Lens cleanability and how to clean lenses: a review

WHITE PAPER

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Introduction

Today's ophthalmic lenses are high-tech products optimised to guarantee outstanding vision correction individualised to the wearer's needs. Sophisticated lens coatings contribute to vision comfort by reducing reflections and protecting against UV radiation and high-energy visible light. Additionally, the technologies chosen for lens coatings also ensure the long-term durability of the ophthalmic lens by protecting against scratches and soiling. To ensure the lenses are easy to clean, the outermost layer of a coating system is chosen from a special material that generates a smooth surface feel and ensures that water forms droplets rather than a closed film on the surface. Droplets with a minimum size can be removed from lenses by agitating, while the remaining small droplets can easily be soaked up by using a cloth or tissue.

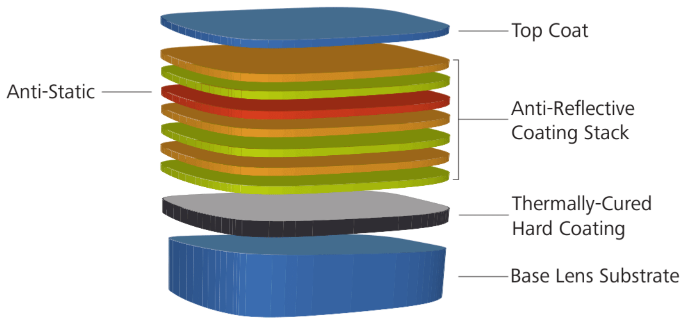

Figure 1: Schematic representation of modern lens coatings.

Soiled lenses are the biggest annoyance to lens wearers. However, lens soiling cannot be fully prevented. Even when extreme care is taken, the lens remains close to the face and, one way or the other, facial grease is always transferred to the lens surface, e.g. through contact between the lens or frames with the skin or via the eyelashes or the eyebrows. Facial grease or grease from fingerprints that is on the lens surface as a result of handling the spectacles forms a white smear that disturbs the wearer's vision.

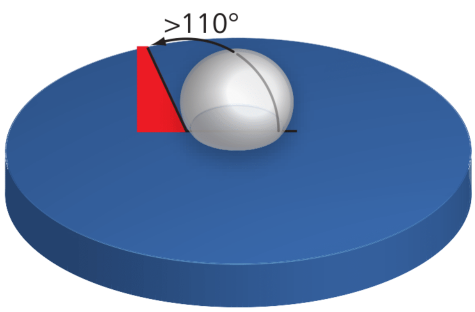

Figure 2: Illustration of a water droplet on a coated ophthalmic lens.

Lens manufacturers typically provide recommendations on how to clean the lenses. The gentlest way to clean lenses is to use water and dishwashing liquid. With this approach, the grease is removed via the detergents in the dishwashing liquid, while solid contaminants like dust particles are removed by rinsing with sufficient water. Agitating the lens after the final rinse means only a few droplets remain on the lens surface. These can then be easily soaked up with a cloth.

As an alternative for when the wearer is out and about, lens manufacturers recommend using special pre-moistened cleaning wipes, which also contain special optimised detergents to collect grease, or microfibre cloths. Using a microfibre cloth is the so-called dry cleaning approach. This is a very efficient method for removing grease from the lenses due to the microfibre material that attracts grease and the large surface area of the microfibre cloth.

Figure 3 shows the results of a survey of approx. 2,500 ZEISS employees. They were asked which type of cloth they preferred for lens cleaning. Microfibre cloths and pre-moistened lens wipes are used by the majority of the participants in this survey.

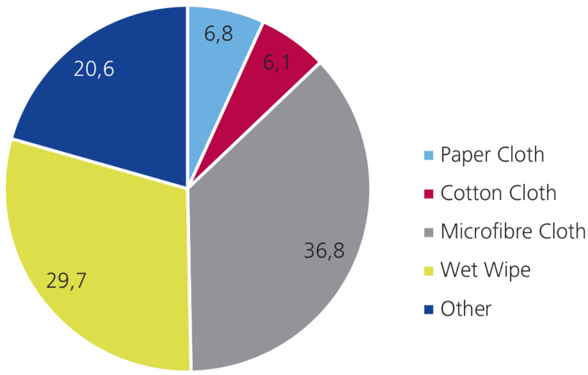

Figure 3: Typical distribution of lens wearers' cleaning habits.

