

Crizal® Sapphire™^{HR}

**The research behind
the best anti-reflective
coating overall¹**



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1. External laboratory tests and internal technical tests - 2020. Compared to the competitor most known lens-brands by consumers (2019 external brand tracking in 11 countries). The word 'overall' refers to anti-reflective coatings important criteria, ranked through an external quantitative consumer study - 2019.

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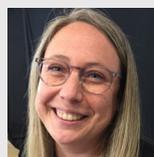
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INTRODUCTION

The Crizal® Sapphire™ HR coating is the new premium generation of anti-reflective coating from Essilor®. Building on Crizal®'s promise in protecting eyes and lenses, it aims to answer all of eyeglass wearers' needs without any compromise thanks to the finest Crizal® lenses technologies combined in one coating.

For this new Crizal® innovation, Essilor® researchers took a holistic approach to develop comprehensive protection against visible and invisible factors that harm vision. The resulting Crizal® Sapphire™ HR coating combines all of Crizal®'s benefits (i.e. 360° reduction of reflections, ease of cleaning, dust and water repellency and UV protection) with a strong improvement on scratch resistance and durability. This all-in-one solution allows the lenses to stay clear and clean in the long run².

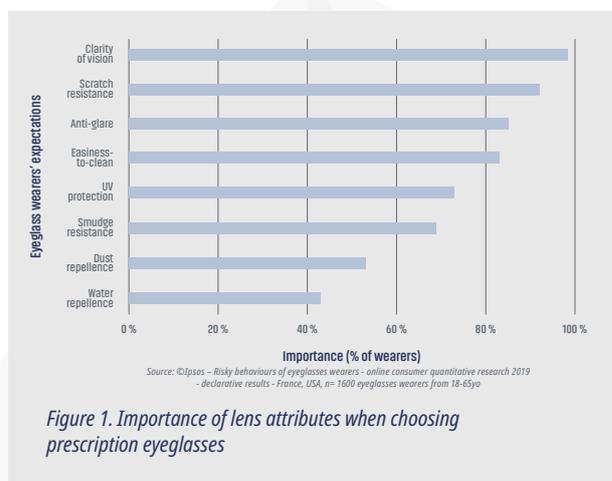
Keywords: Crizal® Sapphire™ HR coating, transparency, durability, 360° Multi-Angular Technology™, High-Resistance Technology™, High Surface Density Process™.

THE CONTEXT

1. The influence of the ever-changing environment and unconscious behaviors on lenses

The eyes are powerful. Vision is by far the most dominant human sense. Indeed, people experience the world and discover what life is about largely through their eyes. The implications of this are significant for eyeglass wearers: their lenses can not only alter the way they see but also the way people see what their eyes intend to express.

Keeping the lenses from being scratched, reflecting light or being stained can be a constant battle for eyeglass wearers. This is why when it comes to choosing the features their next pair of eyeglasses should have, people don't want to compromise on clarity, resistance, ease of care and protection (Figure 1).



Light pollution – defined as excessive, misdirected or obtrusive artificial light – and outdoor air pollution are the consequences of urbanization. Combined with unconscious behaviors, these phenomena lead to reflections, scratches or even smudges that alter the transparency of the lens overtime.

Many people feel they are constantly exposed to different types of artificial light, and more often than not it is either unwanted or uncontrollable, coming from diverse sources and from all directions.

A total of **80%** of wearers experience reflections when indoors or outdoors³.



Unintended actions can also damage the lenses when repeated. The wearer will automatically want to clean the lenses if they are covered with smudges, dust or water. Moreover, when eyeglass wearers wipe their lenses with a T-shirt, a tissue or a towel, scratches can appear on them. In addition to being inaeesthetic, they cannot be removed.

