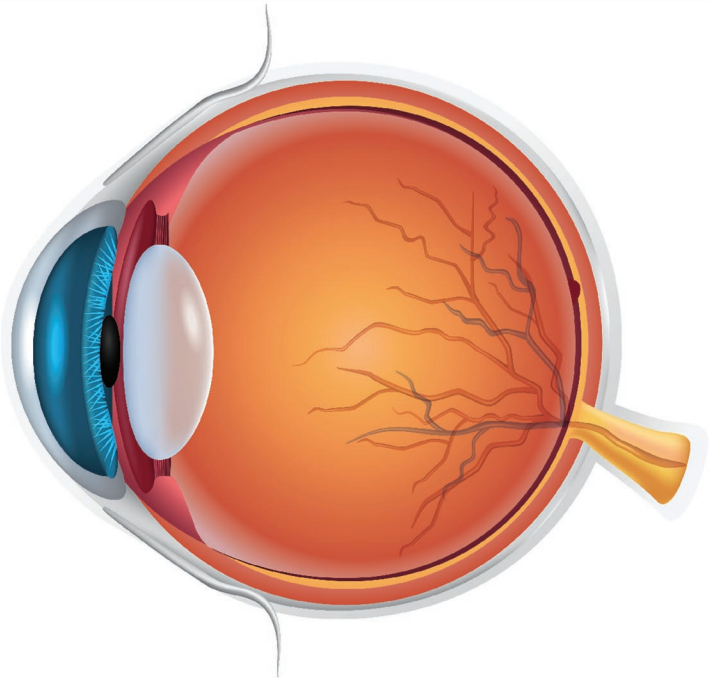
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Fundamentals of OPTOMETRY

Refraction, Dispensing Optics & Ophthalmic Procedures

Ashwani Kumar Ghai

Forewords
Rajender Singh Chauhan
Rajesh Sinha

2nd Edition

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Contents

1. Light 1
- What is Light? 1
- Ultraviolet Rays 1
- Visible Rays 2
- Infrared Rays 2
- Propagation of Light 2
- Speed of Light 4
- How do We See? 4
- Huygens' Principle 4
- Properties of Light 5
- Laser Interferometer 14
- Law of Inverse Square 15

2. Prism 16
- Prism 16
- Compounding and Resolving Prism Powers 20

3. Refraction of Light 22
- Trial Set 22
- Combination of Lenses 32
- Optics of the Eye 40
- Optical Aberrations of Lenses and Eyeball 42

4. Reflection of Light 46
- Mirror 46

5. Visual Angles and Axes of Eye 50
- Axes and Angles of Eyeball 50

6. Refractive Errors 53
- Myopia 54
- Hypermetropia 60
- Astigmatism 63
- Aphakia 67
- Pseudophakia 69
- Anisometropia 72
- Aniseikonia 74
- Amblyopia or Lazy Eye 76

7. Accommodation and Convergence 80
- Accommodation 80
- Presbyopia 83
- Convergence 85

8. Retinoscopy and Transposition 90
- Retinoscopy 90
- Transposition of Lenses 96

9. Ophthalmic Lenses 99
- Types of Ophthalmic Lens Materials 99
- Grinding of Lenses 100
- Best-form Lenses 102
- Pantoscopic Tilt 102
- Types of Lenses 103
- Trifocal Lenses 104
- Progressive Addition Lens 105
- Antireflective Coating 108
- Tinting of Lenses 109
- Photochromism 111
- Scratch Resistant or Hard Coating 113
- Water-resistant Coating 113
- Polaroid Lenses 113
- Ultraviolet Protective Glasses 113
- Balance Lens 114
- Optical Center of a Lens 114
- Ghost Images 115
- Tilting of Lenses 116
- Vertex Distance 116
- Interpupillary Distance 116
- The Prescription 117
- Special Types of Lenses 118