When discussing the cleaning behaviour of ophthalmic lenses, the interplay of many factors has to be investigated, including:

- Surface properties of the lens
- Type of soiling and its chemical and physical parameters
- Wet or dry cleaning conditions
- Type and surface area of the cleaning cloth
- Pressure and speed of cloth movement during wiping
- Influence of cleaning chemicals like detergents and alcohols

Thus the full microscopic understanding of lens cleaning slightly resembles the solution to a complex multibody problem in physics[1].

This technical paper tries to summarise the results of the latest research on the topic of lens cleanability while also taking the wearer's perspective into account. We also try to provide orientation on how to rate and interpret the different claims made by the lens manufacturers.

The nature of lens staining

When investigating lenses after an individual wearer has had them on for some time, the following macroscopic contaminants can be found on the surface:

- Particles which originate in general dust that settles on the lens surface
- Particles that come from cosmetic products that are used around the eye, e.g. mascara
- Dry residues from sweat, especially after sports activities
- Grease: facial grease or grease from fingerprints

Most modern lens coatings reduce the attraction and adhesion of particles via a so-called anti-static layer within the coating stack that prevents the build-up of a static electric charge on the lens. This charge is typically generated when a lens is wiped with a cloth, and the lens coating has not been given an anti-static treatment. With no electrical charge on the lens surface, particles like contaminants can easily be blown- or wiped-off the lens surface.

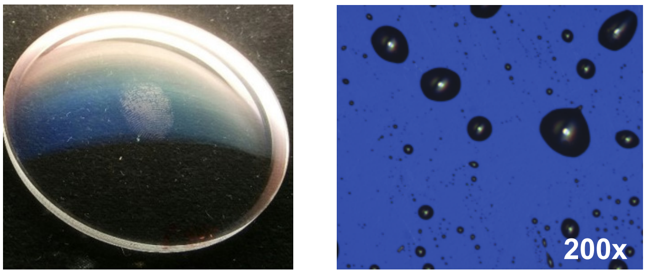

Figure 4a, 4b: Fingerprint and grease on lenses.

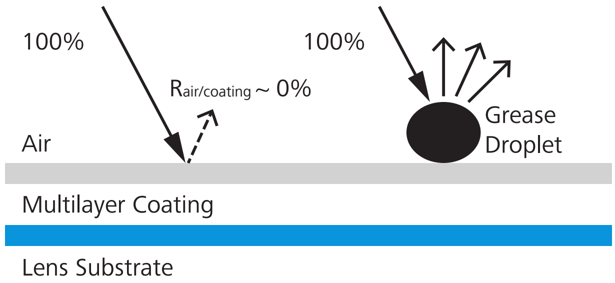

Figure 5: How stray light is generated.

It is especially worthwhile to have a closer look at grease-like surface contaminants on ophthalmic lenses, as these are the ones that cause the most trouble during lens cleaning. In Figure 4a, we show a photograph of a lens with a fingerprint. You can see that the grease of the fingerprint has a white appearance resulting from stray light on grease droplets. On lenses coated with a one of today's Top Coat treatments, grease forms small droplets as can be seen in Figure 4b. The formation of stray light by these droplets is shown in Figure 5. This stray light is the origin of what lens wearers find annoying when their lenses get soiled while being worn during the day.

How to measure lens cleanability

Within the ophthalmic lens industry, no unified testing approach has been established to assess the ease of cleaning an ophthalmic lens.

Cleaning lenses with dishwashing liquid and rinsing with water – an approach recommended by most lens manufactures – typically produces perfect results (clean lenses) once the lens wearer has gained some experiences and practice. The cleaning result typically does not depend on details of the lens coating. Thus this so-called "wet-cleaning" approach is not discussed in detail here. The focus, rather, is on situations where lens wearers do not have the time or opportunity to take this approach, e.g. during the workday or when travelling. In these situations, pre-moistened lens cleaning cloths offer an alternative that comes close to the results of the wet-cleaning. Alternatively, so-called "dry cleaning" is performed by lens wearers using, if available, a microfibre cloth or a shirt/part of their clothing to wipe-off the stain/dirt/smudge from the lenses (something that lens wearers do very often). It is this "dry-cleaning" approach which is worth investigating in more detail.

