

## A Comparative Study on Selected Optical Parameters of Ophthalmic Lenses

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### Article Info

Research article  
Received: 09/12/2025  
Revision: 01/02/2026  
Accepted: 02/02/2026

### Keywords

Abbe Number  
Refractive Index  
Brewster Angle  
Transmittance  
Optical Glass

### Makale Bilgisi

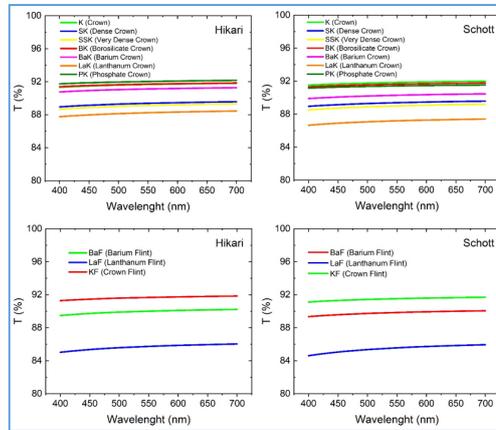
Araştırma makalesi  
Başvuru: 09/12/2025  
Düzeltilme: 01/02/2026  
Kabul: 02/02/2026

### Anahtar Kelimeler

Abbe Sayısı  
Kırılma İndisi  
Brewster Açısı  
Geçirgenlik  
Optik Cam

### Graphical/Tabular Abstract (Grafik Özet)

A comparative analysis of Hikari and Schott ophthalmic glasses evaluates refractive index, Abbe number, transmittance, and Brewster angle. Results demonstrate intrinsic trade-offs: increasing refractive index enhances Brewster angle but reduces transmittance and chromatic performance, providing a practical framework for application-oriented ophthalmic lens material selection. / Hikari ve Schott oftalmik camlarının karşılaştırmalı analizinde kırılma indisi, Abbe sayısı, geçirgenlik ve Brewster açısı değerlendirilmiştir. Sonuçlar, kırılma indisi arttıkça Brewster açısının yükseldiğini ancak geçirgenlik ve kromatik performansın azaldığını göstermekte ve uygulama odaklı oftalmik lens malzemesi seçimi için pratik bir çerçeve sunmaktadır.



**Figure A:** Comparative transmission spectra of Hikari and Schott ophthalmic glasses in the visible region. / **Şekil A:** Hikari ve Schott oftalmik camlarının görünür bölgede karşılaştırmalı geçirgenlik spektrumları.

### Highlights (Önemli noktalar)

- Comparative analysis of key optical parameters of ophthalmic glasses. / Oftalmik camların temel optik parametrelerinin karşılaştırmalı analizi.
- Unified evaluation of refractive index, Abbe number, transmittance, and Brewster angle. / Kırılma indisi, Abbe sayısı, geçirgenlik ve Brewster açısını birleşik değerlendirilmesi.
- Framework proposed for application-oriented lens material selection. / Uygulamaya yönelik lens malzemesi seçimi için bir çerçeve önerilmiştir.

**Aim (Amaç):** This study aims to comparatively evaluate key optical parameters of commercially available ophthalmic glasses from different manufacturers. / Bu çalışma, farklı üreticilere ait ticari oftalmik camların temel optik parametrelerini karşılaştırmalı olarak değerlendirmeyi amaçlamaktadır.

**Originality (Özgünlük):** The study presents a unified and simultaneous assessment of refractive index, Abbe number, transmittance, and Brewster angle to enable application-oriented material comparison. / Çalışma, kırılma indisi, Abbe sayısı, geçirgenlik ve Brewster açısını eş zamanlı ve bütüncül bir yaklaşımla analiz ederek uygulama odaklı bir malzeme karşılaştırması sunmaktadır.