10. Spectacle Frames 120
- Frames 120
- Box System 123
- Spectacle Frame Materials 124

11. Headache after Using Spectacles: How to Manage? 129

12. Ophthalmic Procedures and Instruments 131
- Lens and Loupe 131
- Slit Lamp 131

- Tonometry 136
- Epilation and Electroepilation 140
- Lacrimal Syringing 140
- Fluorescein Staining 142
- Corneal Scraping 143
- Cauterization of Ulcers 143
- Esthesiometry 144
- Conjunctival Swab for Culture and Sensitivity 144
- Fundus Camera 145
- Fundus Fluorescein Angiography 146
- Placido Disk 147
- Keratometry (Ophthalmometry) 148
- Biometry 151
- Corneal Topography 157
- Pentacam 158
- Geneva Lens Measure 159
- Optical Coherence Tomography 160
- Synoptophore 162
- Ophthalmoscopy 163
- Gonioscopy 168
- Pachymeter 170
- Amsler Grid 170
- Visual Field Charting (Perimetry) 172
- Contrast Sensitivity 176
- Color Vision 177
- Ultrasound Biomicroscopy 179
- Sterilization and Disinfection 180

13. Lasers In Ophthalmology 185
- YAG Capsulotomy 185
- YAG Iridotomy 185
- Laser for Photocoagulation in Retinal Disorders 185
- Excimer Laser and Lasik Laser for Corneal Refractive Surgery 186
- Argon Laser Trabeculoplasty 188
- Role of Laser in Trabeculectomy (Under-Filtering Bleb) 188
- Laser in Treatment of Malignant Glaucoma 188
- Laser for DCR Surgery 188

14. Contact Lens Practice 189
- Nomenclature 189
- Anatomy and Physiology of Cornea 190

- Precorneal Tear Film 192
- Indications and Contraindications of Contact Lens 193
- Materials Used for Manufacturing of Contact Lens 195
- Parameters of Contact Lens 196
- History Taking for Contact Lens Fitting 197
- Fitting of Contact Lens 198
- How to Insert Soft Contact Lens? 200
- Instructions to the Patient 201
- Cleaning of Lenses 202
- Post-fitting Problems and Solution 202
- Complications of Contact Lens 207
- Contact Lens Solutions 210

Index ***211***

9 CHAPTER

Ophthalmic Lenses

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TYPES OF OPHTHALMIC LENS MATERIALS

Different types of materials are available for making ophthalmic lenses. They are:

Glass

This has been the most commonly used lens material. It is colorless, transparent, resistant to heat and scratch with good optical qualities. It is available as Crown glass (refractive index 1.523) and Flint (ref. index 1.650). Glasses of higher refractive indices are thinner and lighter than glasses of lower refractive indices, so more suitable material for high power lenses.

Photochromatic lenses darken on exposure to light and become colorless in the dark again. This is because silver chloride crystals are incorporated in the glass material, which on exposure to sunlight become darker in color. Glasses are also available in different tints, which is a permanent feature.

Chemical treatment, lamination or heat treatment makes the lens impact resistant. Chemical treatment is the best method as it gives optically good quality glasses.

Plastic Lenses or Resin Lenses

These lenses are popularly known as fiber lenses or plastic lenses. They are transparent, break-resistant, impact-resistant, lightweight with good optical qualities but prone to scratches and more costly than glass lenses. Most commonly used material is CR-39 (C stands for Columbia and R stands for resin). This material can withstand heat up to 100 °C. Its refractive index is 1.498. Chemically, it is allyl diglycol carbonate. Tints can be easily applied and changed if required later on. It is UV-absorbing lens so protects against ultraviolet radiations.

Resin lenses of higher refractive index are also available suitable for high power lenses. One can easily appreciate that if you come out of air-conditioned environment, there occurs fogging of spectacle lenses. This fogging of lenses in response to change in environment is less in resin lenses as compared to glass lenses. These lenses can be made scratch resistant by a special type of coating over the lens. They are also thicker than glass lenses so the edge of concave lenses becomes prominent.

Polycarbonate Lenses

This material is heat sensitive hence can crack in hot or cold environment, but highly impact resistant, thinnest and lightweight but prone to scratches. A special scratch-resistant coating is required. Vision around edges is distorted. Its refractive index is 1.586 thus thinner than resin lenses. It blocks both UVA and UVB rays. Tinting of these lenses is difficult. Due to their impact resistance, these lenses are suitable for stuntmen and sportspersons, persons involved in hazardous industries, children and single-eyed patients.