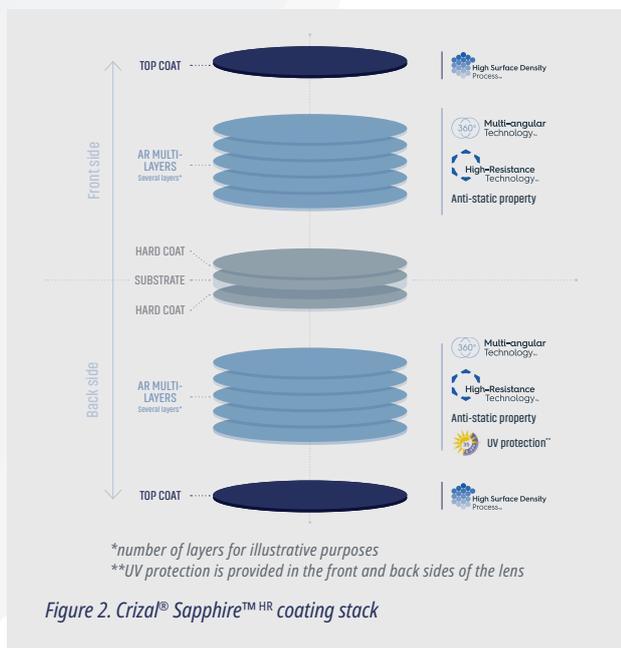
Eyeglass wearers need their lenses to be kept transparent throughout the day, regardless of what they are doing or the environment they are in.

THE APPROACH

2. Finding the perfect combination of the best Crizal® technologies

More than ever before eyeglass wearers were at the heart of the development of Crizal® Sapphire™ HR. Essilor® researchers aimed for no compromise when developing this highly transparent and durable anti-reflective coating.

They screened more than 250 million possible configurations using a simulator that combines big data with deep algorithms to find the most powerful structure able to combine all of the best Crizal® technologies in one coating (Figure 2).



On average wearers wipe their lenses **20,000** times before replacing them⁴.



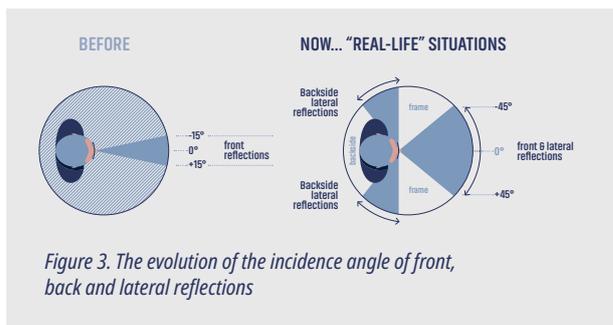
A total of **47%** of wearers renew their lenses because of scratches and wear⁵.



• Anti-reflective efficiency

First and foremost, Crizal® Sapphire™ HR has to possess the right reflection color and a good angular reflection to achieve high anti-reflective efficiency.

On top of this, Essilor® researchers have capitalized on research from 2017 when Essilor® first rethought the way anti-reflective coatings were designed to reach a high level of transparency. At that time, they found that anti-reflective coatings were developed to be efficient around the normal incidence direction. The latter is typically below $\pm 15^\circ$, as required by international ophthalmic standards to be considered anti-reflective (ISO 8980-4 norm [1]). However, this does not match real-life situations. A different approach has since been applied, with reflections being considered in a wider angular range and lateral and back reflections taken into account (Figure 3). Based on this analysis, Essilor® introduced the **360° Multi-Angular Technology™**, an embedded SiO₂ nanolayer in the anti-reflective multi-layers.



The same technology has been incorporated along with several other nanolayers within the Crizal® Sapphire™ HR structure to work together in achieving multi-angular efficiency against light pollution.

3. GfK - online consumer quantitative research 2016 - declarative results - USA, Spain, India, n=2406 wearers from 25-65yo.

4. Essilor® Estimations - France, USA, India - based on the following: average number of times cleaned/week, number of times wiped, «wipe» corresponding to a one-way cleaning motion, and eyeglass replacement rate.

5. ©Ipsos - Risky behaviours of eyeglasses wearers - online consumer quantitative research 2019 - declarative results - France, USA, n= 1600 eyeglasses wearers from 18-65yo.

