

White Glass Outperforms Green Float Glass in Optical Applications

Triptar Lens Company, Inc.

I. Introduction

For visual optical instruments, engineers, manufacturers, and consumers choose white, optical quality glass for its accurate color rendition and its superior image forming quality. Optical quality glass is sometimes called precision glass to distinguish it from glass used in commercial or industrial applications. “Precision” glass gets its name from the precise control of its chemical content and its very homogeneous optical properties. It also gets the name “precision” from its primary application as the material in lenses used for precision work.

Float glass is a commercial grade glass. It typically exhibits a green color. In very thin forms, up to ¼ inch thick, for example, window glass, the limited transparency and problems in chemical and optical properties fail to degrade casual viewing. In thicker forms, the problems with homogeneity and chemical impurities disqualify float glass as the raw material for precision lenses.

II. History and Manufacture of Float Glass

Glass has been manufactured and used for artistic purposes for several thousand years. High purity was not achieved until the 19th century, but artists did not really care. Artists want the colors and tints given to glass by the natural and purposeful impurities added to the glass when it is melted.

In early buildings, windows were simple holes in through the walls to the outside. Oiled animal skins, called window glazing, served to close off the holes and still allow some light to filter through to the inside. In the 17th century, thin glass started to replace oiled skins. Large balloons of glass, made by skilled glass-blowers, were sliced and gently flattened under heat to make window glazings. In the 1800’s, higher quality glass window panes were laboriously ground down to thin sections from slabs of glass that were cast in crucibles. During the 1950’s, Pilkington Glass of the UK developed a continuous melting and forming process for the architectural window markets. This kind of glass is called “float glass”.

Pilkington’s float glass is melted and floated on a molten pool of tin. Gravity flattens the layer of liquid glass into a thin ribbon of very consistent thickness. The molten glass cools to form a viscous sheet and moves onto a conveyor belt for final cooling to room temperature. The continuous nature of the process allows Pilkington to produce window glass at historically low prices. The trade-off, however, is optical homogeneity and chemical purity. Window glass does not require precisely controlled homogeneity or chemical purity because windows are typically thin.

Pilkington licensed its float glass manufacturing concept all over the world. Today, architects use traditional glass sheets only to maintain historical accuracy and appearance when restoring very old buildings.

III. History and Manufacture of Precision Optical Glass

During the 17th century, biologists and astronomers began investigating the physical world with microscopes, magnifying lenses, and telescopes. Lenses and mirrors were developed through trial and error methods. During the 18th century, melting and mixing processes were invented to produce glass of very high quality. In the 19th century, in Jena, Germany, Otto Schott and Ernst Abbe, developed the modern methods of manufacturing ultra-pure glass and the mathematics to specify the qualities of the glass needed for optical instruments. Abbe specified Schott's glass for his lenses because Schott used special crucibles to melt, mix, and cool the glasses specified by Abbe. These methods have been refined and characterize the manufacture of precision optical glass today.

Precision glass is mixed with carefully selected ingredients to avoid coloration and to achieve special optical properties, such as a precise index of refraction. The ingredients are melted very slowly in crucibles designed with platinum linings to avoid polluting the molten liquid with unwanted minerals. Special mixing methods insure an extremely even distribution of the ingredients throughout the crucible. The melt is cooled very slowly, over several days, to prevent problems of inhomogeneity that would occur if the outside of the melt cooled more quickly than the center.

IV. Eye-strain and optical resolution

Eye-strain and visual resolution drive the design of visual optical instruments. Lenses must be manufactured from glass with very specific and homogeneous optical properties to avoid eye-strain and to achieve the desired optical power.

If the glass in a lens contains color impurities, then the objects under inspection will take-on the appearance of that color. In other words, the lens will act like its own color filter. Float glass tends to contain impurities of tin and iron oxides. The tin impurities come from the bath on which the glass is floated. The iron impurities are tolerated in the basic recipe of the glass because the color effects are nearly invisible in thin sheets. However, in thicker sheets, the color becomes visible. Even when the effect is subtle, hours of observation will cause the observer's sense of color to change.

Lenses made of inhomogeneous glass exhibit odd distortions located randomly throughout the field of view. They are visible as wiggles called "straiae" or tiny spots called "seeds" and "bubbles". The human eye is attracted to the distorted part of the image and the observer must consciously avert his stare. Eye-strain develops over a short period of time as the observer exercises his eye muscles to avoid obvious distortions. Even very subtle distortions can induce eye-strain when observations are made for several hours.