V-value Constringence or Abbe's Number

The degree to which the material has the same refractive index for different wavelengths of light. Lenses made with lower V values more quickly show rainbows, color fringes and degradation of best acuity when the eye turns towards the periphery of a spectacle lens, the effect being proportional to the power of lens. In simple language, it is a positive value that indicates the degree of transverse chromatic aberration. High V-value means low dispersive power and vice versa. Thus, crown glass has V-value of 59 and CR-39 has V-value of 57.8 and thus patient does not complain of colored fringes due to their low dispersive power. In contrast, high-index lenses and polycarbonate lenses have a low V-value thus high dispersive power and cause colored fringing of objects.

GRINDING OF LENSES

It is a procedure by which we convert a slab of glass (blank) into a spectacle lens with specific power. It is also known as *surfacing*. This is done by grinding the blank in such a way that curvatures

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are produced on both front and back surfaces. The difference of curvatures on both surfaces gives us the dioptric power of the lens. A wide range of tools calibrated for a specific power are required. These tools are made from cast iron and should be checked from time to time for their accuracy. Various processes involved in the making of lenses are as under **(Fig. 9.1)**.

- **Blocking:** It is a process by which a blank is fixed to the grinding machine. Gluing material is heated and applied between the blank and the platform of grinding machine. Once the material cools down; it holds the lens very tightly and grinding can be carried out easily.
- **Roughing:** It means generating the desired curvature. Surface of the blank is rotated against tool of specific curvature using sand or carborundum as abrasive powder. Thus, a blank is converted into a curved piece of glass with rough surface having approximate desired power.
- **Smoothening:** Here a proper tool with specific power is used to give accurate power to the blank. Fine abrasive material like aluminous oxide is used to grind the blank. Two grades of abrasive 302 and 303 are used one by one. Surface of the blank is trued with 302 and then with 303 to make it smoother. The end product of this process is the lens with correct power. It is ready for polishing.
- **Polishing:** A soft pad of felt cloth or wool cloth or specially designed polishing pads are attached to the tool of rough use.
- **Deblocking:** Polished lens is examined under incandescent bulb and if found satisfactory, the lens is deblocked from the metal block. The lens and the block are immersed in cold water and the block is tapped by a wooden mallet. Ice cubes may also be used to facilitate the deblocking process. Lens is cleaned with a thinner to remove any undesired particle over it.

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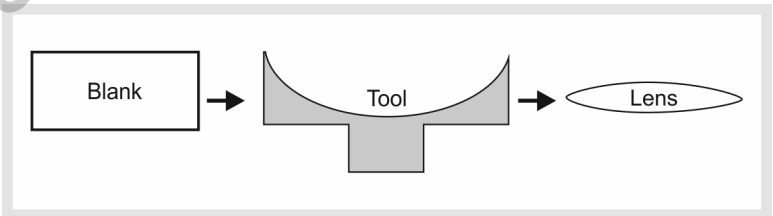


Fig. 9.1: Grinding of lens.

This process is repeated on the other surface of the lens. After each step lens and the block are cleaned properly, thickness of the lens is controlled during grinding of other surface.

BEST-FORM LENSES

An ideal lens should be free from all types of optical aberrations. The most important is that when we look through a lens obliquely, there should not be any aberration. A lens form which eliminates all these aberrations is known as best-form lens. One can easily understand that for different types of lens powers different types of base curves are required to achieve very good results. But practically this is not possible as it requires a huge stock of lenses and tools. Thus, we rely upon certain standard base curves. These base curves are:

From +7D to Plane	Base curve of –6.00D is given on back surface
From 0 to –6D	Base curve of +6.00D on front surface
From –7D to –10D	Base curve of +3.00D on front surface
From –10D to –15D	Base curve of +1.25D on front surface
From –15D to –20D	Plano front surface

A lens with a base curve of 6D is known as *deep meniscus lens* and with a base curve of 1.25D is known as *Periscopic lens*.

Minus base curve is ground on back surface for making up to +7.00D lenses and a decreasing plus base curve is ground on the front surface ranging from +6D to plano for making of up to –20D lenses. Beyond +7D to –20D powers, it is not possible to neutralize the oblique astigmatism of lenses. However, with newer techniques and advent of computers for mathematical calculations it is possible to manufacture lenses of the best forms and services have become personalized.

