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Improving the Properties of Lenses Made of PMMA Polymer

Hanan Khaled Azab Shamkhb
University of Babylon, College of Science for Girls / Department Laser Physics

Zahraa Rasoul Abdul Amir Sharida
University of Babylon, College of Science for Girls/ Department Laser Physics

Eman Muhammad Obaid
University of Babylon, College of Science for Girls Department Laser Physics

Maryam Abdullah Yassin Tarsh
Technology University Department: Applied Sciences Branch: Laser Science and Technology

Abstract:

In this research, a group of samples of a polymer to which silicon dioxide was added were prepared, with different concentrations, by the casting method. And then using a spectrophotometer to study the absorbance and then extract the refractive index and Abbe number in order to use this data in the zemax program and the Lou and Bernan model to find out which of these samples is the best through the MTF examination. It was found that the sample with a concentration of SiO_2 3% is the best sample, as it gave the highest contrast among the rest of the samples.

General Introduction:

The history of using lenses dates back to the third century BC, where the Greeks and Romans used them to magnify small objects to facilitate vision. In the tenth century AD, the first Arab scientist, Al-Razi, used lenses to correct refractive errors in the eye. In the thirteenth century AD, the Italian scientist Roger Piardi developed convex lenses to correct myopia, and succeeded in designing the first eyeglasses in the world. In the seventeenth century, the Dutch scientist Anthony van Leeuwenhoek developed microscopic lenses to study small objects. In the nineteenth century, lenses became more available to the general public, and were greatly developed to correct various visual defects. In 1887, the German scientist Carl Zei invented the first lenses for photography. Since then, lenses have been greatly developed and are available in different shapes, sizes and properties to meet the different needs of users. Lenses are currently an essential part of healthcare, medical industries and technical industries such as cameras and binoculars.

Lenses are rigid or flexible pieces used to correct refractive errors in the eye, or to correct visual defects such as near and far vision. They are also used to improve vision in daily activities such as reading books or driving. Lenses are made of a transparent material, such as glass or plastic, and are designed to refract light in a specific way to improve vision. Refractive errors in the eye are corrected by changing the path of light entering the eye, using lenses of a specific shape and thickness. Lenses are available in different forms, including interchangeable contact lenses and hard lenses, and are used to correct various refractive errors and visual defects. Contact lenses are used to provide the wearer with comfort and freedom of movement, while hard lenses are used to improve vision in daily activities. Lenses are available in several degrees and types that differ in matters such as thickness and the material they are made of, and the appropriate type must be chosen according to the user's needs and the recommendations of the treating physician.[1]

Types of Contact Lenses Types of Contact Lenses:

1. Hard contact lenses
2. Gas permeable contact lenses
3. Soft (flexible) contact lenses

Glass lenses (medical glasses)

Made of different types of glass to correct the performance of the eye and the glass curvatures and thickness help correct aberrations above the field of vision. The result will be high-quality images. Although glass lenses provide exceptional optical aids, they are heavy and can break easily, which can cause serious damage to the eye or even loss of the eye. For these reasons, glass lenses are no longer widely used for eyeglasses [2].

Plastic lenses

In 1947, the Armor lite Lens Company in California introduced the first lightweight plastic eyeglass lenses. The lenses were made of a plastic polymer called 39-CR, which is an abbreviation for "39 Columbia Resin" because it was the thirty-ninth formula of the thermoplastic developed by PP Industries in the early 1940s.

High-index plastic lenses

In the past twenty years, in response to the demand for eyeglasses Thinner and lighter, a number of lens manufacturers have introduced high-index plastic lenses. These lenses are thinner and lighter than glass lenses because they have a high index. Contact lenses work:

Contact lenses stay in place due to surface tension as they float on a layer of tears that covers the cornea. In order for the cornea to remain in good health, it constantly needs to be supplied with oxygen that comes from the outside air and is removed from the tears. Contact lenses form a barrier between the cornea and the air, thus trapping the oxygen needed by the cornea. This problem is overcome during the movement of the eyelids on the eye, which makes the lens move slightly from its place. With each movement of the eyelids on the eye, a blink (the eye produces a quantity of tears loaded with oxygen). The process of blinking the eye is considered the correct method important for achieving comfort and safety in using contact lenses.