Additionally, a small distortion may be more problematic when the object under study has many fine details. The human visual system is designed to recognize repeating patterns. When a distortion modifies a regular pattern, like that of printed circuit boards, the eye is drawn immediately to the illusory break in the pattern.

V. Precision Optical Glass Rather than Green Float Glass

Designers specify optical glass, rather than float glass, for all precision visual instruments. The pure absence of color in the optical glass assures that the observer will

accurately see all the color in his specimen. Additionally, float glass typically has a green cast, so the optical designer typically avoids specifying float glass for his lens prescriptions.

The precise formulation of optical glass enables the optician who makes the lens to achieve the optical power specified by the designer in every lens he makes. The resolution and magnification of the lens corresponds very precisely to the designer's intent. Float glass, whose basic optical properties are not as tightly controlled, can not be used if consistency from one lens to the next is required.

Lens designers are very careful to specify the maximum allowable inhomogeneities within a lens. They know that striae and seeds distract the observer and reduce the quality of the lens. Precision optical glass must be so homogenous, that special interferometers are used to confirm the specifications in each melt. On the other hand, float glass is rarely tested for homogeneity because windows are not sensitive to this problem.

VI. Magnilite® by O.C. White

Optical engineers use the technical term “simple microscope” to describe a magnifying glass. The curved shape of the lens produces the magnifying power. One or both sides of the lens must be convex. For powers of about 3 diopters, the curvature of the surfaces must be substantial. As the curvature of the surface increases, the thickness of the lens must increase, too. Otherwise, the lens simply cannot be manufactured.

Additionally, the thickness of a lens must be increased as its width is increased. Therefore, magnifiers that feature very wide area fields of view are larger and thicker than magnifiers with smaller fields of view.

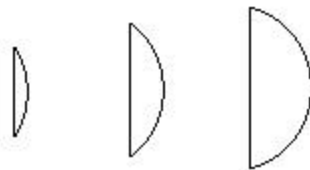


Figure 1: A lens of particular curvature gets thicker as its width increases.

For magnifying glasses, a large lens makes continuous observation easier. If the operator can use both eyes to peer through the lens, then eye-strain is reduced. With binocular vision, the operator maintains stereoscopic vision, too. If the operator was required to close one eye, fatigue would rapidly exhaust the individual's vision, and she would not have the benefit of 3-D, stereo vision.

O.C. White's Magnilite® is designed to maximize field of view and binocular viewing comfort. The magnifier must be large enough to allow the operator use of both eyes; therefore, the lens must be thick enough to allow for the proper curvatures to be manufactured.

Magnilite® features a particular precision optical glass, called B270, for several reasons. The thick glass must be extremely homogeneous to avoid striae and bubbles that would degrade the image quality and introduce weird distortions. Even gradual inhomogeneities would introduce distortions.

Secondly, precision optical glass is so pure that there is no color hue. The resulting image retains all the accurate color information on the object under study.

Competing products manufactured with green float glass, suffer from several defects. If these products feature the same size and power as the Magnilite®, then they are just as thick. But float glass was designed for thin windows. As the thickness of float glass exceeds about ¾ inch, the appearance of striae, bubbles, and gentle changes in homogeneity become more problematic. Lenses of this thickness inevitably suffer from the distortions caused by inhomogeneities in the glass.

The green color hue of float glass also detracts from the overall quality of the competing products. The lenses act as filters and shift the color of the object under study such as a printed circuit board. It is harder for the operator to determine the true color of components or identifying marks. The thickness of the lens amplifies the color problem. The thicker the green lens, the more is the green filtering effect. The Magnilite®, made with pure white precision optical glass, does not alter the colors of the specimen.

VII. Conclusion

Float glass, with its characteristic green hue, was developed in the 1950's to offer extremely low priced window panes to the architectural and building-trades industry. Float glass offers substantially lower price by sacrificing quality because thin window glass does not require the same high quality glass as is required for precision lenses.

Precision optical glass, manufactured in crucibles rather than in a continuous melt-and-cool process like float glass, is designed for optical instruments. Lenses are sensitive to small problems with homogeneity and small deviations from the requirements defined by the lens designer. The slow, smaller volume process used to make precision optical glass produces a product that is more expensive than float glass, but precision optical glass exhibits pure whiteness and extremely good homogeneity. Image quality and user comfort are maximized.

When compared to competing products manufactured with green float glass, the Magnilite® by O.C. White produces superior image quality and color rendition while offering minimum eye-strain and maximum stereo-viewing comfort.