PANTOSCOPIC TILT

It is the angle between the plane of the lens/frame front and frontal plane of the face. Upper 180° of eye wire is farther from the frontal plane of face and the lower 180° of the eye wire is nearer to the frontal plane of face. This is about 10–12°. This is required for proper relationship of frame front and the eyebrows/cheeks of patient's face. It also gives the widest view for reading as the vertex distance of the lower half of lens is minimized.

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However, this tilt introduces some astigmatism and changes the effective power of the lens.

If the tilt is made in such a way that the upper 180° of frame comes closure to the frontal plane of face as compared to the lower 180°, it is called the retroscopic tilt.

TYPES OF LENSES

Single Vision Lenses (Monofocal)

The lenses which have same power throughout the entire surface of the lens are called single vision lenses. These lenses are used when the same prescription is used for distance and near both, e.g., young persons below the age of 40 years. They are also used when presbyopic patients require correction only for near vision or patient is not comfortable with bifocal prescription and wants to use spectacles for distance and near made separately.

Bifocal Lenses

Depending on design, they are of different types **(Fig. 9.2)**:

- Kryptok bifocal lenses
- Straight bifocal or executive bifocal lenses
- D-bifocal lenses
- Moon-shaped bifocal lenses
- Round bifocal lenses

Depending on manufacturing technique, they may be of different types:

- **Split bifocal:** It is also known as two-piece bifocal. Here two separate pieces of glass of different power are held together in a frame.
  This bifocal was invented by Benjamin Franklin. It is no more used nowadays.
- **Cemented bifocal:** A small plus lens is glued to the back of a distance prescription with a glue like Canada balsam which has the same refractive index as glass. This is used today in some low vision prescriptions which require very high additions.
  The modern variant of the cemented bifocal is the Fresnel lens which sticks in place with water or alcohol. It is used sometimes as a temporary bifocal, but it is cosmetically unappealing, expensive, and optically poor, hence not fit for permanent use.
- **Fused bifocal:** This is the most commonly used variety. Here a piece of glass of higher power with higher refractive index

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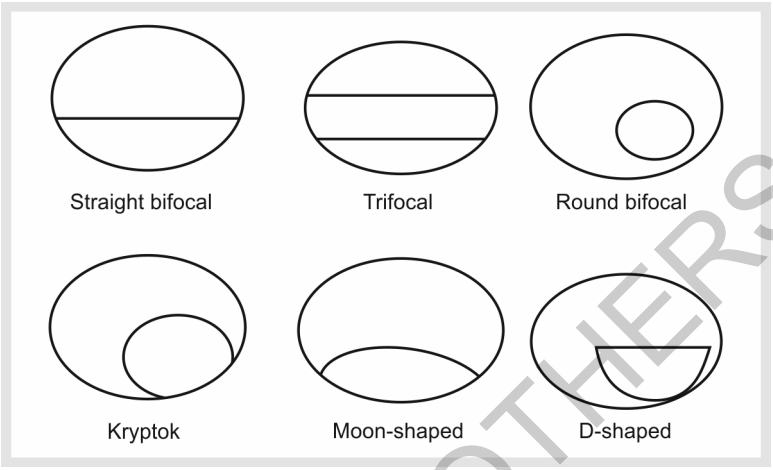


Fig. 9.2: Types of bifocal lenses.

(flint glass) is fused on the surface of crown glass. This part acts as segment for near vision. It has a good cosmetic appearance as there is no visible or palpable demarcation. An example of this type is Kryptok which means hidden in Latin.

A countersink curve is made on the front surface of crown glass with refractive index of 1.523. A button of flint glass with refractive index 1.65 with same curvature is prepared and fused on the countersink of crown glass at very high temperature of above 650°C. Since the ref. index of flint glass is higher, hence a round-shaped segment can be seen on the front surface without any palpable demarcation. Size of this round segment is between 22–26 mm. If any cylindrical power needs to be ground on the lens, it must be done on the back surface of the lens.

- **Solid bifocal:** This type of bifocal lens is made from a single material but different segments are ground with different curvatures. The line between the two segments is visible but can be made to disappear by joining the two segments with a transition zone. This is also known as one piece or seamless solid bifocals.

Trifocal Lenses

This lens has three segments for distance, intermediate (e.g., for computer) and near with different powers. Intermediate segment is 6–8 mm. This lens is no more used these days.