The multi-angular alpha (α) criterion, defined from an integral in the angular range (0° - 45°), is used to quantify the overall anti-reflective efficiency whatever the light direction. Its measurement includes the luminance reflectance factor R_v , used in international standards to indicate light intensity reflected by the lens, as perceived by the human eye (Figure 4).

$$\alpha = \int_0^{45^\circ} R_v(\theta) \sin(\theta) d\theta$$

θ is the incident angle of light

Figure 4. The multi-angular criterion

• UV protection

The eyes are constantly exposed to UV rays outdoors – on both sunny and cloudy days. This UV radiation can have a detrimental effect on the eyes. Lenses commonly absorb UV radiation to protect the eyes from rays on the front side of the lens of most indexes. Yet UV rays are also reflected on the lateral back sides of the lenses and directly into wearers' eyes. Since 2012, Essilor® has introduced an **E-SPF35®** index, the best index of UV protection on Crizal® clear lenses. This E-SPF® index⁶ rates the overall UV protection of a lens. It was developed by Essilor International and has been endorsed by third party experts. Crizal® Sapphire™^{HR} draws on this to provide a high level of protection for the eyes from the hazards of ultraviolet radiation, taking into account UV reflection on the back side of the lens.

$$R_{L/Hi} = \frac{\text{Thickness of the outermost LOW refractive index layer(s) of the interferential coating}}{\text{Thickness of the outermost HIGH refractive index layer(s) of the interferential coating}}$$

Figure 5. Ratio of thickness between refractive index layer

3. Redefining scratch resistance measurement

There are many abrasion tests in the optical industry (e.g. the Bayer test, the tumble test and the linear abraser test). The Bayer test⁷ is one of the most famous and is used by lens manufacturers.

Essilor® was instrumental in developing this test in the 1990s. It has become a standard for the optical industry and was set up in external laboratories in the USA.

More recently, premium anti-reflective coatings have reached such a high level of scratch resistance that the differences in ratings with the current methodology have become less meaningful.

As a result, Essilor® experts conceived a new test protocol in order to rank products according to their abrasion resistance level. This resulted in the Sand Resistance test, based on the same principle as the Bayer test but with sand used instead of alundum (a dispersive material leading to variations in results). It has a more rigorous testing protocol, with temperature and humidity storage control for all elements, including lenses, and consequently a higher reproducibility

• Ease of cleaning

Wearing eyeglasses can be a constraint if there are smudges, fingerprints or drops of water on the lenses.

The **High Surface Density Process™** present in the top coat of Crizal® Sapphire™^{HR} works efficiently to repel water and oil off the lenses while making sure they are easy to clean. With this Essilor® technology, both sides of the lens are densely packed with fluorinated molecules.

• Scratch resistance

Essilor® researchers have found the best stack composition to improve the durability of the lens.

With Crizal® Sapphire™^{HR}, the scratch resistance as well as the thermal resistance of the lenses have been increased thanks to the association of three components:

- An increased ratio of thickness between some of the high-index and low-index layers in the anti-reflective stack to achieve a better resistance to abrasion (Figure 5)
- An optimized process that increases the density of the final stack to ensure stronger resistance
- A stack composition that includes Essilor® **High-Resistance Technology™**, combining specific oxides known for their resistance against dust, scratches and temperature (one of these oxides is used in the aerospace industry and in electronics for its thermal resistance)

In short, Crizal® Sapphire™^{HR} combines the best Crizal® technologies to shield eyeglass wearers' eyes and lenses against the factors that harm vision.

of test results. Lastly, it makes use of a normalized haze indicator on a more linear scale to better take into account the increase in lens scratch resistance, making it easier to assess performance.