However, there is a concern for users of these lenses in the possibility of ulcers occurring in the cornea or its infection with bacteria. Contact lenses have a long and complex history of innovation and development. The first reference to them can be traced back to the Italian painter and engineer Leonardo da Vinci in (1503) and to the scientists René Descartes in (1632) and Thomas Jung in (1801). The astronomer John Hirsch also suggested in (1827) a mechanism to make it conform to the appearance of the eye by making a mold for it and he can perhaps be considered the first to refer to the hypothesis of cosmetic lenses. The Hungarian scientist (1) Dallas developed a method for taking a mold of living optical corneas for the purpose of adapting manufactured contact lenses to these corneas. The first American-made contact lens made of plastic was implemented by (W. Feinbloom in (1948). The American obtained a patent for the manufacture of the first solid contact lens made entirely of polymer (PMMA). As for the contact lenses with a double focal length, they were invented by the scientist (DeCare in (1957). In (1960), flexible (water) contact lenses were invented, which are characterized by their flexibility, transparency, and having a refractive index close to the refractive index of the cornea in addition to their ability to carry oxygen gas.

Advantages and disadvantages of glass lenses:

At first, when medical lenses appeared, they were made of glass because it was the purest of all the transparent solid materials known at that time.

Glass lenses are characterized by the following points:

- Purity.
- Protection from ultraviolet rays.
- Anti-scratch.
- Disadvantages of glass lenses:
- Heavy weight
- Possibility of breakage, which leads to the glass lens being considered the least safe for the wearer's eyes

Disadvantages and advantages of plastic lenses:

When a high-purity plastic material was invented, it became comparable to glass in its purity, so medical lenses were manufactured from it. Medical lenses made of plastic are characterized by the following:

Advantages of plastic lenses:

- Relatively light weight.
- Shock resistant.

Disadvantages:

- Susceptible to scratching.
- Only compressed lenses protect against ultraviolet rays.
- Susceptible to cracking.[3]

Focal shift:

The term "focal shift" is not used in the context of optical lenses, but rather the term "lens shift" or "focal adjustment" is used. This term refers to the process of adjusting the position of the camera lenses, telescopes, or contact lenses to achieve precise focus on the object to be photographed.

The lenses are moved by rotating or moving them axially to change the distance of the lens from the image plane, which leads to changing the focus of the lens and thus achieving focus on the object to be photographed.

Contact lenses rely on the same principle to achieve focus, as the position of the contact lens is adjusted to change its distance from the eye and achieve focus on the object to be seen clearly.

Focal displacement is an optical problem caused by spherical aberration in this case when a source, an aperture and a lens are placed at the intersection of the beam at the focus. This shifts the focus when working at close distances with small apertures. Due to the use of multi-wavelength visible light, chromatic aberration will have an obvious effect on the efficiency of vision (image). The less the aberration, the better (LCA Longitudinal Chromatic Aberration). It is known that when a converging monochromatic spherical wave deviates at a circular aperture, the point of maximum intensity may not be at the geometric focus of the incident wave, but may be closer to the aperture. As in Figure (1)[4]

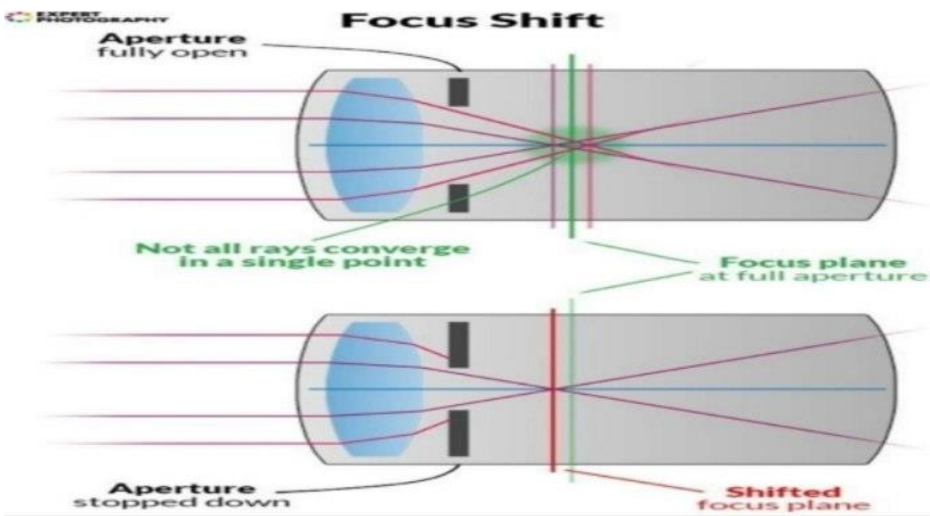


Figure (1): Spot Diagram shows the focus displacement.

The point distribution diagram can be illustrated by viewing the light spot as the bending of light rays as they pass through the lens, which is considered a point-like circle. The size and shape of the point distribution circle varies from one lens to another, and depends largely on the diameter of the lens and the wavelength used in the test.