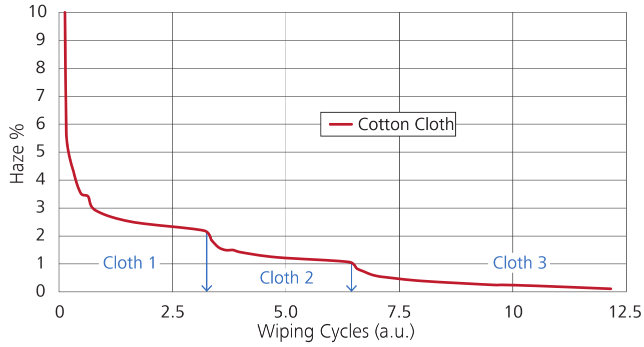

Figure 6: Result plot of a cleanability measurement. The reduction of the haze shows the progress in cleaning

Investigating the testing approaches employed by independent test laboratories[2] or advertisements by lens manufacturers, we found that none of these tests represents the real cleaning situation that lens wearers face: the removal of grease transferred from the face to the lens or from touching the lens surface. Some tests try to simulate this by applying penetrating oil or ink from a permanent marker to the lens surface. They then measure how many wiping cycles are needed to remove the contamination. The assessment of the cleaning progress is done by measuring the reduction of stray light generated by the contaminants.

However, the contaminants used in these tests hardly resemble facial grease, which is the main contaminant on lenses. This is true as it concerns the chemistry and physical properties of facial grease like its viscoelastic behaviour. Neglecting these differences will result in questionable results, as the "dry-cleaning" process is an interplay between the chemistry and rheology of the contaminant, the surface properties and surface area of the cleaning cloth and the particular wiping process, e.g. the pressure applied during wiping and the speed of the wiping movements.

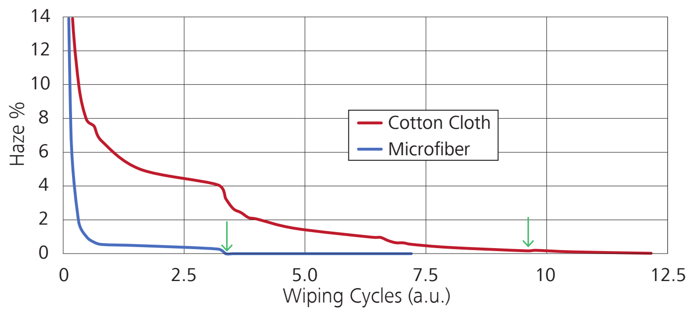

Figure 7: Result plot of a cleanability measurement that shows the superior cleaning performance of a microfiber cloth.

To overcome these limitations a testing protocol is presented that uses artificial sebum for pharmaceutical applications to simulate facial grease as a lens contaminant. A small, defined amount of sebum is placed on the lens (1-10 µl) and evenly distributed by wiping. This contamination results in haze (stray light) that is measured. Now the lens surface is wiped in a reproducible manner with an automatic device that moves a cloth in a defined movement over the lens.