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PROGRESSIVE ADDITION LENS

Progressive addition lens (PAL) lens is made with power for distance at the top of lens and power for near at the bottom of lens and there is a gradual transition of power from distance to near in the intermediate segment but no line is visible so gives better cosmetic appearance. A person using PAL can view the distant objects from the topmost segment, can do computer work from the intermediate segment and do his reading work from the bottom segment. This type of lens is particularly useful for persons who need to read and type and at the same time deal with public means who need to work at near, intermediate and far distance at the same time, e.g., officers working in banks need to read the cheque no. type it and confirm on monitor and at the same time deal with the public. The presence of a bifocal segment is taken as a sign of old age so a PAL without a demarcation appears more youthful.

The disadvantage is that periphery of lens has unwanted astigmatism hence not good for vision, thus eye movements are restricted. These lenses are costly and not affordable for every person. Fitting of lens requires special care. The optical center of lens must match the pupillary center to avoid difficulty in adjustment, on axis blur and the need to adopt uncomfortable head positions. Another point to be noted in the prescription of PAL is that the frame chosen should be of good vertical height otherwise there will be a problem in adjustment. Difficulty faced by small vertical height frame is that the patient has to move his head back and forth to see clearly on a monitor. This is described as moving one's head back and forth as if he is watching a tennis match. This is particularly important if the addition required is higher like +2.00DS or more. Problems faced by a beginner during adjustment period are headache and dizziness. Answer to this adjustment problem is removing the lens for some time and reusing it again once the symptoms are over.

The *Varilux* lens was the first PAL of modern design. It was developed by Bernard Maitenaz and patented in 1953.

Designs of PAL Lenses

There are different designs of PAL lenses. They are monodesign and multidesign, asymmetry and symmetry design, and hard and soft

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design. In multidesign the position for near vision segment goes up as the power of addition increases. This is because a patient holds the reading material nearer if the addition is higher. This is not the case with monodesign hence it is considered of inferior quality. In symmetrical PAL design right and left lenses are identical. Lenses have to be rotated 10° anticlockwise in right eye and 10°clockwise in left eye for nasal decentration of near segments. This causes uneven peripheral optical features and difficulty in adjustment. Asymmetrical PAL design lenses are made separate for right and left eyes hence no need for lens rotation. This results in better optical performance, better BSV and convergence and improved visual comfort. In hard design PAL, there is small intermediate zone (called small corridor), wide distance and near zones. It is difficult to adapt. Unwanted cylindrical power is pushed towards center of the lens therefore intermediate and peripheral visions are restricted. In soft PAL design distance and near zones are relatively smaller and intermediate zone is wider (called long corridor). Power changes gradually from distance to near. Unwanted cylinder power is pushed towards the periphery. Further modifications are being done to minimize adaptive problems with PAL lenses **(Fig. 9.3)**.

Bifocal, trifocal and progressive lenses should be better avoided in old patients who are using glasses for the first time and particularly if the addition for near is considerable. This is because there is a considerable problem while looking down and climbing down the stairs. This problem is doubled up in patients suffering from vertigo

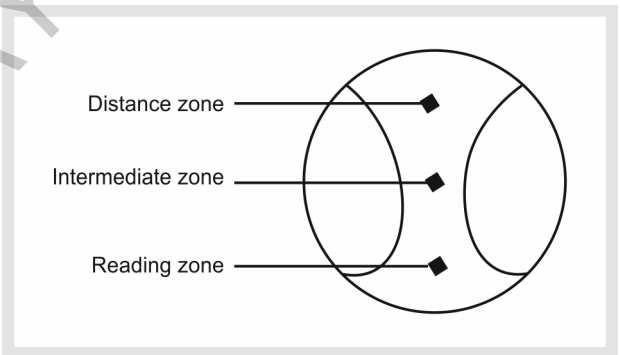


Fig. 9.3: Progressive addition lens (PAL).

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and there are high chances of patient falling down. A separate pair of glasses for distance and near vision is ideal for them.

Markings of Progressive Addition Lenses

PALs consist of two types of markings:

1. **Temporary markings include:**
   - *Distance reference circle:* It contains the distance prescription.
   - *Fitting cross:* Point which centers in front of the pupil.
   - *Prism reference point:* It marks the beginning of the corridor of the lens.
   - *Near reference circle:* It contains the near prescription.

