

Plasma Basics

Source: Contamac Ltd
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The plasma surface treatment of contact lenses is undoubtedly becoming a topic of increasing interest. Historically plasma treatment has been fundamental to the clinical success of hyper oxygen transmissible materials. First experimentation with its use was almost certainly with silicone elastomers, reducing their propensity to adhere to the cornea making their wear tolerable. Without such treatment, the original extended wear silicone hydrogels could not be worn for more than a few hours before lipid build-up made the lenses unwearable, and hyper Dk RGP materials became possible by relying on plasma to provide surface wetting. More recently, the advantages of plasma treating all RGP materials has become apparent, as it affords high initial comfort that can contribute to fitting success. A review of plasma treatment fundamentals would be useful, in order to better understand the benefits and limitations of the technique.

probably most familiar as lightning or high voltage arcs. Low temperature plasma can be seen in neon signs and some modern day televisions. It is this low temperature form that is most useful for surface modification and of interest to our application.

Low temperature plasma can be either created at atmospheric pressure (corona discharge) or more usefully to ourselves, at reduced pressure (glow discharge.) The advantage of both these techniques is that they only modify the surface of the material, leaving the bulk properties unaltered.

the characteristics of the plasma and consequently the characteristics of the treated surface. In general, plasma has the ability to clean, cross-link, functionalize, deposit, or etch a surface.

Oxygen (O_2) is commonly used for many applications and its plasma will contain, amongst other things, O^+ , O^- , O_2^+ , and O_3^+ ions. Oxygen plasma can be very effective at cleaning the surface of a lens. In fact, much more effective than using a lens cleaner that can leave residues. The reactive oxygen species will react and break-up surface contaminants such as wax and grease, volatilizing them and removing them from the

Figure 1 shows a typical set-up for the creation of glow discharge. The chamber is evacuated and the process gas is introduced at low pressure. Application of high frequency waves ionizes the gas into a mixture of excited charged species (ions,) radicals, electrons, and produces the characteristic visible glow. The particles are very unstable and highly reactive. Operating at low pressure reduces the probability that these species will collide, and thus extends their life. The relatively low density of these particles also accounts for why the plasma remains cool.

A surface placed within the plasma will be bombarded by these highly reactive particles, and the effect they have on the surface will depend upon the treatment conditions. Variables such as the type of process gas, treatment time, pressure, and power will all affect

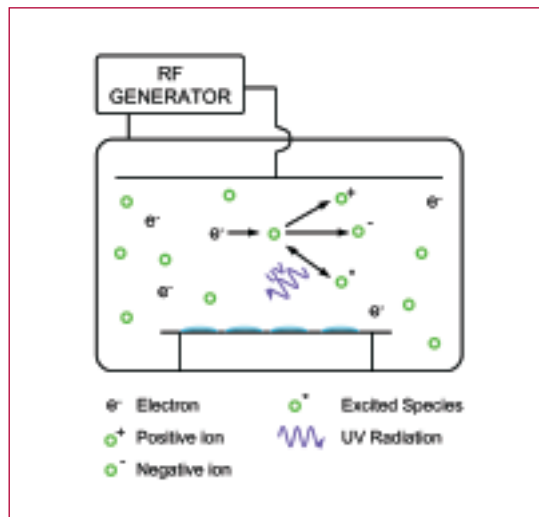


Fig. 1. Plasma Generation

Plasma is a gas that has been ionized into electrically charged particles and is a mixture of highly reactive species. It is sometimes branded as the fourth state of matter because its behavior is different to that of solids, liquids, or gases. There are two types of plasma, low temperature and high temperature. High temperature plasma is

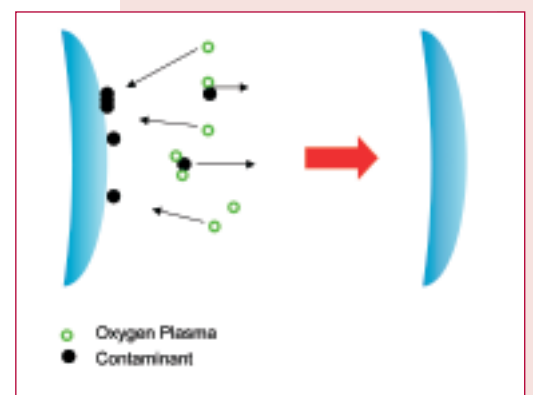


Fig. 2. Surface Cleaning

surface, figure 2. This treatment, in its own right, can greatly improve the initial wetting and comfort of an RGP lens.