**Results (Bulgular):** The results reveal clear trade-offs between refractive index, chromatic dispersion, transmittance, and polarization behavior across Hikari and Schott glasses. / Elde edilen sonuçlar, Hikari ve Schott camları arasında kırılma indisi, kromatik saçılma, geçirgenlik ve polarizasyon davranışı açısından belirgin ödünleşimler olduğunu göstermektedir.

**Conclusion (Sonuç):** No single glass type optimizes all optical parameters simultaneously. Therefore, ophthalmic lens material selection must be guided by application-specific requirements that balance visual comfort, optical performance, and design constraints. / Hiçbir cam türü tüm optik parametreleri aynı anda optimize etmemektedir. Bu nedenle oftalmik lens malzemesi seçimi, görsel konfor, optik performans ve tasarım gereksinimleri arasında dengeli bir değerlendirmeye dayanmalıdır.



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### Abstract

This study presents a comparative analysis of the optical properties of ophthalmic lenses manufactured by different commercial producers. The analysis focuses on key optical parameters—namely the Abbe number, refractive index, transmittance, and Brewster angle—which play a critical role in determining lens performance and visual quality. The Abbe number describes chromatic dispersion and color fidelity, while the refractive index quantifies the degree of refraction of light within the lens material. Transmittance measures the efficiency of light transmission through the lens, and the Brewster angle is the angle of incidence at which polarized light is transmitted without reflection. By systematically examining these parameters, the study highlights their influence on lens material selection, optical performance, and suitability for various ophthalmic applications. The results provide a practical, well-defined framework for informed lens material selection based on visual comfort, optical clarity, and application-specific requirements. A direct comparison between Hikari and Schott glasses reveals realistic trade-offs in material design relevant to both industrial and ophthalmic applications. In particular, Hikari PK glass exhibits the highest transmittance, whereas Schott PK glass demonstrates the highest Abbe number, emphasizing the inherent trade-offs between key optical parameters across manufacturers.

## Oftalmik Lenslerin Seçilmiş Optik Parametreleri Üzerine Karşılaştırmalı Bir Çalışma

### Makale Bilgisi

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### Öz

Bu çalışma, farklı ticari üreticiler tarafından üretilen oftalmik (gözlük) lenslerin optik özelliklerini karşılaştırmalı olarak incelemektedir. Analiz, lens performansı ve görsel kalite açısından kritik öneme sahip olan Abbe sayısı, kırılma indisi, geçirgenlik ve Brewster açısı gibi temel optik parametrelere odaklanmaktadır. Abbe sayısı kromatik saçılmayı ve renk doğruluğunu tanımlarken, kırılma indisi ışığın lens malzemesi içindeki kırılma derecesini nicel olarak ifade eder. Geçirgenlik, ışığın lens üzerinden ne kadar etkin iletiltiğini değerlendirirken, Brewster açısı polarize ışığın yansıma kaybı olmaksızın iletiltiği geliş açısını tanımlar. Bu parametrelerin sistematik olarak incelenmesi, lens malzemesi seçimi, optik performans ve farklı oftalmik uygulamalara uygunluk üzerindeki etkilerini ortaya koymaktadır. Elde edilen bulgular, görsel konfor, optik netlik ve uygulamaya özgü gereksinimler doğrultusunda bilinçli lens malzemesi seçimi için pratik ve iyi tanımlanmış bir çerçeve sunmaktadır. Hikari ve Schott camları arasındaki doğrudan karşılaştırma, hem endüstriyel hem de oftalmik uygulamalar açısından malzeme tasarımındaki gerçekçi ödünleşimleri açıkça göstermektedir. Özellikle, Hikari PK camı en yüksek geçirgenliği sergilerken, Schott PK camı en yüksek Abbe sayısına sahip olup temel optik parametreler arasındaki doğal ödünleşimi vurgulamaktadır.

