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CET

Plastic fantastic

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This article will explore a brief history of plastic frame materials, look at different plastic frame production methods, consider some new frame materials, explain how plastics play a part in children's eyewear, and just what makes plastic so fantastic.

Historically, plastic frames have been made from a variety of materials including cellulose acetate, cellulose propionate, nylon and its polymers, and cellulose nitrate. For those dispensing opticians too young to remember first hand, I recall a story from a former colleague about adjusting a cellulose nitrate frame as a trainee...

Feeling confident whilst his supervisor was out to lunch, he was called upon to adjust a new pair of spectacles for a young lady. He very quickly learnt that the softening point of cellulose nitrate, 65°C, is very close to its flash point of 70°C and returned to the patient with smouldering remnants of a frame – not to mention newly fashioned eyebrows. Thankfully, this material is now banned in the UK, but it is still used in frame production in the developing world[1], so as an optician you need to be able to differentiate it from other plastics.

Produced by machine routing and made from cotton linters and nitric acid with a camphor elasticiser, cellulose nitrate looks very similar to cellulose acetate with a high surface lustre. However, it does yellow with age and become brittle. Confirmation tests with a suspected new cellulose nitrate frame are to look for pinned joints and a lack of CE mark if produced in the developing world. A discreet file at the hinge point of a new frame may give off a mothball or camphor smell.

Figure 1. NHS 525

The first commercially available plastic frames came into the optical market in the 1910s, becoming common by the 1930s[2]. Post war, production levels rose with the advent of nylon – the name being construed from a combination of New York and London reflecting both the USA and UK involvement in its development. Nylon frames have a high resistance to breakage, which unfortunately makes them very hard to adjust. They often have metal sides because of this.

NHS plastic frames were, for many, their first venture into the realm of a plastic frame (**Figure 1**). They were produced in 1948 and then from 1951 until the mid-80s of cellulose acetate[3], which is the material of norm for plastic frames today. Made from cotton linters and possibly wood pulp, acetic acid and plasticiser, the recipe ingredients are first mixed together to form a homogenous paste. This paste is then filtered and extruded ready for colouring with mineral pigments or vegetable dyes.

Heated machine callipers then transform the coloured paste into sheets, which are then cut, stacked and pressed together to form endless effects and colour possibilities (**Figure 2**). The quality of the acetate is determined by the quality of its cotton linters and the filtration processes[4]. Italian Santino Mazzuchelli, and his son Pompeo, first produced cellulose acetate in sheet form in the late 1800s[5]. To this day, six generations later, Mazzuchelli continues and is revered to be one of the highest quality cellulose acetates available – now known by its trade name, Rhodoid.

This article has been approved for 1 CET point by the GOC. It is open to all FBDO members, and associate member optometrists. The multiple-choice questions (MCQs) for this month's CET are available **online only**, to comply with the GOC's Good Practice Guidance for this type of CET. Insert your answers to the six MCQs online at www.abdo.org.uk. After log-in, go to 'CET Online'. **Questions will be presented in random order**. Please ensure that your email address and GOC number are up-to-date. The pass mark is 60 per cent. The answers will appear in the May 2015 issue of Dispensing Optics. The closing date is 10 April 2015.

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Fig 2. Cellulose Acetate in sheet form - showing the colour and effect possibilities

Cellulose acetate frames are generally produced by routing from a block or sheet by a computer aided CNC machine. The acetate is cut into rectangular blocks and fed into the machine. The milling head may contain as many as eight to 10 different sizes and types of cutting head – all programmed to produce a shaped frame front and include a stage to produce the required bevel to hold the lens in place.

A high gloss finish is achieved by tumbling in a barrel with an abrasive such as woodchips or walnut shells for many hours – usually 24 hours per stage. This process can involve up to four stages utilising decreasing abrasive substances. A polishing paste can also be added at each stage. A paste with pumice can be used at the first stage, decreasing to something similar to car polish at the end stage to give the high gloss finish. A protective lacquer is then sometimes applied to provide a hard, long-life finish.