Haze is the result of light scattering through an uneven surface or material. This new criterion, the normalized haze value, is described in Figure 6.

$$\Delta H \text{ test nor } (\%) = \Delta H \text{ test cor. } \Delta H \text{ ref } 0 / \Delta H \text{ ref}$$

Figure 6. Normalized haze value criterion

The ΔH corresponds to the difference in haze of the lens before and after 300 cycles of abrasion. The " ΔH test cor" takes into account the lens curvature. The " ΔH test nor" corresponds therefore to a "normalized" haze difference, taking into account the UNCOATED reference lens ("ref", where the initial value is taken at 13% to normalize the value and enable comparison).

6. It relates to lens performance only and excludes direct eye exposure that depends on a wearer's morphology, frame shape and the position of wear.

7. The Bayer test is a repetitive friction abrasive test of a reference uncoated lens together with a tested coated lens. See Frenette, B., & Lucea, V. (2010), "Relative usefulness of the Bayer ratio as an indicator of the hardness of different coatings", *Canadian Journal of Optometry*, 72(6), 16, <https://doi.org/10.15353/cjo.72.606>

PERFORMANCE

4. A compilation of technical and consumer tests

Lenses are subject to different unpredictable situations on a daily basis: reflections, risk of scratches, traces of smudges and everyday life risks. Real-life situations and extreme testing will therefore provide an indication of how the anti-reflective coating will react to protect the lenses and the eyes of eyeglass wearers in all circumstances.

To ensure Crizal® Sapphire™ HR provides the highest possible performance a Crizal® coating can offer, Essilor® researchers developed the **Crizal® Lifeproof multi-test** – a thorough protocol of tests which assess the resistance of the lenses to eyeglass wearers’ hectic lives.

4.1. Proven enhanced durability

To test the resistance of Crizal® Sapphire™ HR, Essilor® researchers conducted a combination of technical and wearer tests.

The **Sand Resistance Test** assesses the resistance of the lenses against scratches. By pushing this test protocol and extrapolating from the results, we can compare products’ resistance.

Compared to the previous generation, Crizal® Sapphire™ HR is up to 70% more scratch-resistant (Figure 7).⁸

After 300 sand shake cycles in the test, Crizal® Sapphire™ 360° reaches a haze level close to 2% in terms of diffusion of light. Crizal® Sapphire™ HR requires more than 500 shakes (+70%) to reach this same level.

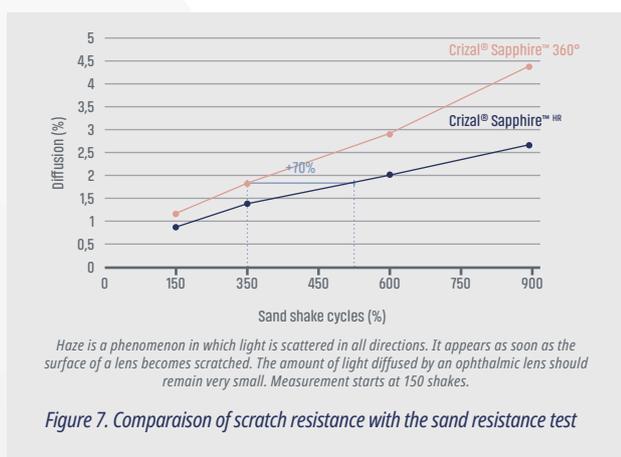


Figure 7. Comparison of scratch resistance with the sand resistance test

Lenses are cleaned on average 20,000 times over a typical two-year life span of a pair of eyeglasses.⁹ The **Stain Release Test**, a standardized test run in an external laboratory in the US, reproduces the lenses’ life span in terms of cleaning cycles to measure ease of cleaning after extensive smudging. This test consists of wiping the lens 5,000 times, dirtying them, cleaning them and then repeating the process four times for a total of 20,000 wipes.

Lens transmission loss is then evaluated. Crizal® Sapphire™ HR lost three times less transmission than competing lenses. (Figure 8). It is therefore 3 times easier to clean after extensive smudging than premium competitors¹⁰.

Above all, it is important to test the long-term resistance of Crizal® Sapphire™ HR in real-life conditions. To do so, Essilor® conducted a **durability wearer test** for 18 months to assess the long-lasting resistance of the lenses in real-life situations.