The dot distribution diagram is used in many optical applications, such as analyzing the properties of lenses and testing their quality, designing optical devices and improving their accuracy, determining the ability of lenses to disperse small objects, and analyzing images, photography, and medicine.

It is a geometric radiation trace of an optical system used to plot a final location on a focal plane and is also used to determine the sharpness of the optical system to focus light primarily. The schematic diagram is a fairly accurate representation of how a given design range works. Geometric optics can be used to estimate the size and shape of the point particle image with an acceptable degree of accuracy by dividing the entrance opening of the optical system into a large number of equal areas and drawing a ray diagram from the point sources on the body to the center of the corresponding area. The spot diagrams give a lot of information about the image formation of the optical system, in order to evaluate the quality of the lens image quantitatively as in Figure (2)[5]

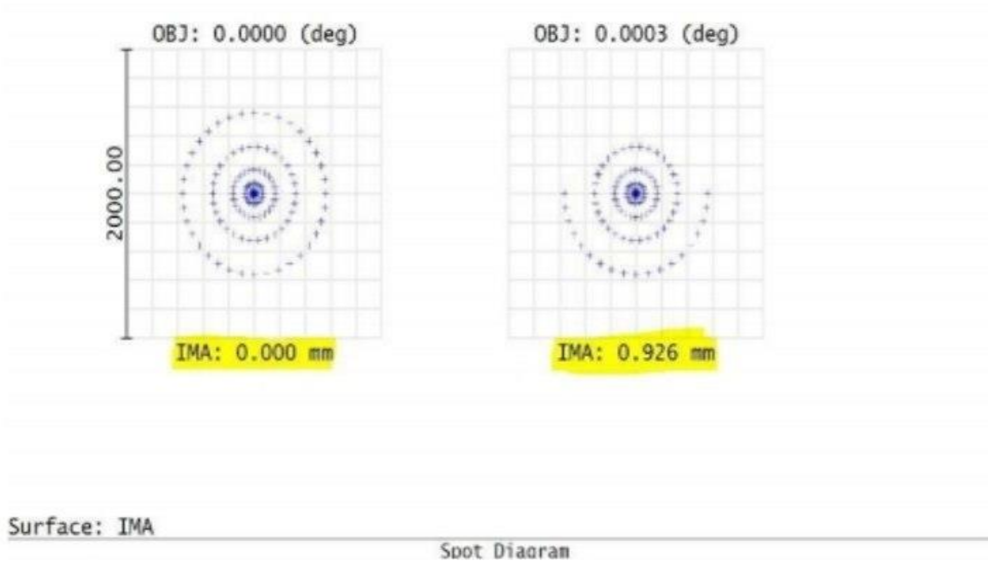


Figure (2): shows the point distribution plot.

Ray Fan: An optical system used in cameras and contact lenses to improve image quality and reduce optical distortions.

The scheme consists of several different optical elements that work together to correct the visual distortions that occur when wearing contact lenses. These elements include convex, concave, conical, segmented lenses, and other specialized optical elements.

The scheme aims to improve image quality by correcting optical distortions, such as geometric, chromatic, and lateral distortions, and misfocus. It also helps to improve clarity, contrast, and light distribution in the image. As in Figure (3)[6]

