Spectroscopic Study of the Manufacturing Process of Contact Lenses

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Personal Details
For the first two years of my degree I studied physics and chemistry preferring physics and physics technology for the latter two years of the course. Other subjects studied in the first three years included maths, management studies and German.

Amongst my academic interests are medical imaging systems, spectroscopy, remote sensing, biophysics and nuclear physics. I am also interested in environmental science. My foremost hobbies are painting, reading Irish literature, listening to music, playing golf and soccer.

Project Summary
The objective of this project was to explore an alternative to fluorescent ultraviolet lamps currently used by contact lens manufacturers. These lamps are used to initiate a process whereby a liquid monomer mix is photopolymerised to form a solid polymer. This polymer is the material of soft contact lenses.

By investigating a new UV source to provide similar qualities in terms of achieving polymerisation, it was hoped to demonstrate a possible alternative for manufacturers to the UV lamps used at the moment. If the alternative source proved to be a viable option for the curing of the sample it could substantiate a more economical selection for the ultraviolet source. This project involved a spectroscopic study of the alternative source’s capabilities to polymerise the monomer sample.

The contact lens manufacturing industry currently uses UV fluorescent lamps to initiate the photopolymerisation process. The process is optimised using wavelengths between 300nm and 380nm. The new source used in this project had a wavelength of 370nm.

There are several drawbacks to the use of UV lamps. Examples of these drawbacks are that their intensity decreases over time, they are bulky and they must be warmed up fifteen minutes before use. The alternative source is more stable and should need little to no warm up time. Other advantages in the use of the alternative sources over the lamps are; smaller size, less power consumption and longer life. This should lead to substantially greater efficiency.

However there are also some disadvantages associated with the use of the new source. It has a lower intensity than that of lamps. It is expected that the lower intensity will take longer to cure the monomer than the UV lamps.

A monomer must have a double bond in its structure for addition polymerisation to occur. That double bond must be accessible to attachment by a free radical, resulting in a single carbon-to-carbon bond that extends along the chain (Figure 1). As that reaction repeats itself, the addition polymer grows.

The first step in the polymerisation process is breaking a double bond between two carbon atoms. A free radical with an unpaired electron forms bonds readily with other species. Such a radical can form a bond to one carbon atom, breaking the carbon-to-carbon double bond in the process.

The process of photopolymerisation is the reaction
that makes a polymer out of a monomer using light to initiate the conversion. In this project, the monomer mix used was 2-hydroxyethyl metacrylate (HEMA) and 2,2-dimethoxy-1,2-diphenylethen-1-one (Irgacure 651). This monomer is described as a hydrophilic monomer as the OH group in HEMA is soluble in water. The monomer will copolymerise to form a hydrogel. Irgacure 651 was the photoinitiator in the monomer mix and is sensitive to UV radiation. When exposed to the alternative source radiation the sample begins to photopolymerise or cure.

The curing process was monitored using the FTIR and Raman spectrometers. Both external (at 296K, 308K and 323K) and in-situ (Figure 2) curing was observed using the FTIR spectrometer. An in-situ (Figure 3) cure was monitored by the Raman spectrometer. FTIR and Raman spectroscopy are both forms of vibrational spectroscopy. These are based on the reaction of the functional groups within the polymer chain due to molecular vibration. Infrared spectroscopy and Raman spectroscopy are complementary techniques.

Figure 2 and 3 show the spectra of HEMA plus photoinitiator before photopolymerisation (t=0) and after (t= 240 min and 21 min respectively). It was clear that after curing for the said times the C=C peak at 1636/1638 cm\(^{-1}\) had disappeared. This is what indicates the complete curing of the monomer sample. The reference peaks also decreased due to the sample changing state from a liquid to a solid and not due to the photopolymerisation process.

It was illustrated with the displays from the FTIR and Raman spectrometers that an extent of photopolymerisation had occurred.

The effects of the alternative source were explored and showed a possible alternative to the use of UV lamps for photopolymerisation. This could mean a more economical process for manufacturers. The new source could act as an alternative which is more compact, less power consuming and one which provides a more consistent intensity with much less warm up time.