A total of 35 eyeglass wearers in France were recruited and equipped with a pair of eyeglasses, each with one Crizal® Sapphire™ HR lens and one from a previous Crizal® generation¹¹.

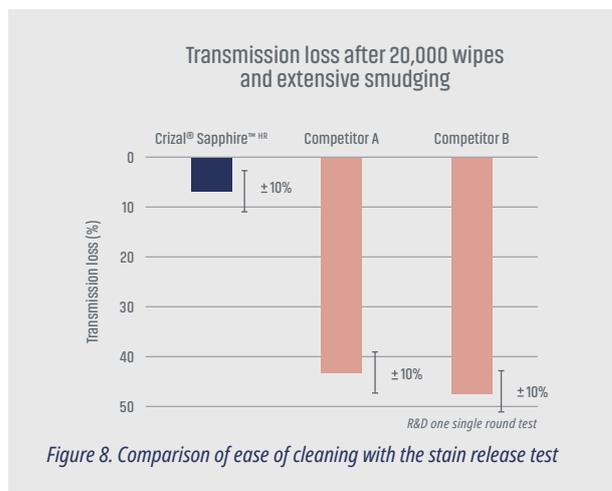


Figure 8. Comparison of ease of cleaning with the stain release test

Essilor® experts assessed the lens regularly. As scratches can appear all over the lens and vary greatly (e.g. deep scratches vs. multiple nicks), it is not enough to assess the average transmission of a lens. Given this, Essilor® experts have drawn a seven-point scale to assess scratches on lenses based on detailed analysis of more than 10,000 lenses over the past 20 years.

After six months of wear, Essilor® experts detected significant differences between the two products – and this trend is constant.

Crizal® Sapphire™ HR has significantly better scratch resistance than the previous generation (Figure 9).

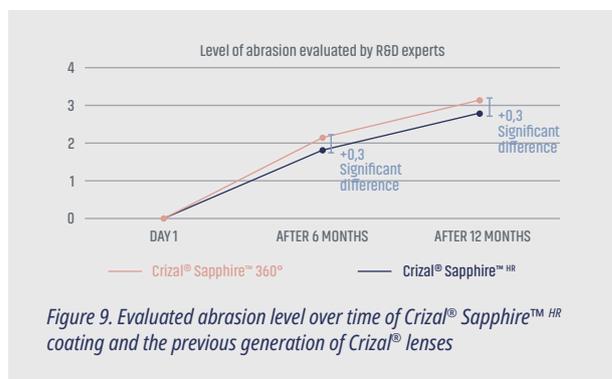


Figure 9. Evaluated abrasion level over time of Crizal® Sapphire™ HR coating and the previous generation of Crizal® lenses

4.2. Measured and perceived transparency

Consumers look for lenses that can reduce reflections efficiently when they choose a pair of eyeglasses.

To measure Crizal® Sapphire™ HR’s performance when it comes to reflections, researchers conducted a **multi-angular reflection measurement**. With the use of a spectrophotometer, the spectrum of the reflected light that is modified by the anti-reflective coating is analysed on the convex and concave side of the lens in the angular range from 0° to 45°.

The result was Crizal® Sapphire™ HR has the same anti-reflective efficiency when compared to the previous generation⁸.

Because what consumers perceive is paramount, Eurosyn, a third independent party institute in France, carried out a study using **sensory analysis methodology**. This applies principles of experimental design and statistical analysis to the use of the five senses to evaluate consumer products. Panels of trained consumers test the products under controlled conditions, and their responses are recorded.

8. Internal R&D measurement – 2020 – compared to Crizal® Sapphire™ 360°.

9. Essilor® Estimations - France, USA, India - based on the following: average number of times cleaned/week, number of times wiped, «wipe» corresponding to a one-way cleaning motion, and eyeglass replacement rate.

