to be copper–nickel alloy. Bronze is a catchall term for a number of copper alloys, most notably the 'spring bronzes' often used in metal sides. In spectacle frames, the best known are beryllium bronzes, but there is no evidence that other bronzes (e.g. tin and phosphorous) are not used. Beryllium is currently being marketed as the latest high-tech metal frame material. Copper alloys other than beryllium bronzes and copper–nickel alloys are difficult to find information on. As the majority of metal frames have a yellowish tinge to their base metal colour (albeit often very slight), copper is almost certainly in the alloy mix. Copper is also used in 'red gold' used occasionally for plating frames. There has been a report of copper in a spectacle frame as a cause of green hair (22, 23).

Nickel. Nickel is seldom, if ever, used in its pure form in spectacle frames except as a plating to improve the adherence of outer layers of other metals, most notably some gold-plated titanium frames (24). Spectacle allergic contact dermatitis is well recognized (1, 25–29). Its best known alloys are those with copper, titanium (some memory metals) and iron (some stainless steels). Compliance with the Nickel Directive appears to be improving in comparison with data from before its introduction but is not yet 100% (13, 15, 30–32). Some 'nickel-free' spectacle frames have been shown to contain nickel (14). Although it is common practice to dispense plastic frames to nickel-allergic patients, the exposed metal areas often contain nickel, and problems have also been reported with nickel-alloy side reinforcements if the plastic is cracked (33).

'Memory metals' have been widely publicized in recent years. Free surface nickel has been detected on some frames made from one of the common memory metals (titanium–nickel) since the introduction of the Nickel Directive (15). Many frames are only partly made from the memory metal, and the rest from some more mundane alloy. Vanadium is present in some.

Stainless steels containing nickel may be relatively safe (34, 35), with some frame suppliers indicating that they use these steel types. Stainless steel is often marketed as being 'hypoallergenic'. 'Genium'—a steel composed of iron, chromium, manganese, carbon and silicon—has recently been marketed as a particularly 'hypoallergenic' material.

Cobalt. Cobalt and its alloys are very similar in use to nickel and alloys. Cobalt and cobalt alloy frames have been marketed as ‘hypoallergenic’ in recent years, and the metal’s use appears to be on the increase. The logic behind this is unclear given the high rate of cosensitization between nickel and cobalt (36).

Chromium. Chromium is used for plating frames and is also used in some of the alloys for the underlying base metals, most notably some stainless steels. Chromium salts (unnamed) are sometimes used to obtain a black surface on copper–nickel spectacle frames. Chromium carbide is also very occasionally used for colouring titanium frames (white).

Palladium. Palladium is used relatively frequently in the spectacle industry for plating metal frames and has been reported as a cause of allergy in this context (37). It is also sometimes used as an underlying plating to improve the adherence of other metal over it.

Titanium. Titanium and its alloys, unlike many other metals, are usually clearly marked as such or with a trade name. Titanium is always marketed as ‘hypoallergenic’. Unfortunately, ‘100% titanium’ and ‘pure titanium’ do not mean that. Frames marked this way are sometimes plated with nickel, usually under a gold alloy. Additionally, parts such as screws, pads and side-tips are usually not of titanium. It is difficult to obtain information on many of the titanium alloys in use, but they appear to fall into 2 principal categories: β -titanium (titanium–aluminium–vanadium) and Nitinol (titanium–nickel). There was a titanium–cobalt alloy marketed in the 1990s, and there are undoubtedly other alloys on the market today under an assortment of trade names.

The finished product is sometimes plated with more questionable materials, lacquered or surface dyed. Takamura (24) suggested plating with an alloy of nickel and any from chromium, copper, iron, silver, sulfur, lead, platinum, gold, tin, cobalt, ‘rare earth elements’, molybdenum, aluminium, niobium and titanium; his methods were taken up by leading manufacturers, although there is no evidence which of these has been adopted other than the nickel element. Frames specifically claiming to be nickel free, yet which contain nickel, are found (15, 38).

Titanium salts are very occasionally used to colour the surface of titanium spectacle frames. Titanium nitride gives a gold tone and titanium carbide purple. However, colours are usually

applied to titanium in the more conventional lacquer form.