## 1. INTRODUCTION (GİRİŞ)

The refractive index is one of the most fundamental optical parameters for evaluating the suitability of materials in diverse optical and photonic applications [1–3]. In this context, the refractive index describes the extent to which light is bent within a material and directly influences lens thickness and optical power. The Abbe number is a

measure of chromatic dispersion and indicates the material's ability to minimize colour fringing in the visible spectrum. The Brewster angle defines the incidence angle at which reflected light is completely polarized, providing insight into polarization behaviour and reflection losses at optical interfaces. Glass has historically been the

dominant material for optical instruments and corrective eyewear due to its well-established refractive behaviour, optical clarity, and long-standing reliability. Its ability to bend light precisely has made it indispensable in classical optics. However, glass also presents inherent limitations: being inorganic, brittle, and relatively heavy, it is prone to scratching and fracture, compromising its durability and functionality in ophthalmic use [4]. These parameters were selected because they collectively govern lens thickness, chromatic performance, light transmission efficiency, and polarization-related reflection, all of which are critical factors in ophthalmic lens performance and visual comfort. Unlike previous comparative studies that typically focus on a limited set of optical parameters or generalized performance indicators, this study presents a unified, simultaneous evaluation of refractive index, Abbe number, transmittance, and Brewster angle for commercially available ophthalmic glasses, enabling a more application-oriented comparison across manufacturers.

The continuous advancement of optical devices is closely linked to the development of new functional materials. In recent decades, optical polymers have attracted considerable attention for their combination of favourable optical properties with practical advantages in manufacturing and applications. Of particular significance are polymers with high refractive indices and large Abbe numbers ( $v_D$ ) at the sodium D-line ( $n_D$ ), as these properties are critical for minimizing chromatic aberration while maintaining precise light manipulation [5,6]. Such features make polymers attractive for various micro-optics and optoelectronic applications, including lenses, prisms, waveguides, and diffraction gratings, all integral components in advanced optical systems.

Compared to inorganic glasses, polymers provide several advantages that enhance their technological appeal [7]. Their malleability allows fabrication into complex geometries via scalable processing techniques, while their lower density reduces the overall weight of optical assemblies. Polymers typically demonstrate superior impact resistance, improving robustness and safety—an especially valuable property in ophthalmic applications.

Among thermoplastic polymers, poly(methyl methacrylate) (PMMA), polycarbonate (PC), and cycloolefin polymers are widely utilized in optical device fabrication [8]. PMMA is known for its high clarity and UV stability, PC for its excellent impact resistance, and cycloolefin polymers for their low

dispersion and superior optical quality. Their compatibility with injection molding further enhances their industrial relevance, enabling efficient, large-scale production.

In contrast, thermoset polymers are often selected when dimensional stability and high optical performance are required. Poly[ethylene glycol bis(allylcarbonate)] (CR-39) remains the most notable example, being extensively used in ophthalmic lenses due to its optical clarity, lightweight nature, and abrasion resistance [9]. Other thermoset systems derived from episulfides [10], polythiols [11], and polyisocyanates [12] also contribute to optical applications, typically processed via die casting to produce high-quality, precision optical surfaces.

This study provides a unified and simultaneous evaluation of refractive index, Abbe number, transmittance, and Brewster angle for commercially available ophthalmic glasses from Hikari and Schott. By directly comparing materials from different manufacturers, the work reveals intrinsic trade-offs in optical performance and establishes an application-oriented framework for informed lens material selection relevant to both conventional corrective eyewear and emerging photonic technologies.

## 2. MATERIALS AND METHODS (MATERIALS AND METHOD)

The optical behaviour of polymeric and glass-based materials can be systematically described using classical dispersion theories. These models help to understand the fundamental interactions between light and matter and provide predictive tools for designing advanced optical materials. The Lorentz–Lorenz theory is a foundational framework for relating a material's refractive index to its molecular composition [13]. According to this model, the refractive index depends on the constituent molecules' molar refractivity and molar volume. Incorporating molecules with high molar refractivity and relatively low molar volume significantly increases the polymer's refractive index. This principle has been beneficial in developing high-refractive-index polymers for optical applications.