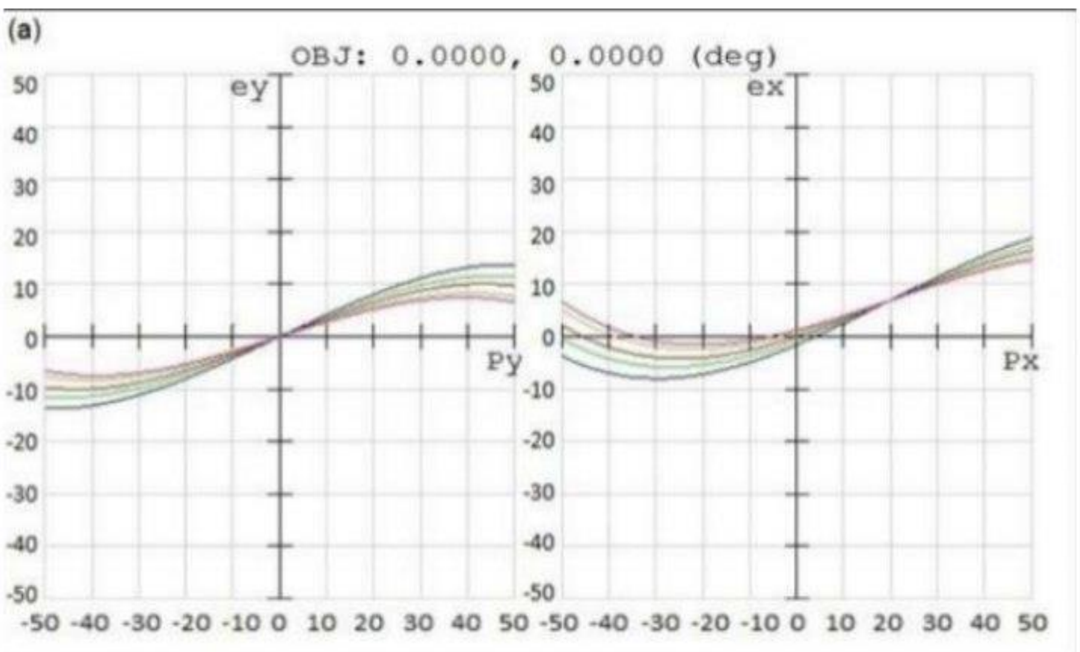


Figure (3): shows the fan diagram.

Point Spread Function: (PSF) Point Spread Function:

It is a mathematical representation of the effect that an optical system, such as lenses, has on a small point of light called a "point source".

The point spread function expresses the shape of the pattern that arises when light passes through an optical system and is focused on a specific point. The shape of this pattern is affected by several factors, such as the properties of the optical system and the wavelength of light.

The point spread function is used in many applications, such as determining the accuracy of lenses, controlling blur, and correcting optical distortions in images. It is also used in image analysis and processing to improve their quality and better interpret them. As in Figure (4)[7].

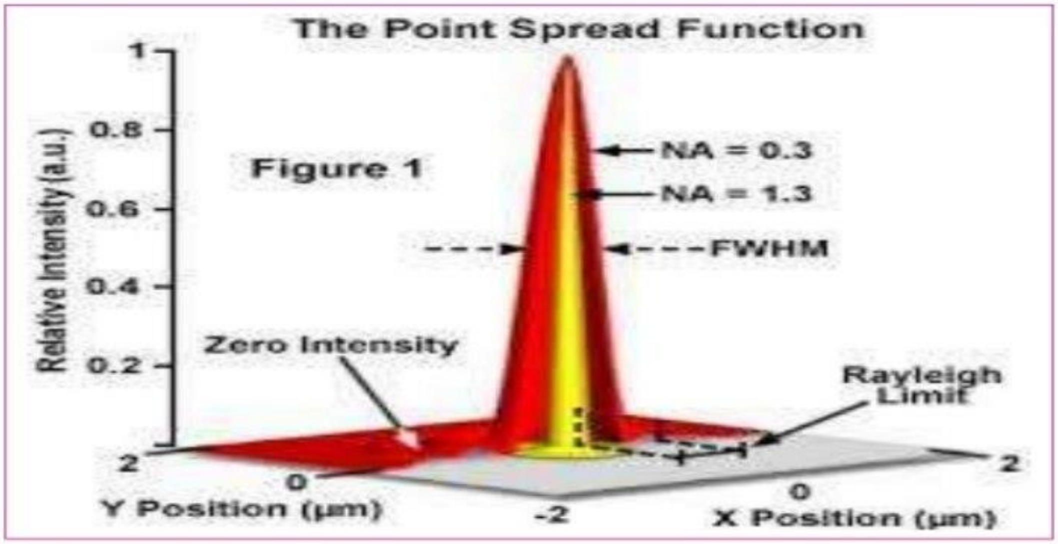


Figure (4): shows the point spread function.

Image Contrast:

Image contrast in lenses is a measure used to measure the differences in the bright surfaces in the image. It is calculated in several ways, as it represents the difference between the bright and dark surfaces in the image.

Image contrast is one of the important criteria for evaluating image quality, as it reflects the ability of the optical system (such as lenses) to produce a clear and accurate image. Image contrast is affected by several factors, such as the quality of the lenses, the distribution of lighting, and the contrast resulting from the camera device itself.

Image contrast in lenses can be improved by using techniques such as correcting optical distortions, increasing the quality of lenses, and improving the distribution of lighting in the area to be photographed. As in Figure (5)[8].

Figure (5): shows the clarity of the image.

Contrast or modulation function: MTF) (Modulation Transfer Function:

The contrast or modulation function in lenses is a mathematical representation of the effect that an optical system, such as lenses, has on the final image. This function expresses the differences in the illuminated surfaces in the image, and determines the ability of the optical system to distinguish fine details in the image.

The contrast function depends on several factors, such as the quality of the lenses, optical distortions, light distribution, camera sensitivity, and contrast of the elements in the area to be photographed. Contrast is usually measured in percentage units, where contrast is higher when the differences between the illuminated and dark surfaces are greater.