Aluminium. Aluminium and its alloys are usually, light, soft, ‘chunky’ and easily bent out of shape. However, some of the more ‘springy’ titanium alloys and ‘memory’ alloys such as ‘ β -titanium’ also contain a significant pro-portion of aluminium. It is now seldom used and is usually associated with older frame styles. It was used extensively, particularly for sides, 20+ years ago, but also lends itself well to combination with high-tech plastics and is easily mistaken for composite material if not inspected closely. The surface may be ‘anodized’ (oxidized and dyed) but is equally likely to be lacquered or plated with another metal.

Silver. Silver spectacles must conform to the Hallmarking Act (1973) (39) and its later amendments (40), as would gold ones. They are rare, although not unheard of particularly antique ones.

Gold. Gold is seldom hallmarked when present in a spectacle frame. Frames made from gold alloys should be hallmarked, but items weighing less than 1 g are exempt. 24-carat (‘pure’) gold is seldom used in spectacle frames in either the trim or frame, and information on the alloying metals is seldom available. It is well established that metal coatings are imperfect and that nickel can penetrate metallic coatings, including both electroplated and the more costly mechanically plated (‘rolled’) gold (15, 17–19, 30, 41, 42). Modern ‘white gold’ can contain nickel, palladium, zinc and sometimes cadmium. Reactions are reported in patients who are highly sensitive to nickel (43).

Platinum. Platinum, as with gold and silver, must be hallmarked if used for a significant part of an object. This has only been the case since 1976 (44, 45). It is usually rarely used for plating metal components.

Solders. ‘Solders’ are metals that are used to join frame parts made of other metals. They must have a melting point that is lower than that of the metals to be joined, therefore tend to contain metals which would not be found elsewhere on a frame. There is no reliable information on the metals present in the solders used on spectacle frames, but obvious candidates include cadmium, copper, gold, indium, lead, manganese, nickel, phosphorous, silver, tin and zinc (46). Historically, tin plate was used as a cheap imitation of silver, and it may still be

used to increase the adherence of superficial plating layers. There are also fluxes and other reagents to expedite the process.

Other metals (Table 1) used include indium, iridium, niobium and rhodium in plating and magnesium and manganese in some frames. Antimony (47) and cadmium (48) should no longer be used in spectacles. Cadmium was used to improve the properties of many 'silver solders', but it is unclear whether these are still used (illegally) in spectacle frames. Cadmium pigments may also have been used in the past in plastic spectacle frames (1), but there is no evidence of this continuing.

Plastics and rubbers

Cellulose acetate. Cellulose acetate is also called zylonite, zylo or zyl, particularly in products aimed at the US market. In the UK, the 'z' becomes an 'x', but the name is seldom used. Confusingly, the original zyl was cellulose nitrate (49). It is the most common plastic spectacle frame material, although cellulose propionate is now catching on in popularity and is used for any part that can be made of plastics. Any plastic frame made before about 1975, which is still in reasonable condition, is likely to be made from cellulose acetate. There are few reported instances of allergy to cellulose acetate spectacle frames (50), but some reports of reactions to additives and polishes (51–53).

Cellulose propionate is the name that appears to be applied both to some copolymers and to some mixtures of plastics. Historically, cellulose propionate was marked CP although this no longer appears to be common. There are reports of reaction to additives in cellulose propionate (54, 55). Cellulose acetate butyrate is sometimes used mixed with cellulose acetate for the side-tips used on metal sides (20). Cellulose nitrate is highly flammable, and it has not been sold in the UK for many years. However, the international standard (8) was initially introduced in 1998 (7), and there is no guarantee that this is being followed everywhere even now. Except that it crystallizes with age, cellulose nitrate is often almost indistinguishable from some forms of cellulose acetate—until it catches fire when heated to adjust it!

Acrylates. 'Acrylic' is usually used to describe spectacle frames made from polymethyl methacrylate (PMMA, Perspex), although acrylics are also used for coatings on metal frames. It is now used only very occasionally as a frame material. However, it is sometimes used

as a powder coating to protect the surface of metal frames. These are heated, and the particles coalesce to form an impermeable layer. There is a popular belief in the optical world that PMMA is hypoallergenic, but PMMA has never been a common frame material, even in its heyday of the 1950s and 1960s. Clinical quality (CQ) PMMA is singularly inert biologically and was used for intraocular lenses and contact lenses for this reason, but not all PMMAs are of CQ. PMMA has also been bonded to cellulose acetate (49), although this appears to no longer be done.