Acetate frames usually have 'shot' reinforced sides. In this process, the side is made out of a routed piece of acetate, placed in a metal mould, which heats the side up to its plasticity temperature. The side is then placed in a cold metal mould; the side cools from the outside inwards and as it does so, the heated metal core reinforcement is pushed into the soft plastic centre. This metal reinforcement is guided down the centre of the side by the hardened exterior. During this stage, designs can be moulded into the softened plastic of the side. Metal sides can also be embedded into the acetate with the use of ultrasound.

The adjustment temperature of cellulose acetate is 57°C; it is non-flammable but excessive heat will cause the material to distort and bubble. This occurs when the centre of the plastic starts to boil and the resultant gas formed produces small vacuoles within the substance of the plastic.

As cellulose acetate frames age, the plasticiser can dry out making the material more brittle. This drying out requires a higher heat to be applied to soften the material and, therefore, more care should be taken when adjusting and re-glazing older frames. It's not uncommon to see a cellulose acetate frame surface lose its polish and appear chalky– especially with darker colours. Life can easily be breathed into these frames with a little TLC.

A wipe over with rubbing alcohol removes any surface lacquer and chalkiness, and then the frame can be re-polished with a little hard wax and a polishing mop. Interestingly, broken acetate frames can be repaired by soaking the broken parts in acetone for a few hours or so. The broken parts are then held together whilst the material sets (it's probably best not to advise your patients of this!

Spectacles made of cellulose propionate are hard to differentiate from those of cellulose acetate. They are harder and yet more flexible than cellulose acetate frames and have a slightly lower density, making them more transparent, and they often have the demarcation 'CP' somewhere on the side. The material is made from cellulose flakes, propionic acid, acetic acid and stabiliser by injection moulding. The adjustment temperature is 67°C, but excessive heat can cause shrinkage so care must be taken when glazing.

NYLON POLYMERS

Optyl is a trade name for an epoxy resin, which is a thermosetting plastic. This is a favourite material used by the Safilo Group and has a plastic memory, meaning it can be heated to a high heat and distorted, but once cooled and reheated will return to its original moulded form. Care should be taken to heat sufficiently before undertaking adjustments, as the material is rather brittle below its softening point. Optyl frames are compression moulded, surface dyed and lacquer coated. Its strength and rigidity meant that many original designs did not have full metal reinforced sides, although now most do have this feature.

Many different nylon polymers are now used in frame production, mostly from crude oil, and include the trade names of Grilamid manufactured by EMS Grivory and Ultam, which is almost exclusively used in South Korea. The first products made of the polymer Grilamid TR were transparent shirt buttons in the late 1970s, which could stand up to being machine washed. This resistance to hydrolysis was a novelty at the time. Due to its chemical and crush resistance, Grilamid TR is used for protective tubing for fibre optic cables. With polymer modification, the homopolyamide Grilamid TR90 came into existence with its high transparency and remarkably low density compared to other transparent polymers. It is the lightest engineering plastic in existence[6].

Grilamid BTR green-line is an eco-friendly polyamide with a high biocontent of around 54 per cent. It has excellent transparency, low density but high toughness. It has good UV resistance. By using monomers obtained through chemical processes from the renewable raw material castor oil, the environmental impact of this material is significantly lower compared to crude-oil based polyamides. The total emission of climate-damaging gases during the whole manufacturing process of the polymer and its precursors can be reduced by up to 75 per cent[3]. Grilamid BTR is utilised in many models in the Charles Stone range, available from William Morris Eyewear (**Figure 3**).

Figure 3. Charles Stone Grilamid frame

A new nylon polymer being utilised by Safilo is XE4066. This particular polymer has a higher rigidity than TR90 and BTR and produces a semi-transparent material that can be dyed with mineral pigments. The frame design utilises a metal side along with Safilo's new Elasta 80 hinge mechanism, offering a very lightweight and durable style.