The contrast function in lenses can be improved by using techniques such as correcting optical distortions, improving the quality of lenses, distributing light in the area to be photographed, and improving camera sensitivity. The contrast function is used to evaluate and improve image quality in many applications, such as medical imaging, photography, surveillance, space imaging, and others. As in Figure (6)[9]

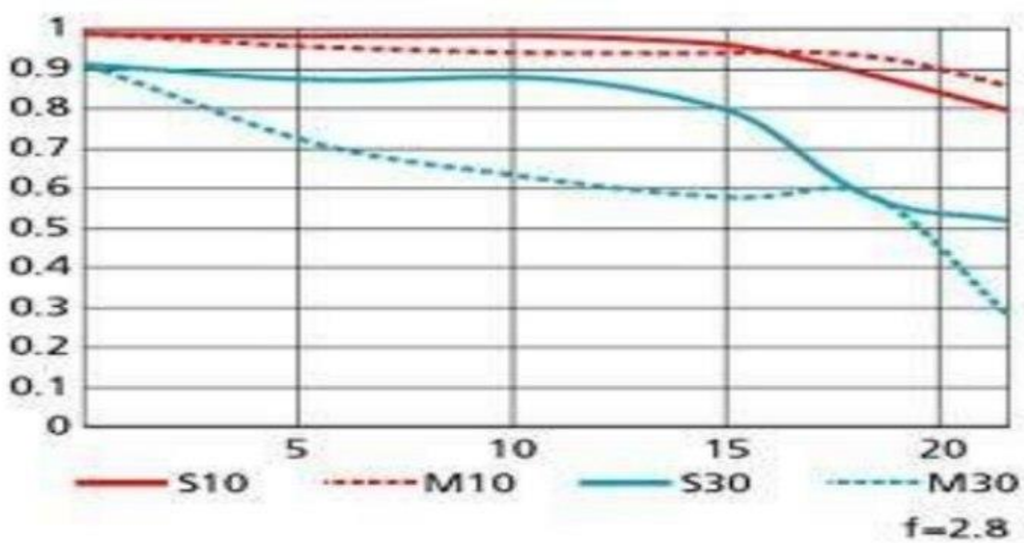


Figure (6): shows the variance or inclusion function.

Optical Path Difference (OPD):

Optical Path Difference in lenses refers to any change in the direction of light rays as they pass through lenses. This difference occurs as a result of the optical properties of lenses, such as their shape, concentrations, and angles of curvature and refraction.

Lenses differ in the optical path that light rays follow, and this difference affects several factors, such as image quality, image size, resolution, and optical distortions. Different techniques are used to analyze and correct the optical path in lenses, such as correcting optical distortions, correcting focus, and improving lens quality.

There may also be a difference in the optical path between different lenses, as lenses are manufactured in different shapes and designs to meet different needs, such as photography, medical and scientific imaging, and other applications. Lenses differ in optical path based on these different needs and designs. As in Figure (7)[10].

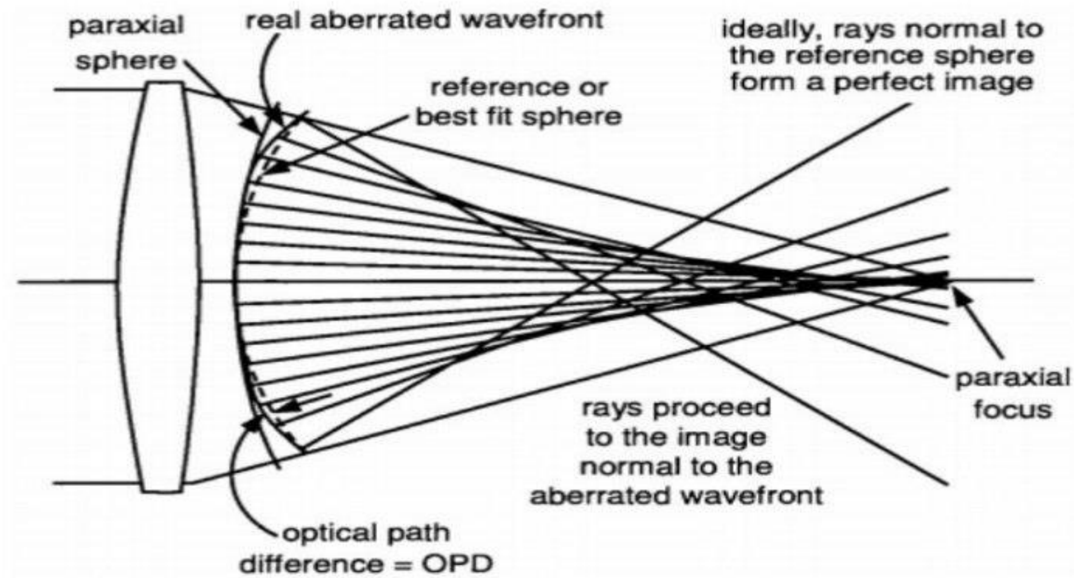
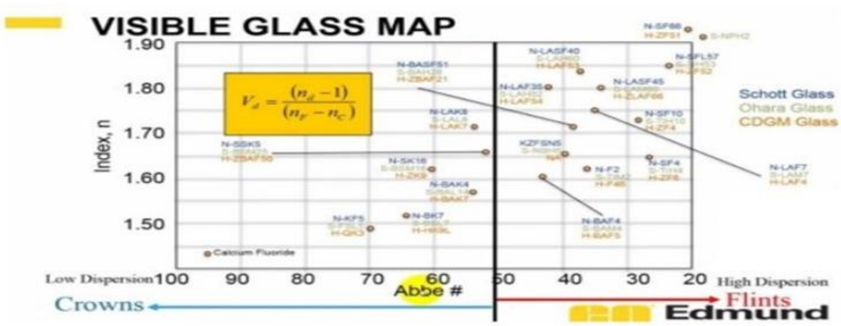