   All these markings are removed after the fitting of lenses.
2. **Permanent markings:** Also known as microetchings. These include laser marks which depict add power on temporal side of the lens and logo of the product on nasal side of the lens. These are visible only when focused against the light.

In case of first-time wearers, following instructions need to be given in order to promote adaptability:

- Make sure the frame sets appropriately on the face and behind the ear to ensure clear vision.
- Initially, wear the spectacles for a short duration of time and adapt to various zones of vision, i.e., distance, near and intermediate.
- While walking, the floor ahead needs to be seen through distance portion and avoid viewing through near portion.
- The sides of the lens have blurry vision due to its construction. In case, the patient wants to view on the sides, he is expected to turn his head in that direction. For example, while driving if one wants to see on the sides, he has to turn his head in that direction to get clarity.
- Take some time so that you get adapted to the progressive lenses before you drive a vehicle or step up or step down a stair with progressive lenses.

Troubleshooting of Progressive Lenses

In cases of progressive lenses, the patients can report complaints. Each complaint has its own cause and solution. Most common complaints are as follows:

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Sl. No	*Complaint*	*Cause*	*Solution*
1.	Difficulty in distance vision	• Inappropriate distance refraction • Ill-fitted lenses • High-fitted lenses	• Appropriate refraction • Review prescription of lenses • Widening of nose bridge • Refit lenses
2.	Difficulty in near vision	• Inappropriate near refraction • Ill-fitted lenses • Low-fitted lenses • Inappropriate pantoscopic tilt	• Appropriate refraction • Review prescription of lenses • Narrowing of nose bridge • Change pantoscopic tilt of frame • Refit lenses

ANTIREFLECTIVE COATING

This coating is used to avoid glare faced by computer users and night drivers. When a ray of light strikes our glass of spectacles most of it enters the medium of glass but some of it is reflected back from air-glass interface which creates glare, i.e., the object appears less sharp. This problem causes trouble to persons who work on computers for long hours and drive at night.

Antireflective coating works on the principle of destructive interference, i.e., when two light waves meet in such a way that the crest of one wave falls on trough of other wave (180°out of phase), they cancel out each other. Glass is coated with a special type of coating in such a way that the light reflected from air-coating interface and coating-glass interface forms destructive interference as shown in **Figure 9.4**.

AR coating is done on both the surfaces of lens, i.e., front and back surface to avoid glare from both the surfaces of lens. It is a multilayered coating which can be done on almost all types of glasses.

Material (dielectric) for coating is chosen in such a way that its refractive index is equal to the square root of the refractive index of spectacle lens and thickness of coating material is one-fourth of wavelength of light. Now because white light is a combination of different wavelengths hence multiple coatings are required to prevent reflection of light.

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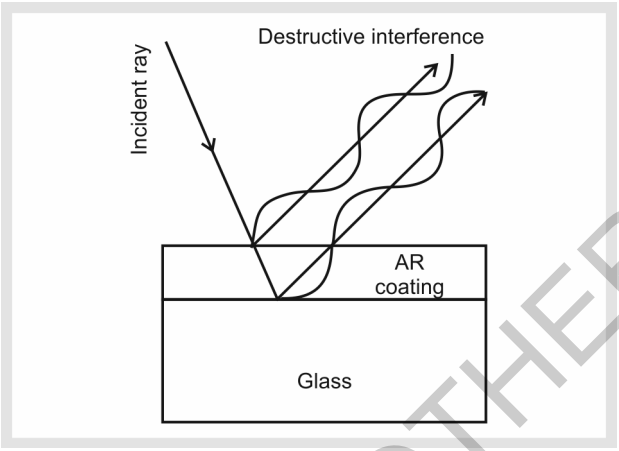


Fig. 9.4: Antireflective (AR) coating.

Advantages

It improves optical performance of lens, i.e., the wearer sees better and looks better with AR-coated glass. As maximum light passes through the lens, it improves contrast. It is very useful in persons who drive at night and use computers for long hours.

TINTING OF LENSES

This is done to decrease transmission of light through lens by making it appear colored. These lenses are used to avoid bright sunlight and sometimes for cosmetic reasons.