SPX is peculiar to Silhouette and is a super-polyamide, the X being Silhouette's X factor secret ingredient. The company's latest foray in frame materials is SPX+, which with up to eight composite polymers is even lighter and stronger – twice the strength of acetate. Therefore, it can produce the thinnest full-rim eyewear on the market weighing as little as 4.1grams[7], as seen in Silhouette's Urban-Lite range (**Figure 4**). The rims are in-line glazing in style due to their thinness, so care must be taken when ordering, glazing and springing in the finished lenses.

Figure 4. SPX+Silhouette frame

All of these nylon polymers have a high dynamic strength, and due to the lack of plasticisers, are hypoallergenic. Spectacle frames are manufactured from these materials by injection moulding, and can be brilliant in colour, due to the materials' transparency before colouring. Care should be taken when cleaning and adjusting any Grilamid frame; some are easily damaged by solvents and all need to be cold glazed.

INJECTION MOULDING PROCESS

The injection moulding process is initially fairly costly. A mould is first made from chromium steel or sometimes aluminium by CNC machining of a mould base, a process which is accurate to within 1/100mm and can take up to 20 hours to complete. The mould itself is made in two halves with guide pins and bushings to aid alignment when setting the two halves together in readiness for production (**Figure 5**). The

Figure 5. Injection frame/mask mould (Courtesy of Stepper UK Limited)

mould surface is highly polished to give a smooth frame surface, or can incorporate texture and intricate design if desired. The injection machine process comprises of the following four stages (**Figure 6**).

Stage 1: The two halves of the mould are clamped together, utilising the guide pins and bushings to aid alignment. Polymer beads or granules are fed through a hopper into the chamber containing a screw. The screw 'drag flows' the polymer along the chamber in three zones: the first rids the polymer of air; the second, known as the 'melt zone', reduces the polymer's volume by compacting the material; the third zone is known as the 'meaturing zone' and acts as a pump to the screw head. Whilst traversing these three zones, the polymer beads or pellets turn to molten plastic at high pressure though heat, friction and force. Plastic temperatures can vary from 160-320°C at this point, depending on the polymer.

Stage 2: Once the plastic reaches its necessary viscosity, the screw is then forced forwards by a hydraulic ram, and the plastic is forced under pressure of 20-30,000 PSI through a one-way valve at the screw head into the mould. Moulds may have multiple injection points. It's worth noting here that the designer has to pay attention to the placement of injection points, avoiding weak points on the frame such as the bridge or thinner frame rims, which will affect the longevity of the finished article.

Stage 3: Cooling. This is either just a waiting game or can be accelerated by cooling the mould with water.

Stage 4: The mould is then opened and the frame parts ejected – either by air blast, ejection plate or rods.

PLASTIC FRAME PRODUCTION – THE FUTURE?

The latest addition to the plastic frame market is 3D printed spectacles. These are created using specialist computer aided design programmes, and produced by printing with a nylon polyamide powder with selective laser sintering (SLS) technology. This is an exciting new avenue, and obviously the possibilities are endless with improved production afoot.