Figure (7): shows a difference in the optical path.

Table (1): Dispersion values and refractive indices of some materials



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High Dispersion				
υ_d	N	S	H	Flints
18	-----	NPH2	-----	
20	SF66	TiH51	-----	
22	SFL57	TiH53	ZF52	
26	SF4	TiH4	ZF6	
28	SF10	TiH10	ZF4	
34	LASF45	LAM60	ZLAF66	
35	LAF7	LAM7	LAF4	
36	F2	TiM2	F46	
37	LASF40	LAH60	LAF53	
38	BASF51	BAH28	ZBAF21	
40	KZFSN5	NBH5	NA	
42	LAF35	LAH52	LAF54	
43	BAF4	BAM4	BAF5	
Low Dispersion				
51	SSK5	BSM25	ZBAF50	
52	LAK8	LAL8	LAK7	
53	BAK4	BAL14	BAK7	
60	SK16	BSM16	ZK9	
65	BK7	BSL7	HK9L	
70	KF5	FSL5	QK3	
95	Calcium Fluoride			
				Crowns

Methods:

In this part, we will explain what was done in terms of preparing the samples and examining the absorption using a U.V spectrophotometer, and then extracting the refractive indices and the Abi number in order to use them in the Zemax program and determining which of the prepared samples has the highest efficiency in order to use them in the lens manufacturing industry.