Different colors and shades are available for this purpose. Shades are usually expressed as a number or percentage. The percentage indicates the percentage of light transmission blocked. Persons using tinted glasses are advised not to drive at night.

Some Important Facts about Tinting

- Tint is a permanent feature in glass lenses. It cannot be changed. In resin lenses, tint can be darkened or lightened. However, if a light tinted resin lens is darkened, scratches on it become more prominent.
- It does not change its color from light to dark if exposed to sunlight.

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- Polycarbonate lenses can also be lightened or darkened but with more difficulty.
- Tints cause more reflection and transmission of light is decreased.
- A plane lens where thickness of center and periphery is equal, tint appears uniform. However, in convex lens tint is more prominent in the center and in concave lens it is more prominent at the periphery.
- Special care has to be taken if the refractive error on two sides is significantly different.
- Tinted lenses attract dust and debris, hence need cleaning more frequently.
- Red, green and yellow tints should not be used as they interfere with traffic signal interpretation.
- If both antireflective coating and tinting are required, tinting has to be done first.
- Silver or chromium coating can be applied on lenses to give the effect of mirror coating so that the patient can see everything but passersby cannot see his eyes.
- Tint can be applied in a uniform manner over the whole lens or in a gradient manner. In gradient manner, the top of the lens is tinted the darkest and gradually faded to clear at the bottom.
- The smaller the lens, the lesser are the color shade variations.

Technique of Tinting Lenses

- **Surface coating:** A deposit material is coated on the back surface of the lens to increase surface reflections. This method is used to tint glass lenses.
- **Dye tinting:** Resin lenses are tinted by this method. Lens is kept in a dye chamber bath. The dye penetrates the lens material. Polycarbonate lenses are difficult to tint. However, the hard coat over polycarbonate lenses takes up the tint.
- **Solid glass tint:** Here the material of the glass itself is being tinted by adding some special chemical to the raw material of the lenses. Different tints available in the market are:

A1 = Light blue	A2 = Deep blue	B1 = Light gray
B2 = Deep gray	SP2 = Light pink	SP4 = Deep pink
SP9 = Light brown	SP10 = Deep brown	

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Salient Features

- This book has been written keeping in mind the latest updates in the field of ophthalmology and optometry. The needs of undergraduate and postgraduate students of optometry have been kept in mind while selecting contents and language of the book.
- The syllabus of different prestigious universities like SGT University (Gurugram), Amity University, All India Institute of Medical Sciences, Regional Institute of Ophthalmology, PGIMS, Rohtak, Haryana, India, have been taken into consideration and every effort has been made to cover the relevant topics which meet the demands of the industry.
- It has been written in a very simple and self-explanatory language with to the point explanations.
- Suitable diagrams and illustrations have been given wherever necessary.
- Technical phenomena have been explained with day-to-day examples of our life.

Ashwani Kumar Ghai MS is a Senior Consultant (Eye Surgeon), having 27 years of post MS experience in the field of Ophthalmology and Optometry. He did his postgraduation from Regional Institute of Ophthalmology, PGIMS, Rohtak, Haryana, India, in 1997. Since then, he has been treating patients of different ocular diseases, performing stitchless cataract surgeries, glaucoma surgeries, squint correction, entropion correction, Lasik Laser for removal of spectacles, and other procedures related to his field. He started teaching students of Optometry in Institute of Public Health and Hygiene, Mahipalpur, Delhi, in 2002 affiliated with IGNOU, Allahabad Agricultural Institute-Deemed University, and Vinayak Mission University. He has been associated with many prestigious hospitals like Apollo Group of Hospitals, Baba Mastnath Educational Institutes, Sunder Lal Jain Hospital, Karuna Sindhu Hospital, Nazar Kanwar Surana Super Speciality Hospital, Gulabi Bagh, New Delhi, Mojiram Lions Eye Hospital, Akbarpur Majra, Delhi, and many more. He runs his own clinic in Rohini, New Delhi. He was awarded with the prestigious "Vishisht Chikitsa Ratan Award" on July 1, 2023, by Delhi Medical Association in recognition of his contributions to the medical profession. He believes that a book should be written in such simple language that it can substitute a teacher in a class. This fact is quite evident when we go through the contents of the book.

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