One notable example involves sulphur-containing polymers, in which the high polarizability of sulphur atoms substantially enhances the material's overall polarizability, thereby increasing its refractive index. These polymers are especially advantageous in thermoset-based optical systems.

In addition to refractive index enhancement, dispersion control is equally critical. Dispersion is typically quantified by the Abbe number ( $v_D$ ), which measures the variation of refractive index with wavelength and is calculated using Eq. (1) [14,15].

$$v_D = \frac{n_d - 1}{n_f - n_c} \quad (1)$$

where  $n_d$ ,  $n_f$ , and  $n_c$  represent refractive indices measured at 587.56 nm, 486.13 nm, and 656.27 nm, respectively. A higher Abbe number indicates lower chromatic dispersion, minimizing chromatic aberrations and improving color fidelity in the visible spectrum [16].

Different mathematical formulations are applied to model dispersion more comprehensively. The dispersion behavior of transparent materials such as glasses and optical polymers can be described by the Cauchy equation (Eq. (2)) [17].

$$n(\lambda) = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4} + \frac{d}{\lambda^6} + \dots \quad (2)$$

where  $a$ ,  $b$ ,  $c$ , and  $d$  are material-dependent coefficients. In practice, the first two terms are often sufficient to provide accurate results in the visible spectrum. A simplified expression of the Cauchy relation is given in Eq. (3).

$$n(\lambda) = n + \frac{n - 1}{v} \left( \frac{523.655}{\lambda^2} - 1.5168 \right) \quad (3)$$

For higher precision, the refractive index variation with wavelength is often fitted using the Sellmeier equation (Eq. (4)), which provides an accurate description of dispersion properties across a wide spectral range [18]:

$$n^2(\lambda) = \frac{b_1 \lambda^2}{\lambda^2 - c_1} + \frac{b_2 \lambda^2}{\lambda^2 - c_2} + \frac{b_3 \lambda^2}{\lambda^2 - c_3} + 1 \quad (4)$$

where  $b_i$  and  $c_i$  are empirically determined fitting parameters, this equation accurately describes the refractive index variation with wavelength. It is widely adopted in optical design and simulation.

Another important parameter is the Brewster angle, which describes the condition at which incident light is perfectly polarized upon reflection. According to Brewster's law, the tangent of the Brewster angle ( $\theta_B$ ) equals the refractive index of the medium (Eq. (5)) [19,20].

$$\tan \theta_B = n \quad (5)$$

where  $\theta_B$  is the Brewster angle and  $n$  is the refractive index of the material. At this angle, the reflected and refracted beams are orthogonal, resulting in complete linear polarization of the

reflected light. Determining the Brewster angle thus offers an additional experimental approach to evaluate the refractive index of optical materials. From an ophthalmic perspective, the Brewster angle is particularly relevant for reducing surface reflections and glare, providing important guidance for anti-reflective lens design and improved visual comfort.

The combination of Lorentz–Lorenz theory, dispersion equations (Cauchy and Sellmeier), and Brewster's law provide a comprehensive methodological framework for analyzing and designing optical materials with tailored refractive and dispersion properties.

Table 1 summarizes the key optical parameters that govern the performance of ophthalmic lenses. Each parameter provides distinct insights into how light interacts with lens materials. The Abbe number reflects the degree of chromatic dispersion, with higher values ensuring reduced chromatic aberration and sharper visual clarity. Quantitatively, Schott PK glass exhibits an Abbe number approximately 15% higher than that of Hikari PK, whereas Hikari PK glass shows about 1.2% higher transmittance. The refractive index, by contrast, defines the extent of light bending and directly influences lens thickness, aesthetics, and wearer comfort. Transmittance quantifies the proportion of light passing through the lens, affecting brightness, visual comfort, and suitability under varying illumination conditions. Finally, the Brewster angle highlights the relationship between refractive index and polarization, offering important guidance for minimizing reflection losses and glare. Collectively, these parameters form the foundation for evaluating and optimizing lens materials in ophthalmic applications. These parameters were selected because they collectively govern lens thickness, chromatic performance, light transmission efficiency, and polarization-related reflection, all of which are critical factors in ophthalmic lens performance and visual comfort.

