PMMA, from plexiglass window to a packaging for an implantable glucose sensor

*by Elke Van De Walle*

The unique versatility of polymers allows them to be manufactured into both commonly used household items and specialised medical devices. ‘Plastic’ windows and contact lenses form one such example, as both are manufactured from the same material, called poly(methyl methacrylate), or PMMA.

PMMA, a thermoplastic polymer often used as a substitute for glass, was discovered in 1877 and patented in 1933. Referred to as ‘acrylic glass’ or ‘plexiglass’, PMMA has one important feature in common with inorganic glass, namely its transparency. Nevertheless, from a chemical perspective each is a completely different material. Glass mainly consists of SiO$_2$, rendering it an inorganic material, while PMMA is an organic material built up of carbon, hydrogen and oxygen (see structure in Figure 1). PMMA is often preferred over glass because of its higher shatter resistance, ease in processing, and low cost and weight. Conversely, this plastic is less scratch-resistant and more flammable than glass [1]. Because of its advantages, plexiglass can be found in aquariums, caravans, and in the delineation of a children’s playground, but also in police shields, car lights, etc...

**Medical discovery: lucky strike or pure observation?**

The first major application of PMMA took place during World War II, when it was used for aircraft windows, submarine periscopes, gun turrets for airplanes, etc. It was during this time that the biocompatibility of PMMA was discovered by the English ophthalmologist Harold Ridley. Pilots often suffered from eye injuries caused by PMMA splinters coming from the windows of their airplanes. Dr. Ridley observed that, compared to glass splinters, almost no rejection occurred in these cases. As a consequence, in 1949, Dr Ridley implanted the first intra-ocular lens in an attempt to cure cataract. Meanwhile, plastic PMMA contact lenses began to replace their glass antecedents [2-4]. (see Figure 2).
Customising polymer properties based on future application—My research = a small piece of the future puzzle

Polymer implants should of course fulfill certain requirements determined by the implantation site in the body (subcutaneous, heart, knee, bone, etc.), its surrounding environment, and the physiological role that it has to play (skin graft, bone defect filler, heart valve replacement, etc.). Subcutaneous implants, for example, require soft and flexible material to assure patient comfort.

Known for its hard and strong nature, PMMA is frequently used for load-bearing functions. In the 1950s, for example, PMMA was mainly used for head prostheses. It is still frequently used as “glue” to fixate hip and knee replacements (see Figure 2). In dentures and biochips, too, its robust nature is desirable [5-7].

Recently, PMMA has been investigated as a potential packaging material for implantable medical devices, including glucose sensors. How to create such a polymer packaging? In order to ensure sufficient flexibility, the bulk properties of hard and brittle PMMA are adjusted by introducing long side chain oligomers in the basic structure of PMMA, creating copolymers with improved flexibility and softness. An implant interacts with the human body mainly through its surface; surface properties of the packaging material therefore play an important role and must be tailored accordingly. In the case of a glucose sensor, it would be advantageous to grow blood vessels in the vicinity of the implant, as glucose needs to reach the sensor. Since blood vessels are built up of endothelial cells, these are the ideal cell types to attract towards the sensor.

Figure 1. Chemical structure of PMMA. x denotes a repetition of its building units, called monomers

Figure 2. Applications of PMMA in the medical world include bone cement (top left), an intra-ocular lens (bottom left), and a contact lens (bottom right).
Youth Views on Sustainability

Researchers have immobilised biological compounds on the packaging outer surface through various surface modification techniques in an attempt to improve sensor sensitivity towards glucose. Such research is presently followed within the Polymer Chemistry and Biomaterials (PBM) Group at Ghent University.

The next piece of the puzzle is how to manufacture such a polymer packaging? A film casting technique is one possibility often used in industry and academia due to its straightforward approach and concomitant results. As shown in the figure below, a monomer solution is injected between two glass plates and irradiated with UV-light. Through irradiation, the initiator (present in the solution) will be activated and form radicals (i.e., reactive species). These radicals will then trigger the initiation of different monomers in the solution and, as a result, polymer chains will start to form and grow (i.e., propagation). In the end, a solid material will be obtained. The shape of the material will be determined by the shape of the central cavity (in this case rectangular). This technique differs from other processing techniques, such as bioplotting or electrospinning, in the sense that the polymer production and moulding are combined in one step. In other techniques, the polymer needs to be produced prior to processing.

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References

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Figure 3. Film casting technique: the central hole in the silicone spacer (blue rectangle) will determine the shape of the plastic created.