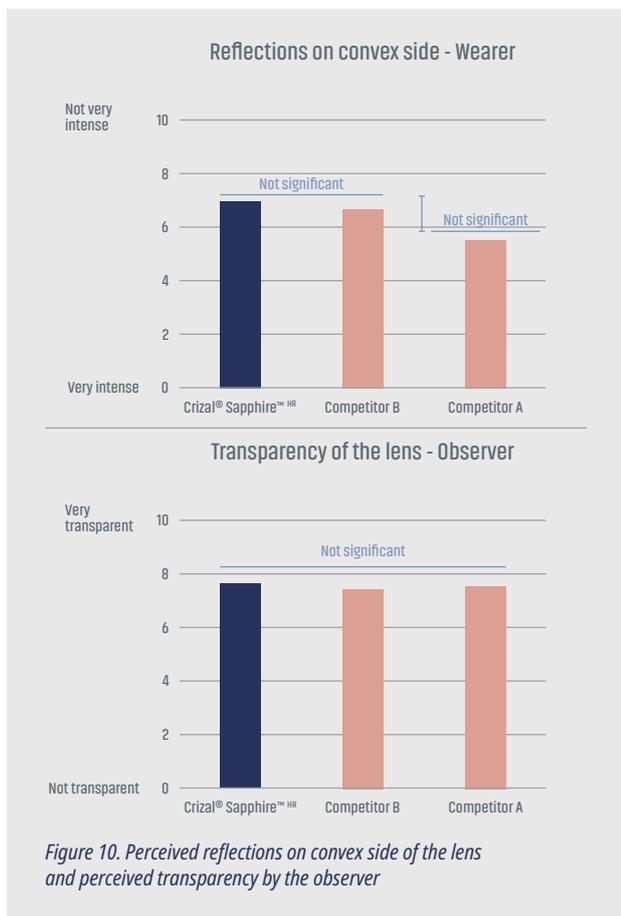
10. External laboratory test - 2020 - compared to the competitor most known lens-brands by consumers (2019 external brand tracking in 11 countries).

11. Essilor® R&D wear test - 2020 - n=35 eyeglass wearers - abrasion level on a seven-point scale (from 0 to 6), significant difference between Crizal® Sapphire™ HR and Crizal® Sapphire™ 360° with statistical student test.

The aim is to translate consumer perception into words (attributes) and correlate them to the product's measurable physical properties.

Essilor® was the first in the ophthalmic industry to use sensory analysis to assess the efficiency of its new lenses. In the context of the Crizal® Sapphire™ HR coating, a variety of attributes were assessed by trained experts panelists: front reflection, backside reflection, transparency, ease of cleaning, etc.

The results show that Crizal® Sapphire™ HR offers best-in-class transparency, compared to the competitors most known lens-brand by consumers¹² (Figure 10).



4.3. Pushing the lenses to their limit

To further demonstrate the tangible benefits offered by Crizal® Sapphire™ HR, a new approach of testing has been set-up. A real-life test was conducted with eyeglass wearers and under the supervision of a judicial officer. It consisted of comparing and demonstrating the performance of Crizal® Sapphire™ HR and a standard anti-reflective coating in six successive tasks inspired by real-life situations. Through this protocol, performance was assessed in terms of dust and water repellency, smudge resistance, ease of cleaning, anti-reflective efficiency and scratch resistance.

Six participants were equipped with a pair of eyeglasses with one Crizal® Sapphire™ HR lens and one standard anti-reflective lens (Figure 11).