**Table 1.** Summary of key optical parameters analyzed in ophthalmic lenses (Oftalmik lenslerde analiz edilen temel optik parametrelerin özeti)

Parameter	Definition/ Description	Importance in Ophthalmic Lenses
<b>Abbe Number</b>	Measures chromatic dispersion; higher values indicate less chromatic aberration.	Determines visual clarity and color fidelity, reduces chromatic distortion.
<b>Refractive Index</b>	Ratio of light speed in vacuum to speed in lens material; a higher index bends light more.	Enables thinner lenses with the same power, improves aesthetics and comfort.
<b>Transmittance</b>	Percentage of incident light transmitted through the lens material.	Affects brightness, visual comfort, and suitability under different lighting.
<b>Brewster Angle</b>	Angle at which reflected light is completely polarized, minimizing reflection losses.	Important for anti-reflective performance and glare reduction.

**Note:** These parameters form the basis for the comparative evaluation of Hikari and Schott glasses presented in Tables 2 and 3. For example, Schott PK glass exhibited an Abbe number approximately 15% higher than Hikari PK, while Hikari LaK glass demonstrated ~1.2% higher transmittance than Schott LaK. These differences highlight manufacturer-specific design trade-offs.

### 3. RESULTS (BULGULAR)

Tables 2 and 3 summarize the optical properties of ophthalmic glasses from two manufacturers, Hikari and Schott, including refractive index, Abbe number, Brewster's angle, and transmittance. These parameters collectively determine the suitability of glasses for various optical applications. As demonstrated in Tables 2 and 3, these values vary across glass types and manufacturers, underscoring the importance of careful material selection in lens design.

A consistent trend observed across both datasets is the positive correlation between refractive index and Brewster's angle. For example, Hikari's LaF ( $n = 1.7495$ ) exhibits the highest Brewster angle ( $60.248^\circ$ ), while Schott's LaF ( $n = 1.7440$ ) similarly shows a Brewster angle of  $60.170^\circ$ . This indicates that as the refractive index increases, the polarization angle also rises, which is particularly advantageous for applications involving polarized optics such as laser systems, polarizers, and advanced imaging devices.

Conversely, an inverse relationship is evident between refractive index and transmittance. Glasses with higher refractive indices exhibit reduced transmittance due to increased reflection losses and

intrinsic absorption. For instance, Hikari's PK glass ( $n = 1.5038$ ) demonstrates the highest transmittance (92.027%), whereas LaF shows the lowest (85.555%). Similarly, Schott's K glass exhibits the highest transmittance (91.836%), while LaF records one of the lowest values (85.743%). This trade-off highlights the need to balance refractive index and transmission efficiency based on the intended application. Lenses requiring maximum brightness and clarity, such as ophthalmic and photographic optics, benefit from higher transmittance, whereas systems emphasizing compactness and high refractive power may tolerate slightly lower transmittance.

The Abbe number further complements this analysis by providing insights into chromatic dispersion. High Abbe numbers, such as Schott's PK glass ( $v_D = 76.97$ ), indicate lower chromatic dispersion and therefore better control of color fringing. In contrast, Hikari's LaF glass ( $v_D = 34.95$ ) shows significant dispersion, which can be detrimental in applications requiring color accuracy but may be acceptable in specialized optical designs where refractive power is prioritized over chromatic correction. Quantitatively, Schott PK glass exhibits an Abbe number approximately 15% higher than that of Hikari PK, whereas Hikari PK shows about 1.2% higher transmittance.