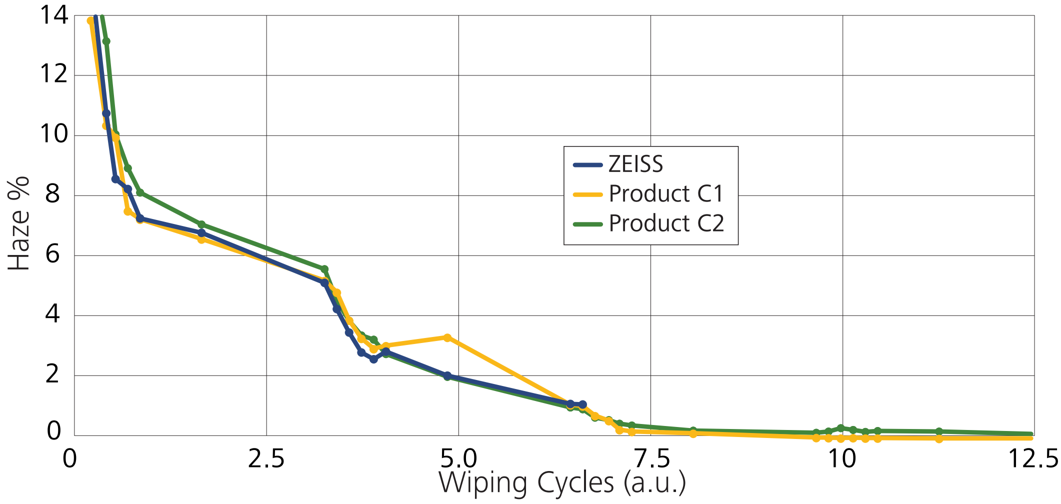

Figure 8: Result plot of cleanability measurements on lenses from different lens manufacturers.

The pressure during the wiping can be adjusted. After a defined number of movements, the procedure is interrupted and the haze level is measured. As is typical with every measurement, the haze level is reduced, showing progress in the cleaning of the surface. In many cases, after a number of wipes the haze level stays constant, indicating that the cleaning cloth's capacity to pick up contaminants has been reached. The cleaning cloth is then exchanged. Figure 6 shows the result graph of a cleaning experiment as described above.
With this test, it is also easily possible to compare the cleaning efficiency of a microfibre cloth versus a cotton cloth, which represents the habit of cleaning glasses with a piece of the clothing. The steep descent of the haze curve clearly indicates that the cleaning efficiency of a microfibre cloth by far exceeds the cleaning efficiency of a standard cotton cloth (see Figure 7).

The setup also allows the cleanability of lenses from different suppliers to be compared. FSV lenses from the suppliers ZEISS, C1 and C2 were sourced and tested. No differences in the cleanability were detected, as is shown by the results for a cotton cloth in Figure 8. This is of special interest as supplier C1 claims the highest contact angle for water, which should result in better cleanability.

How do lens wearers assess lens cleanability

Besides laboratory testing of the cleanability of ophthalmic lenses, it is also of particular interest to know and to understand the perception of cleanability of different lens products by spectacle lens wearers.
In a study[3], 50 participants (single vision lens wearers, same lens frame type for all spectacles) received four different pairs of glasses sequentially for one week. Each pair had to be worn for one week and was then replaced by the next pair. Each different pair of glasses had lenses from a different lens manufacturer, designated here as ZEISS$_{Rx}$, ZEISS$_{FSV}$, C1 and C2. All the lenses were finished single vision lenses coated with the respective top-tier coating (as of July 2017).
For each of these pairs, the participants had to rate their impression of the lenses' cleanability in accordance with a rating system of between 1 (best) and 6 (worst) using their habitual cleaning approach. For all four different lens types, wearers provided the same, statistically significant feedback: the cleanability received an average rating of 2, which shows general consumer satisfaction with respect to cleanability for lenses with a top-tier coating independent of the manufacturer. The distribution of answers for the lenses is shown in Figure 9.

Technical parameters related to lens cleaning used in lens marketing

In the previous sections, the data presented show that, in laboratory testing and in assessment by lens wearers, no differences in the cleanability of the top-tier coating products from different lens manufacturers can be detected. This is a result of the fact that the basic technology for Top Coatings on AR-coated lenses is fairly similar independent of the lens manufacturer.

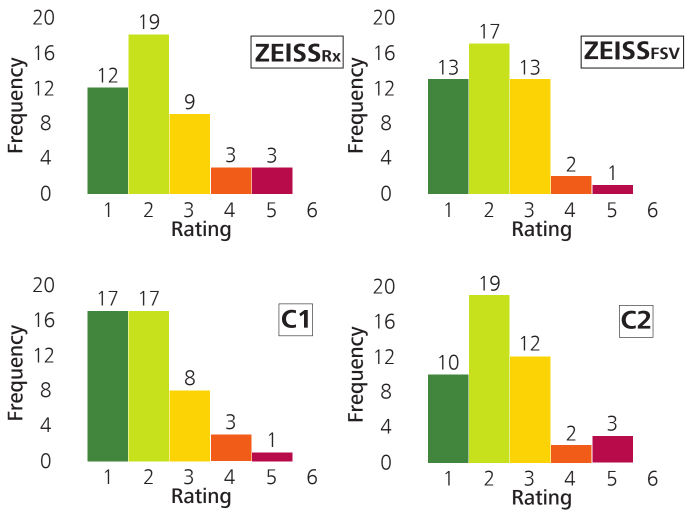

Figure 9: Distribution of results for lenses ZEISS$_{RX}$, ZEISS$_{FSV}$, C1 and C2 as rated by lens wearers (rating: 1 best; rating 6: worst).