Methyl methacrylate (MMA) is the monomer used in the production of PMMA. It has been reported as probably being present in CQ PMMA contact lens blanks (20), although these are now seldom used. Where PMMA is still used, such as for coating metal frames, trace amounts of MMA would be expected to remain if CQ is not completely free. There are no reports of any skin problems from MMA in the context of spectacle frames. Butyl acrylate has been reported as being present in nose pads and cellulose acetate frames as a cause of dermatitis (56).

Cyanoacrylate adhesives are occasionally used to join 'memory metal' components to non-memory metal ones. They are also occasionally used for repairs to spectacles.

Epoxy resins. Epoxy resins are used for the principal plastic in some frames and as a coating on metal frames. Epoxy frames are usually marked 'Optyl' or with the manufacturer's trademark, but the markings on many of the models rub off very easily in use. There have also been other epoxy resins used for frame production (or other suppliers using the same material under a different name), but these do not appear to have been readily available for many years. Optyl is always lacquered and surface coloured, with clear polyurethane lacquers usually being used. Optyl is often claimed to be hypoallergenic, but there is little information to support or contradict such claims. There are reports of allergy to spectacle frame epoxies (57, 58).

Polyamides. Polyamides (Nylon) are often marked on the frame with a trade name. This often tells little of the frame material beyond what the immediate supplier wants us to know. 'Nylon' is indicative of conventional nylons—although not which type. 'Grilamid' is a version of nylon 12 which is commonly used. Information on other related materials such as 'Acelon' and 'SPX' is not available. Many polyamide frames are coated with a polyurethane (or similar) lacquer to improve the surface gloss.

Table 1. The metals reported as being present in spectacle frames or present in alloys bearing the same names as those used for spectacle frames

Material	Colour ^a	Symbol	Density (g cm ⁻³)	Role ^b	Allergen ^c	β-Titanium ^f Titan Next Generation	Cobalt alloy ^{g,h}	Copper, beryllium, bronze ^{g,h}	FX9 ^h	Genium ⁱ	Monel ^{g,h}	Nibrodal ^{g,h}	Nichrome ^{g,h}	Nickel silver ^g	Nitrolo ^k (Flexon, Euroflex)	Stainless steel ^g	Super Invar ^g	Ticral ^h
Aluminium	Silvery	Al	2.7	Base metal, pure and alloy	Rare	3			4									
Antimony	Silvery grey	Sb	6.7	*Solders?	Doubtful													
Beryllium	Lead grey	Be	1.8	Base metal, pure and alloy	Rare			2		4	5							
Carbon (graphite)	Black	C	1.7–2.3	Fibres (in composites), base metal alloys	No													
Chromium	Silvery	Cr	7.2	Plating, base metal alloy	Yes		3			2		2						3
Cobalt	Lustrous, grey tinge	Co	8.9	Base metal, pure and alloy	Yes		1											
Copper	Copper (red/pinkish)	Cu	9	Base metal alloy, interplating	Rare			1	1	2	1			1	3	3		2
Gold	Gold (yellow)	Au	19.3	Plating, ^d interplating	Yes													
Iridium	Silvery/white	Ir	22.7	Plating	Doubtful					1	3							1
Iron	Lustrous, grey tinge	Fe	7.9	Base metal alloy	Doubtful/rare													
Lead	Lead grey (bluish white)	Pb	11.3	Solder?	Doubtful													
Magnesium	Silvery/white	Mg	1.7	Base metal alloy	No					3	4							
Manganese	Silvery	Mn	7.44	Base metal alloy	Doubtful				2	3	4							
Molybdenum	Steel grey	Mo	10.2	Base metal alloy	Doubtful		4											
Nickel	Lustrous, silvery tinge	Ni	8.9	Base metal, pure and alloy, interplating, plating (pure and alloy)	Yes		2			1	2	1	1	2	2/1	2		2
Niobium	Steel grey	Nb	8.6	Plating, interplating	No													
Palladium	Silvery/white	Pd	12	Plating, interplating	Yes													
Platinum	Silvery-grey/white	Pt	21.5	Plating	Rare													
Rhodium	Silvery/white	Rh	12.4	Plating	Rare													
Ruthenium	Silvery/white	Ru	12.3	Plating	No													
Silicon	Dark grey/bluish tinge	Si	2.3	Base metal alloy	No					5	6							
Silver	Silver/white	Ag	10.5	Base metal, pure and alloy, interplating	Rare													
Tin	Grey (α) or white (β)	Sn	*e	Solder, base metal alloy	Rare				3									
Titanium	Lustrous, white	Ti	4.5	Base metal, pure and alloy	Doubtful/rare	1												1
Vanadium	Pale bluish grey	V	6.1	Base metal alloy	Doubtful	2												1/2
Zinc	Pale bluish grey	Zn	7.1	Solder, base metal alloy, rarely plating alloy	Doubtful/rare													3
Zirconium	Silver/white	Zr	6.5	Plating	Rare													