**Table 2.** The refractive index, Abbe number, Brewster's angle, and transmittance of some glass for Hikari. Optical parameters were obtained from manufacturer datasheets and the Refractive Index Database [21] (Hikari için bazı camların kırılma indisi, Abbe sayısı, Brewster açısı ve geçirgenliği incelenmiştir. Optik parametreler, üretici veri sayfalarından ve Refractive Index Database [21] kaynağından elde edilmiştir)

<b>HIKARI</b>				
	Refractive Index	Abbe Number	Brewster's Angle (°)	Transmittance (%)
PK (Phosphate Crown)	1.5038	66.81	56.376	92.027
BK (Borosilicate Crown)	1.5168	64.11	56.604	91.702
K (Crown)	1.5182	58.91	56.629	91.663
KF (Crown Flint)	1.5235	51.54	56.719	91.519
BaK (Barium Crown)	1.5400	59.68	57.002	91.117
BaF (Barium Flint)	1.5890	48.45	57.817	89.842
SK (Dense Crown)	1.6074	56.75	58.113	89.382
SSK (Very Dense Crown)	1.6172	53.96	58.269	89.123
LaK (Lanthanum Crown)	1.6510	56.17	58.797	88.238
LaF (Lanthanum Flint)	1.7495	34.95	60.248	85.555

**Table 3.** The refractive index, Abbe number, Brewster's angle and transmittance of some glass for Schott. Optical parameters were obtained from manufacturer datasheets and the Refractive Index Database [21] (Schott için bazı camların kırılma indisi, Abbe sayısı, Brewster açısı ve geçirgenliği incelenmiştir. Optik parametreler, üretici veri sayfalarından ve Refractive Index Database [21] kaynağından elde edilmiştir)

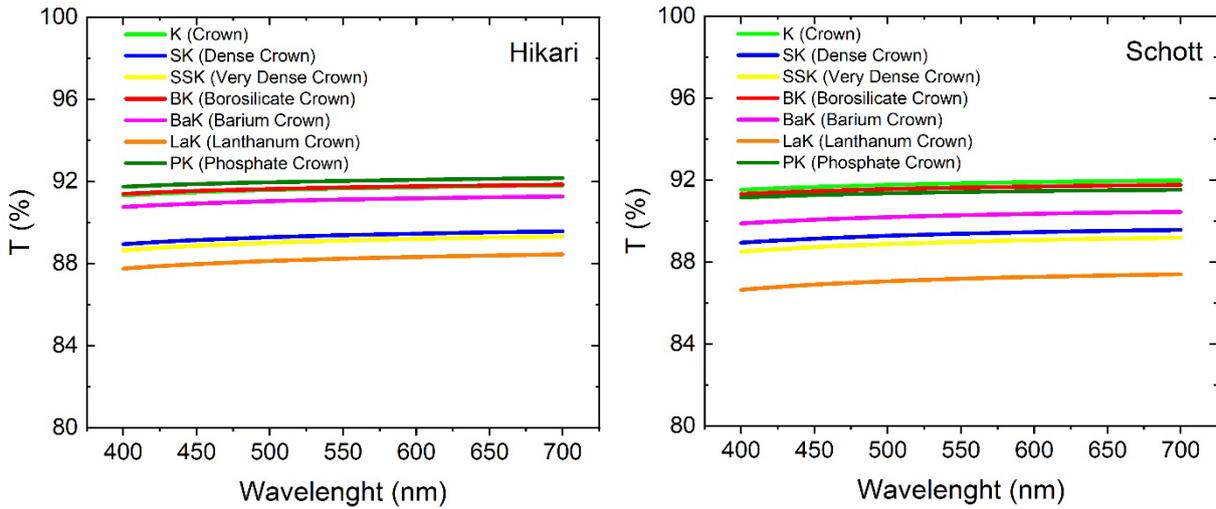
<b>SCHOTT</b>				
	Refractive Index	Abbe Number	Brewster's Angle (°)	Transmittance (%)
K (Crown)	1.5111	60.41	56.505	91.836
KF (Crown Flint)	1.5174	52.30	56.615	91.677
BK (Borosilicate Crown)	1.5197	63.58	56.655	91.623
PK (Phosphate Crown)	1.5286	76.97	56.807	91.411
BaK (Barium Crown)	1.5725	57.55	57.546	90.279
BaF (Barium Flint)	1.5827	46.48	57.713	90.011
SK (Dense Crown)	1.6074	56.65	58.113	89.375
SSK (Very Dense Crown)	1.6223	53.27	58.350	88.981
LaK (Lanthanum Crown)	1.6906	54.76	59.396	87.177
LaF (Lanthanum Flint)	1.7440	45.01	60.170	85.743