In the sales literature from different lens manufacturers, reference is made to the water contact angle. This is a measure of a lens surface's wettability with water and measures the angle a water droplet forms on the surface. A typical picture can be seen in Figure 2. The higher the angle, the less water wets the lens surface. In much of the sales literature, this is attributed to superior lens cleanability. Making reference to the water contact angle alone, however, is only part of the story. As we showed in the sections above, facial grease is the substance which must be considered as a lens contaminant when discussing lens cleanability. A technical measure of how well a lens coating repels facial grease (and therefore reduces the tendency of a lens surface to become soiled) is not the

contact angle of water (water is a high surface tension liquid). Rather, it is the contact angle of hexadecane, a low surface tension liquid which is much closer in its wetting behaviour to facial grease than water.
In Table 1, we show the data measured on stock lenses coated with the top-tier coating from different lens manufacturers. It can be easily seen that higher contact angle data for water measured on the lenses does not automatically result in higher contact angles for the low surface tension liquid hexadecane, a liquid that more closely approximates facial grease.

Product	***CA water***	***CA hexadecane***
ZEISS	110°	68°
C1	116°	68°
C2	110°	68°
C3	117°	67°

Table 1: Comparison of contact angle data (initial state).

The data shown on Table 1 were measured on unused lenses. As lens cleanability is important for the lens wearer over the full period of use for lenses, the durability of the Top Coat treatment is of equal importance.
The most common approach to simulate the real-life stress for the Top Coat treatment on a lens surface is to subject the lens surface to a high number of wipes with a cloth. The procedures implemented by different lens manufacturers differ in terms of the type of cloth, the pressure during wiping and the number of wipes. To assess the durability of a Top Coat treatment, the contact angle of water is an appropriate probe, as it drops significantly when the Top Coat is removed. In Table 2, we show the results of stock lenses coated with the top-tier coating from different lens manufacturers regarding the durability of their top coating treatment. It can be seen that especially those lens treatments with a high initial contact angle are not as durable and long-lasting than those with an initial contact angle of 110°.

Product	***Initial***	***800 cycles***	***3200 cycles***	***6400 cycles***
ZEISS	110°	106°	106°	105°
C1	116°	83°	*NA**	*NA*
C2	110°	106°	106°	105°
C3	117°	96°	*NA*	*NA*

*Table 2: Comparison of contact angle data for water as a probe for the Top Coat durability for unused lenses (initial) and after different numbers of abrasion cycles. *NA: Testing stopped once contact angle < 100°*

Summary and outlook

The data presented in this review indicate that the top tier coatings from different lens manufacturers are on par regarding the ease of cleaning. This is demonstrated by a newly developed laboratory cleaning test as well as by a wearer trial, in which lens wearers gave ratings for different lens products with respect to cleaning using their regular cleaning habits. This finding is not surprising as the basic technology used is very similar independent of the lens manufacturer.
Differences in the water contact angle of unused lenses as advertised by some lens manufacturers do not indicate a better cleaning behaviour, but are rather only a technical measure. The durability of the Top Coat treatment is of greater importance. As the soiling of lenses during wearing will never be fully avoided, the future task in the development of lens coatings needs to further reduce the hassle of lens cleaning by making significant progress in the Top Coat treatments that goes far beyond an increase of a few degree in the water contact angle.

Source

[1] Bastian Stoehr, Colin Hall, Drew Evans, and Peter Murphy ACS Appl. Mater. Interfaces, 2016, 8 (28), pp 18534–18539

[2] Colts Laboratories. Test catalogue can be found at http://www.colts-laboratories.com/testing-services/catalog/

[3] Sandra Kaefer „ZEISS DuraVision® Platinum Clean-Coat im Wettbewerbsvergleich" March 2018, Hochschule für Technik und Wirtschaft Aalen

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