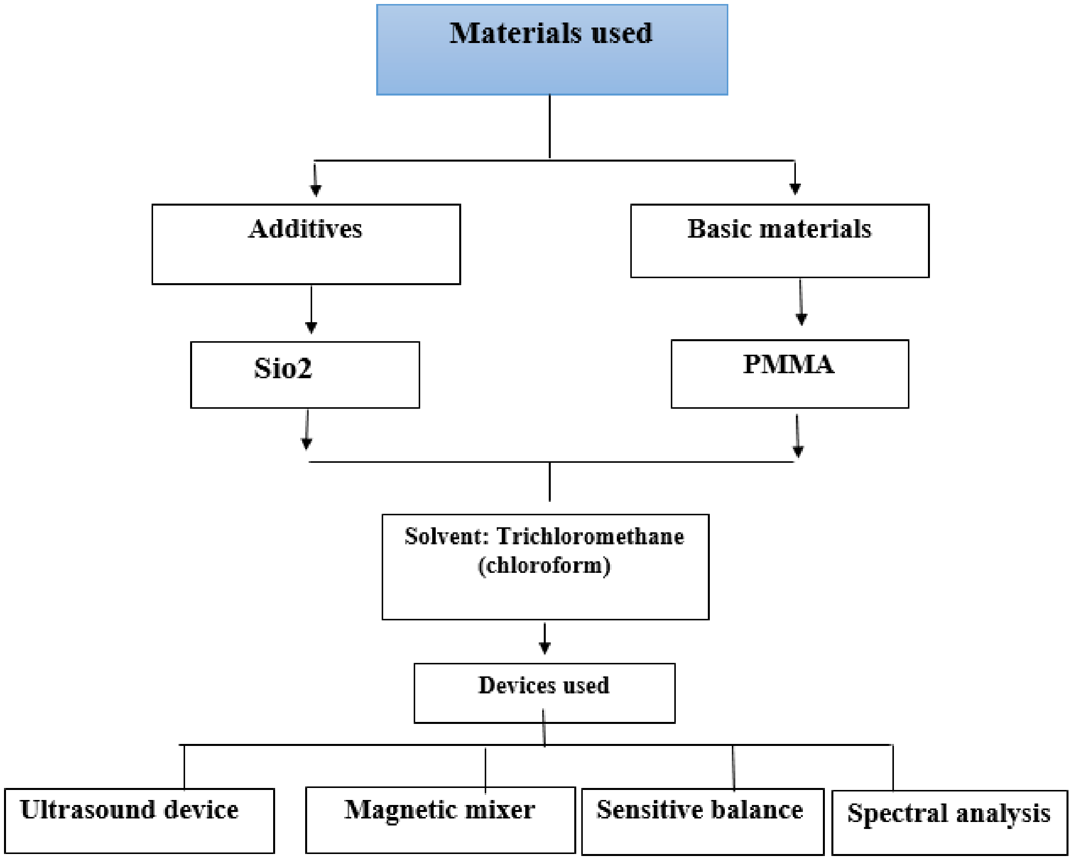

Table (2): Sample mixing ratio table:

PMMA	Sio2	The weight	Solvent volume
100%	0.00	1gm	10ml
0.99	0.01	1gm	10ml
0.98	0.02	1gm	10ml
0.97	0.03	1gm	10ml
0.96	0.04	1gm	10ml
0.95	0.05	1gm	10ml

Improving the properties of lenses using the Zemax-13 program:

The (Liou and Brennan) model is relied upon to improve the properties of lenses using the Zemax program. It is recommended in describing and evaluating the eye because it uses aspherical lens surfaces and uses the gradual refractive index.

Table (3): The refractive index and Abbe number used in the Brennan and Liou model are:

sample	n_{486}	n_{587}	n_{656}	V_d
PMMA 100%	1.163206211	1.180824367	1.137708313	7.091736272
PMMA+1%SiO_2	1.455327205	1.438372211	1.420711913	12.66411989
PMMA+2%SiO_2	1.612464903	1.586641386	1.562428834	11.72436996
PMMA+3%SiO_2	1.776113626	1.746074984	1.720499069	13.41510246
PMMA+4%SiO_2	1.909675853	1.862130524	1.824447118	10.11549126
PMMA+5%SiO_2	1.954195297	1.914308597	1.882200277	12.69960883

الامتصاصية (Absorbance) :

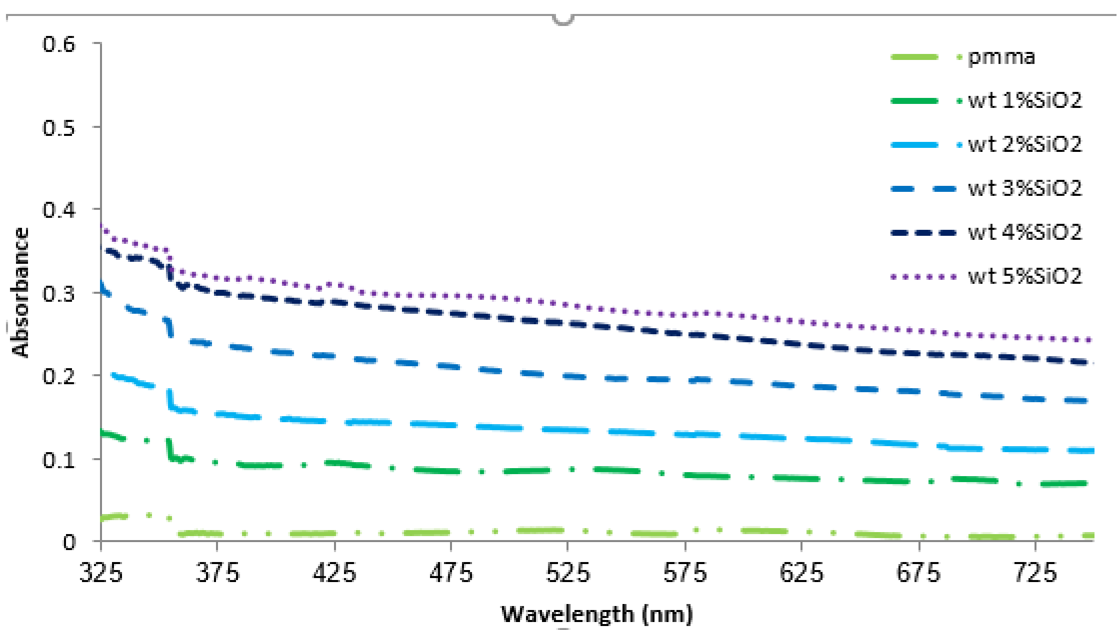

Figure (8) represents the absorbance.