Figures 1 and 2 provide a spectral perspective of the transmission behavior. Both manufacturers' data show a gradual increase in transmission with wavelength, reflecting the general reduction of scattering and absorption losses in the visible spectrum. Notably, Hikari's PK and Schott's K glasses consistently achieve the highest transmission across the visible range, underscoring their suitability for applications demanding high optical clarity, such as ophthalmic lenses and precision windows. In contrast, high-index flint glasses (e.g., LaF and BaF) demonstrate lower transmittance, reinforcing their role in specialized optics where refractive strength outweighs transmission efficiency.

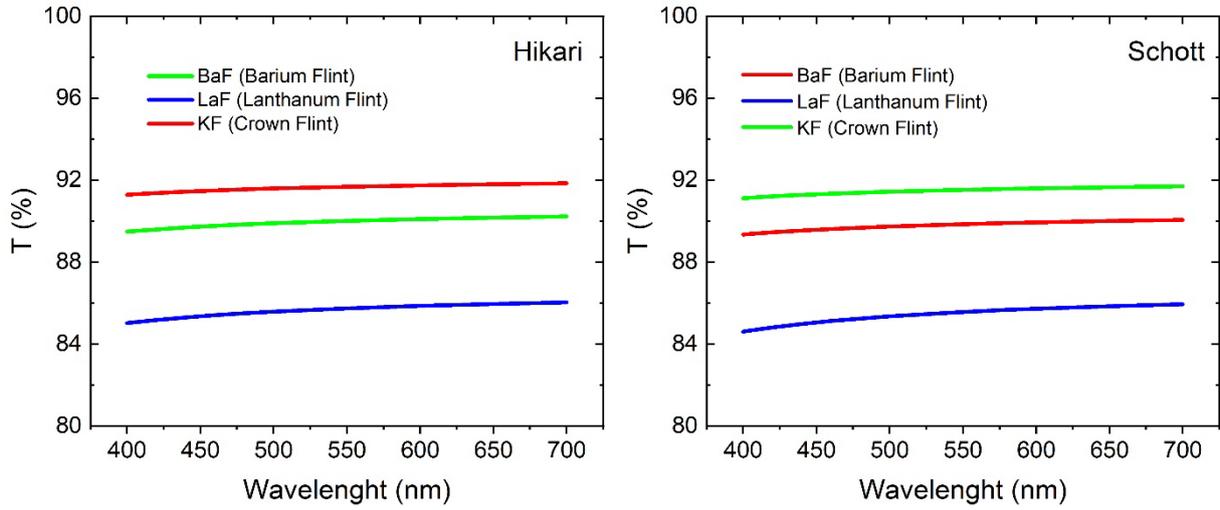
The comparison between Hikari and Schott glasses reveals that while both manufacturers follow similar trends, differences in performance metrics highlight the impact of compositional design and manufacturing techniques. For instance, Schott's

PK glass significantly outperforms its Hikari counterpart in Abbe number (76.97 vs. 66.81), suggesting optimized formulations for chromatic performance. On the other hand, Hikari's glasses show marginally higher transmission in some categories, potentially reflecting different priorities in material processing and application targeting.

The results demonstrate that no single glass type universally optimizes all optical properties. Instead, the choice of lens material must be guided by application-specific requirements: high transmittance and Abbe numbers are critical for selecting suitable ophthalmic lenses and are also relevant to broader applications such as AR/VR optics, smart glasses, and other advanced photonic devices.