Plasma can also bind and chemically alter the surface, in a process known as functionalization (Fig.3.) Oxygen plasma reacts with the surface of the material to form a variety of molecular structures that can enhance wetting.

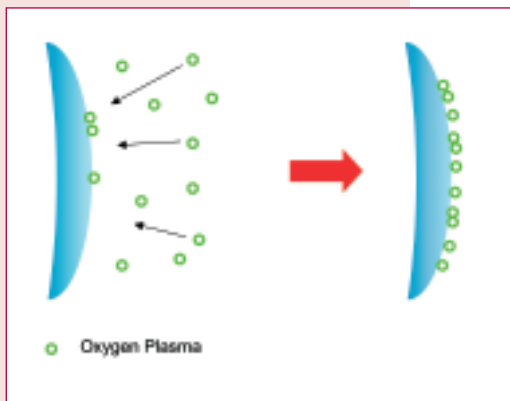


Fig. 3. Functionalization

Oxygen plasma is generally the method of choice for RGP lenses. The combined effect of surface cleaning and modification produces lenses with significantly improved wetting, so the initial comfort of a new lens being placed on the eye is greatly improved. Under an average cleaning and wear regime the treatment wears off over a period of months, but the underlying RGP material remains wettable and by this time the patient's own tear components will have interacted with the lens and improved its biocompatibility.

Unwanted processes when treating contact lenses are surface etching and over oxidation. Etching occurs in competition with functionalization, and is caused by the plasma reacting with the material's surface atoms to form volatile products. Significant etching can

often be visible to the naked eye and appears as a hazy surface. Over oxidation can cause patches of weakly bound scales to form that easily flake away during cleaning. Both of these processes degrade the surface and can cause microscopic imperfections that provide a

key for unwanted soiling to accumulate. To avoid such unwanted degradation, the process conditions must be carefully selected and controlled. Once the correct conditions have been established, the sophistication of modern day plasma equipment will ensure the treatments are highly repro-

ducible and such unwanted side effects will be avoided.

Plasma polymerization, also known as deposition, has also been adopted by some manufacturers. Monomer is introduced into the chamber and polymerizes to form a thin polymer film on the surface of the lens. In this manner the composition of the lens at the surface can be completely different to the bulk (Fig. 5.)

Plasma surface treatment techniques have undoubtedly enabled many extended wear products to become viable products. It is probable that the market will see the release of further materials that also rely on these techniques to ensure clinical success. Further improvements to the types of coatings applied to lenses are also probable, providing improved deposit resistance, increased comfort, and greater durability. The treatment of RGP lenses with plasma remains a growing area of interest. Although not essential to the clinical success of many of the materials, the enhanced surface provides much greater initial comfort to the patient, making the concept of a plasma treated RGP lens exceedingly attractive. ■

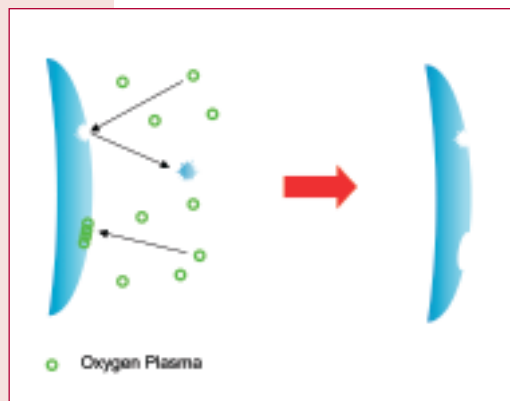


Fig. 4. Etching

ducible and such unwanted side effects will be avoided.

Surface treated silicone hydrogels tend to use either surface cross-linking or plasma polymerization. Surface cross-linking occurs when oxidative plasma forms a high density of cross-links between the silicones, creating a silicate type crust on the lens. This silicate layer is far more wettable than the original mate-

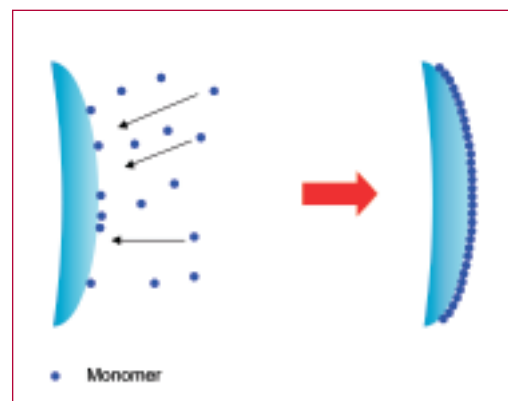


Fig. 5. Plasma Polymerisation