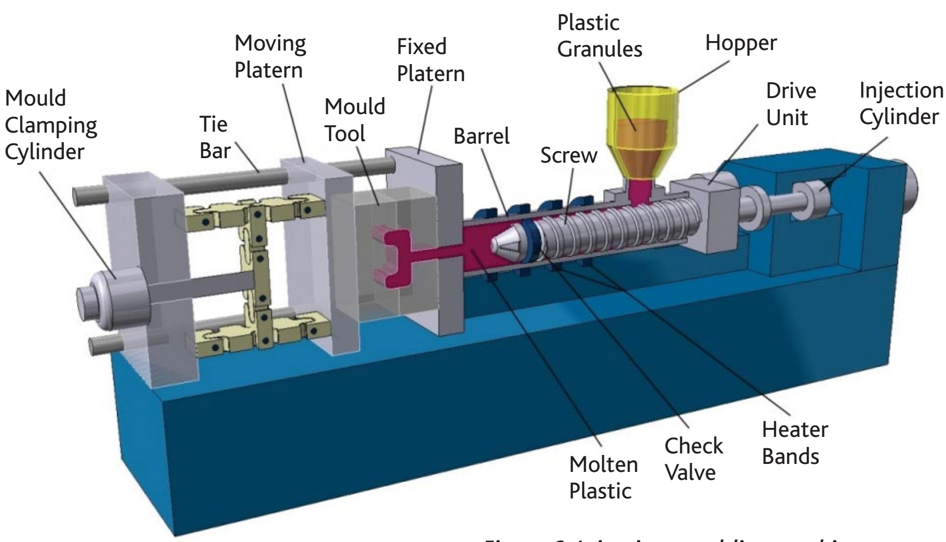

Figure 6. Injection moulding machine

USE OF PLASTICS IN PAEDIATRIC SPECTACLE DESIGN

Upon the demise of the NHS children's frames, the trend for paediatric spectacle frames swung towards metal frames. With current fashion trends for plastic adults' frames, the material de rigueur is now swinging back to plastic. Children's spectacle frames need to address the child's developing facial features, which obviously differ somewhat from an adult. A child's frame cannot simply be a scaled down version of a popular adult's frame, and paediatric frame designers need to consider the following when developing a suitable frame:

- Crest height
- Bridge projection
- Splay angle
- Frontal angle
- Head and temple width
- Length to bend/length of side
- Length of drop and angle of drop if fitting a hockey-end side

The main concerns to be addressed when selecting a child's frame must be fit and safety. Due to the unpredictable habits of children, the frames chosen should be able to withstand the abuse and forgetfulness that is to be expected of children. It is important to choose a frame style and material that will stand up to vigorous use and abuse. Keeping in mind that children play hard, frames chosen for them should be robust.

Figure 7. Miraflex paediatric range, addressing the differing fitting characteristics of paediatric eyewear

An ideal child's frame should be lightweight, robust and comfortable in design. The Miraflex range available from Dibble Optical (**Figure 7**) is made from a specialist polymer, which is a lightweight, flexible and hypoallergenic material. The range is designed in Columbia by an orthoptist, taking into consideration anthropometrical data collected from many local children, and manufactured by an Italian company owned by her sister-in-law. Its design is simple: there are no screws or metal parts so the frames will not fall to pieces and are virtually indestructible.

Centrostyle offers a good range of children's frames too, many made from cellulose acetate or Grilamid and some also incorporate a moulded silicone fixed bridge design to aid comfort and grip on the nose.

Material	Typical density	Softening point	Production method	Additional information
Cellulose acetate	1.27	57°C	Routed	Easily warps with heat
Cellulose propionate	1.21	67°C	Moulded	Will shrink if overheated
Cellulose nitrate	1.24	65°C	Routed	Flash point is 70˚C – take care
SPX+	1.00	70°C	Injection moulded	Will shrink if overheated
Grilamid TR90	1.00	85°C	Injection moulded	Cold glaze Side reinforcement not necessary
Grilamid BTR	1.05	85°C	Injection moulded	Cold glaze Side reinforcement not necessary
Optyl epoxy resin	1.16	80-120°C	Compression moulded	Cold glaze Memory plastic May have short side reinforcement Does not shrink
XE6044	1.05	> 110˚C	Injection moulded	Cold glaze

Table 1[8]

CONCLUSION: SO IS PLASTIC FANTASTIC?

It's important for the optician to be able to make an informed recommendation to the purchasing patient. **Table 1** lists the common plastic materials and their properties to help the practitioner make the right recommendation, and shows how each material must be handled when glazing and adjusting. With these new developments in plastic frame materials and manufacture, spectacle designers are able to offer much lighter, stronger and robust designs in a plethora of colours, effects and finishes offering the wearer the best possible balance of comfort, function and fashion.

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