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. Alloys listed are those for which information on the principal metals present is available. All may contain traces of other metals. The metals are numbered sequentially starting with that which constitutes the greatest proportion of the alloy. The majority of spectacle frame alloys have names that are untraceable beyond the immediate supplier, with no information forthcoming when requested.

^aColour is that of the pure metal. Impure metals and alloys will be coloured differently. All except carbon and silicon can be described as being 'metallic' in appearance.

^bSo far as the authors are aware no metal is used in its '100% pure' form, although 'pure' is used in advertising literature. Some of the materials for which plating alone is indicated may also be used as intermediate platings.

^cBased on an interpretation of reported contact allergy (80).

^dGold is almost invariably an alloy when used for plating.

^eTin can exist in 3 forms: α (5.8 g cm⁻³), β (7.3 g cm⁻³) and γ (6.5 g cm⁻³).

^fOther similar alloys in use.

^gGeneric alloy.

^hPossibly very limited use.

ⁱBranded steel.

^jIll-defined group of generic Cu-Ni alloys.

^kIncludes other memory metals.

Table 2. Suggested chemicals that might form a basis for patch testing patients with suspected allergy to spectacles

Standard series	CAS		Source
Nickel sulfate	10101-97-0	5% petrolatum (pet.)	Frames
Cobalt chloride	7791-13-1	1% pet.	Frames
Potassium dichromate	7778-50-9	0.5% pet.	Plating; colour on metal frames
Epoxy resin		1% pet.	Frames; metal coating
<i>p</i> -Phenylenediamine	106-50-3	1% pet.	Colour in plastic frames; cross-reacts other dyes
Colophony	1065-31-2	20% pet.	Polish
Thiuram mix		1% pet.	Rubber components
Metals			
Palladium chloride	7647-10-1	1% pet.	Plating
Gold sodium thiosulfate	10233-88-2	2% pet.	Plating
Plastics			
Butyl acrylate	141-32-2	0.1% pet.	Frames; nose pads
Methyl methacrylate	80-62-6	2% pet.	Frames; metal coating
Dibutyl phthalate	84-74-2	5% pet.	Plasticizer
Diethylhexyl phthalate	117-81-7	5% pet.	Plasticizer
Tricresyl phosphate	1330-78-5	5% pet.	Plasticizer
Triphenyl phosphate	115-86-6	5% pet.	Plasticizer
Phenyl salicylate	118-55-8	1% pet.	UV inhibitor
Resorcinol	108-46-3	1% pet.	UV inhibitor
Resorcinol monobenzoate	136-36-7	1% pet.	UV inhibitor
Disperse orange 3	730-40-5	1% pet.	Dye
Disperse red 17	3179-89-3	1% pet.	Dye
Disperse yellow 3	2832-40-8	1% pet.	Dye
Scrapings from the frame		As is	

Other materials not commercially available reported to cause dermatitis: aliphatic isocyanate as a coating on metal/plastic frames and the colours disperse blue 27, solvent orange 60, solvent red 26 (CI 26120), solvent red 179 and solvent yellow 3 (CI 11160) in plastic frames (for references, see text).

Polyurethane. Polyurethane lacquers are commonly used to protect the surface of both metal and plastic spectacle frames from attack by body fluids and to protect the body from attack by the frame material. They are also an effective way (as are other surface lacquers) of getting a nice, smooth surface on a frame so that it looks good. Skin problems in spectacle frame wear following reaction with isocyanates, the chemical precursors of polyurethane, have been reported (53). There is no information available on which are being used in the spectacle frame industry.