**Figure 1.** Transmission spectra of crown glass samples from Hikari and Schott, illustrating the wavelength-dependent optical transmission behavior in the visible region. The figure highlights the gradual increase in transmittance with wavelength and reveals performance differences among crown-type glasses, which are critical for evaluating visual clarity, brightness, and suitability for ophthalmic lens applications (Hikari ve Schott'a ait crown cam numunelerinin geçirgenlik spektrumları, görünür bölgede dalga boyuna bağlı optik iletim davranışını göstermektedir. Şekil, dalga boyu arttıkça geçirgenliğin kademeli olarak arttığını ortaya koymakta ve crown tipi camlar arasındaki performans farklılıklarını göstermektedir. Bu farklılıklar, görsel netlik, parlaklık ve oftalmik lens uygulamalarına uygunluğun değerlendirilmesi açısından kritik öneme sahiptir)



**Figure 2.** Transmission spectra of selected flint glass samples from Hikari and Schott, showing reduced transmittance at shorter wavelengths due to higher refractive index and increased dispersion. The comparison emphasizes the trade-off between refractive power and transmission efficiency, which is particularly relevant for high-index ophthalmic lenses and specialized optical applications (Hikari ve Schott'a ait seçilmiş flint cam numunelerinin geçirgenlik spektrumları, yüksek kırılma indisi ve artan dispersiyon nedeniyle kısa dalga boylarında azalan geçirgenliği göstermektedir. Karşılaştırma, kırma gücü ile iletim verimliliği arasındaki dengeyi vurgulamaktadır; bu durum özellikle yüksek indisli oftalmik lensler ve özel optik uygulamalar açısından büyük önem taşımaktadır)

#### 4. CONCLUSIONS (SONUÇLAR)

A delicate balance between refractive index, Abbe number, and light transmittance governs the optical performance of ophthalmic lenses. While a higher refractive index enables thinner, lighter lens designs, it is generally accompanied by increased chromatic dispersion and reduced transmittance due to increased reflection and absorption losses. The comparative analysis of Hikari and Schott glasses clearly confirms these inherent trade-offs. Hikari PK glass exhibits the highest transmittance, making it advantageous for applications prioritizing visual brightness and clarity, whereas Schott PK glass achieves the highest Abbe number, offering superior chromatic performance. In contrast, lanthanum-based flint glasses from both manufacturers provide very high refractive indices at the expense of lower transmittance and increased dispersion. These results demonstrate that no single optical parameter alone is sufficient to define lens performance. Instead, the selection of ophthalmic lens materials must be guided by application-specific requirements that balance optical quality, visual comfort, and practical design considerations. From an industrial and clinical perspective, the findings offer practical guidance on material selection for ophthalmic lenses to reduce chromatic aberration, enhance visual comfort, and improve overall wearer satisfaction. Moreover, the comparative framework presented in this study provides a useful reference for lens designers,

optometrists, and manufacturers, supporting informed decision-making for both conventional corrective eyewear and emerging optical applications such as smart glasses and advanced photonic devices. The presented comparative data can therefore serve as a practical reference for guiding future ophthalmic lens material development and selection based on application-specific optical requirements.

#### DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The authors of this article declare that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarları çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

#### AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

**Mustafa SENAY:** He contributed to the conceptualization and design of the study, participated in data analysis and interpretation, and was actively involved in reviewing and revising the manuscript for important intellectual content.

Çalışmanın kavramsallaştırılması ve tasarımına katkıda bulunmuş, veri analizi ve yorumlanması süreçlerine katılmış ve makalenin önemli bilimsel içeriğinin gözden geçirilmesi ve revize edilmesinde aktif rol almıştır.

**Ismail KABACELİK:** He contributed to the conceptualization and design of the study, participated in data analysis and interpretation, and was actively involved in reviewing and revising the manuscript for important intellectual content.

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#### CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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