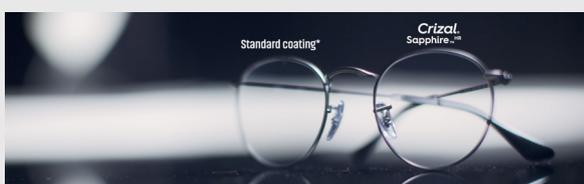
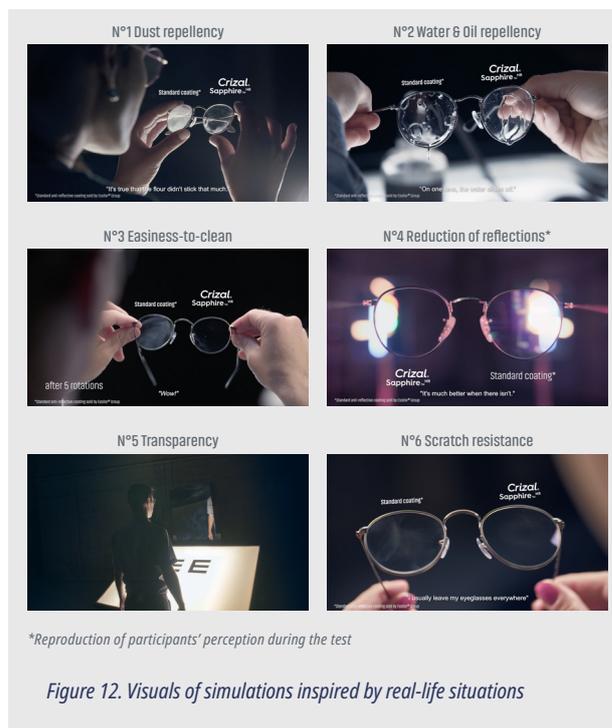


Figure 11. Illustration of the tested eyeglasses

Without knowing which was the Crizal® Sapphire™ HR lens, participants had to carry out certain tests, such as rubbing the lenses with steel wool or soaking them in a bowl of oily water. They were asked to assess the performance of both lenses after each test (Figure 12).



Overall, eyeglass wearers showed strong enthusiasm for the performance of Crizal® Sapphire™ HR in all tests (Figure 13). The statement of facts drawn up by the judicial officer mentioned visible differences in performance for the untrained human eye in all six situations evaluated.

Consumer testimonials

“The smudging went away in just one wiping.”

“It’s quite magical to see because the water takes more time to slide off the other lens.”

“I don’t see any light reflected on the lens. It’s impressive.”

“I really had the impression that a lens was more transparent than the other one.”

“Clearly, we see the difference.”

“I see a quality lens.”

“I have more confidence with this lens which has not been scratched at all despite the intensive scraping I tried to do.”

“It’s quite impressive. The left lens is completely damaged. It looks like I did nothing on the right lens.”

Figure 13. Consumer testimonials after performing the tests

12. Perceived transparency based on in-lab trained consumers study – 2021 – third independent party – FR – (n=15 trained consumers) - compared to the competitor most known lens-brands by consumers (2019 external brand tracking in 11 countries)

CONCLUSION

Essilor® researchers have taken a leap forward in the anti-reflective coating industry by successfully combining the best performance of the finest Crizal® technologies to develop Crizal® Sapphire™^{HR}, the best anti-reflective coating overall¹³.

This new generation of Crizal® takes into account light pollution, unintentional behaviors and the unpredictable environment that eyeglass wearers face on a daily basis.

It protects the eyes and lenses by reducing reflections of light around the wearer and combining high resistance against scratches and smudges with optimal protection against dust, water and UV rays.

In a word, Crizal® Sapphire™^{HR} is designed to provide wearers with lens transparency that stands up to the ultimate test – that of everyday life.

13. External laboratory tests and internal technical tests - 2020. Compared to the competitor most known lens-brands by consumers (2019 external brand tracking in 11 countries). The word 'overall' refers to anti-reflective coatings important criteria, ranked through an external quantitative consumer study - 2019

KEY TAKEAWAYS

- Every eyeglass wearer has different needs and expectations.
- Essilor® researchers have developed a powerful coating that associates the finest of Crizal® breakthrough technologies and is adapted to all lifestyles.
- Crizal® Sapphire™ HR is the best anti-reflective coating overall¹³.
- A Crizal® lifeproof multi-test demonstrated its performance in daily and extreme situations.
- Crizal® Sapphire™ HR holds the promise of transparency, durability, ease of care and UV protection for both the eyes and lenses.

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[1] International standard ISO 8980-4. Ophthalmic Optics-Uncut finished spectacle lenses-Part 4: Specifications and test methods for anti-reflective coatings.