Rubber. Rubber used in the spectacle context is usually silicone rubber, although the properties of some 'silicone' components suggest that the silicone may be combined with carbon-based polymers, as has long been the case with rigid contact lenses. Silicone rubbers are most commonly used for pads, bridges and side-tips on metal spectacles, covering the 'curl' of curl sides and the face/nose protection elements of some protective eyewear. Silicone rubber nose pads commonly have a core of hard plastic (probably cellulose acetate). Rubbers (commonly silicone) are also occasionally used for a shock-absorbing lining in metal rims. Flexible polyvinyl chloride (F-PVC) and neoprene are sometimes used for bridges, headbands and facial protection on some protective eyewear. Acrylonitrile

butadiene styrene is a thermoplastic with many properties that make it well suited to use in spectacle frames (including the ability to be metal plated). It is sometimes used for sunspectacles and safety spectacles. It is commonly used in eye protection equipment other than spectacles, but there is no evidence of it being used for prescription spectacles yet.

There is a huge range of other thermoplastic elastomers/thermoplastic rubbers, which can be moulded more easily than the conventional cross-linked 'rubbers', but again there is no indication that they are yet used.

The only report of reaction to any rubber in spectacles is one to thiurams, accelerators used in the manufacture of natural rubber latex in 'rubberized spectacle retainers' used to stabilize spectacles during vigorous physical activity (59).

PVC. PVC is often used for nose pads which are more flexible than cellulose acetate but more rigid than silicone. It is also used for safety eyewear (goggles, etc.).

Plastic additives

The main allergenic additives include plasticizers and UV stabilizers. Reported plasticizers include:

Phosphates. Tricresyl phosphate (1): although doubt was expressed about the validity of the test confirming its presence, later reports also suggest that it is used (59, 60). Triphenyl phosphates are a large group of compounds, and it is not clear which have been used in spectacle frames other than $C_6H_5O_3PO$ (1). Phosphate esters other than triphenyl phosphates have been implicated in spectacle allergy (60), although these authors did not know which phosphate esters were present.

Phthalates. Diethyl phthalate is used in the manufacture of some plastics and has been reported as a sensitizer in spectacle frames (62). Dimethyl phthalate may also be used as plasticizer in spectacle frame plastics (1).

Glyceryl triacetate is a plasticizer reported as being largely discarded by 1966 (1). There have been no further reports since that review. *p*-Tertiary butylphenol formaldehyde resins have also been suggested as possible sensitizers in spectacle frames (60), but the authors have been unable to determine their role in the spectacle industry. Toluene sulfonamide was reported as a plasticizer, apparently not used in the UK (1). There is no evidence of its continued use in spectacles, although it is still used in plastic production.

UV inhibitors resorcinol and resorcinol monobenzoate were once common in cellulose acetate plastics. Both have been reported as being present in and causing dermatological problems with spectacle frames (55, 63–67). Fisher (63) states that resorcinol is no longer used in spectacle frames. However, it is not clear whether this applies to frames that are available outside the USA. Interestingly, Ongenae (51) in 1998 claimed that it was still the most important allergen in plastic spectacle frames. Phenyl salicylate is sometimes used as a UV inhibitor in cellulose plastics and has been reported as causing dermatitis in spectacle frames (55).

Citric and stearic acids were reported as being present as a stabilizer and lubricant in sheet cellulose acetate (1), but the sole UK manufacturer from whom these authors must have obtained their information ceased production soon after their publication.

Plastic dyes

Colourants, which dissolve fully and are usually found in transparent polymers, have occasionally been reported to cause dermatological problems in spectacle frames. Smith and Calnan (1) cite an early (1943) case of sensitivity to an indeterminate black or brown dye, and there have been a

few reports since. Although in 1966 dyes were stated to be throughout the plastic, the surface dyeing of finished frames is now extremely common.

p-Phenylenediamine has been reported to cause contact dermatitis in spectacle frames (1, 68, 69). The use of dyes likely to have *p*-phenylenediamine as a breakdown product in use is now controlled, but this does not yet appear to affect spectacles (6). A variety of related dyes of anthraquinone, perinone and azo type have been reported to cause contact dermatitis in spectacle frames (Table 1) (64, 67, 70–72). They are used principally in plastic frame materials and polymer coatings. There are no reports of them being used to colour the surface oxide layers of metal spectacles, although they are suitable for use in this context. A number of anthraquinone and azo dyes have been banned in some countries from use in textiles and other contexts with prolonged skin contact because of the risk of breakdown to known carcinogenic and toxic substances. These dyes do not appear to be specifically prohibited from use in spectacle frames (6, 73, 74).

Composites

Composite materials, of which carbon fibre was by far the most popular, went through a phase of popularity—mid-1980s until quite recently. The use now seems to have declined. They consist of fine strands of a strong material set into a plastic. They are almost always named by fibre rather than by plastic in which they are set, although the fibre is volumetrically the smaller component. There are 3 fibres that have been used in spectacle frames to any significant extent—carbon fibre (by far the most common), glass fibre and Kevlar. It is unclear whether some ‘copolyamide’ materials are also composites, as many plastics marketed as such for other roles are clearly such. The presence of a closing block (i.e. the lens is held in by a screw fitting) on a plastic spectacle front is almost diagnostic of carbon fibre set in nylon.

Other materials

Bone is used in spectacles by at least one commercial producer of spectacles (as theatrical props) in the UK. These are usually replicas of early ‘rivet spectacles’, as larger pieces of flat bone are hard to find. It is unlikely to be present in conventional spectacles. Horn from cattle is also used by a couple of producers of theatrical props and European buffalo horn by at least one commercial frame supplier. Formaldehyde has been reported as causing dermatitis from some

‘synthetic horns’ (1), but there is no recent evidence for this. It is likely that the now obsolete casein–formaldehyde was the source when there were supply restrictions during the Second World War.

Leather is used mainly by small-scale suppliers of replicas of historical frames and quite a few people who make them for their own use. The authors have also seen leather (chamois leather) stick-on nose pads on the market on occasion. There is no information available on the tanning process used for such products.

‘Real shell’ is the shell of the Hawksbill turtle. As they are now a protected species, real shell frames are only (legally) made in limited numbers from old stocks.

Wood seems to go through phases, not so much of popularity as of limited production runs. Frames with partially wooden sides are currently being marketed in the UK. There is also at least one (limited) producer of wooden replica spectacles as theatrical props. Centuries ago, its use was quite common. Wood would normally be lacquered in a modern spectacle frame, but not in a historical replica. Plywood has the added complication of the glues used.

Polishes

There is little information available on polishes used on spectacle frames, although the use of colophony appears to have declined considerably in recent years. However, it has been reported as a sensitizer in spectacle frames (49). It is absent from the self-fluxing silver solder most commonly used for in-practice spectacle repairs in the UK. Abietic acid, the main sensitizing agent in colophony (75), is used in polishes and some solder fluxes but does not appear to be used in its pure form in spectacle production. Jordan (76) found a patient sensitive to turpentine/beeswax polish. Another common polishing material, used commonly for buffing frames, is iron oxide (rouge).

Solvents

Acetone is sometimes used as a solvent in spectacle repairs and for attaching nose pads. Its high volatility means that it will seldom be present on frames in use. Ethylene acetate, a better solvent, is now very seldom used, as the pads are now usually integral on new frames. However, it has been stated (63) that nose pads of eyeglasses can produce dermatitis from ethylene acetate solvents. Ethylene glycol has been reported as a cause of contact dermatitis when used as a solvent to join nose pads to plastic frames (77).

However, it does not appear to be a satisfactory solvent for any spectacle frame material currently in use.

Cosmetics

Make-up can cause skin reactions where it is on the surface of a spectacle frame, which is in contact with the face, and is a factor which should be eliminated (78). Nail varnish containing tosyl/amide formaldehyde resin is commonly used in an attempt to reduce or eliminate skin reactions due to nickel-containing spectacle frames and has caused dermatitis in this context (79).

Conclusion

The metals used in spectacle frames can be impossible to identify without destructive testing. The number of alloys used has multiplied phenomenally since 30+ years ago when almost all metal frames were copper–nickel or aluminium alloys. An idea can be gleaned from the weight, thickness and flexibility, but it is only a very vague one. For plastic frames, the identification situation is no better and will become an increasingly problematic activity as cellulose acetate continues to be replaced by increasingly unidentifiable and mixed materials.

Even when spectacle frames are marked with the basic frame material or such information can be gleaned from the importer, this is seldom (if ever) wholly correct, as only the main component is indicated. The identification of spectacle frame materials is now impossible under clinical conditions, and patch testing for ‘predictable’ materials (table 2) may not determine all the causative agents of spectacle frame dermatitis.

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Address:

G. Walsh

Department of Vision Sciences

Glasgow Caledonian University

Glasgow G4 0BA

UK

e-mail: g.walsh@gcal.co.uk