Absorption measurements were performed for the prepared samples, and we note that the absorbance increases with increasing wavelength, and the absorbance increases with increasing concentration of the nanomaterial.

Image Simulation:

Figure (9) represents pmma%.

Figure (10) represents pmma+1%sio2.

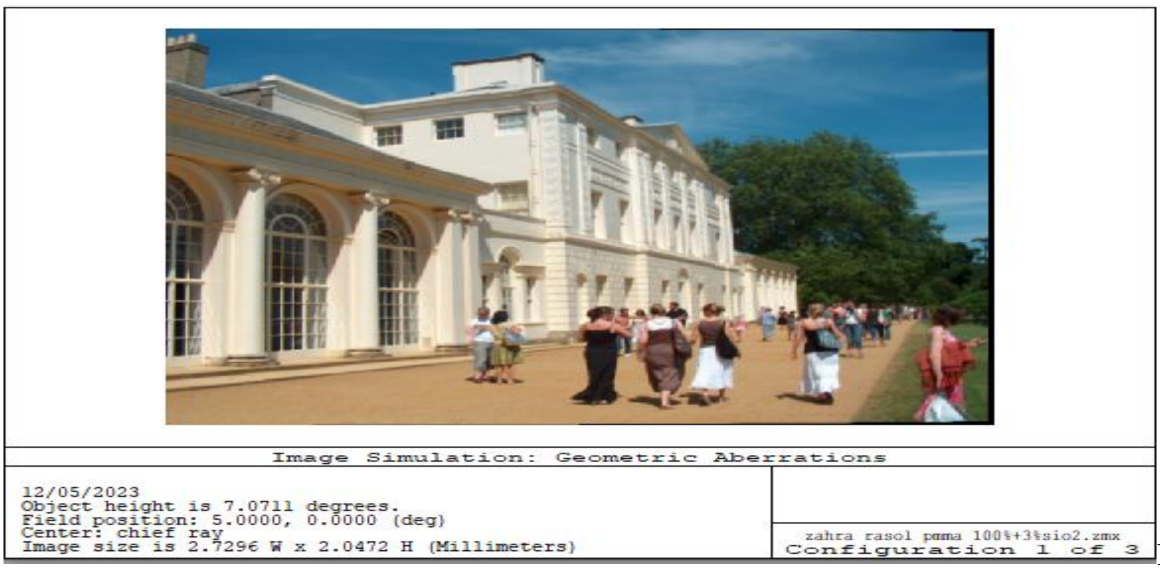

Figure **(11) represents pmma+2%sio2.**

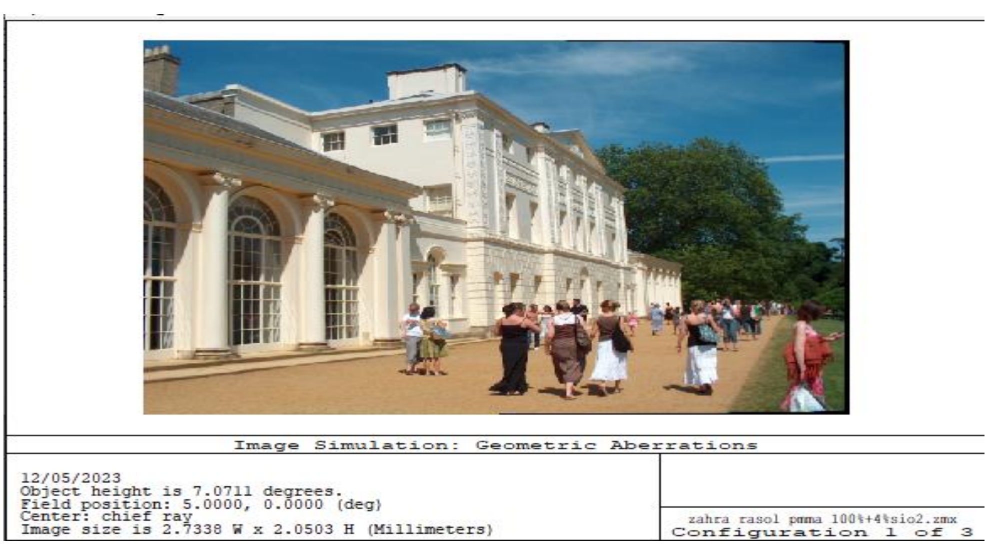

Figure (12) represents pmma+3%sio2.

Figure **(13) represents pmma+5%sio2**.

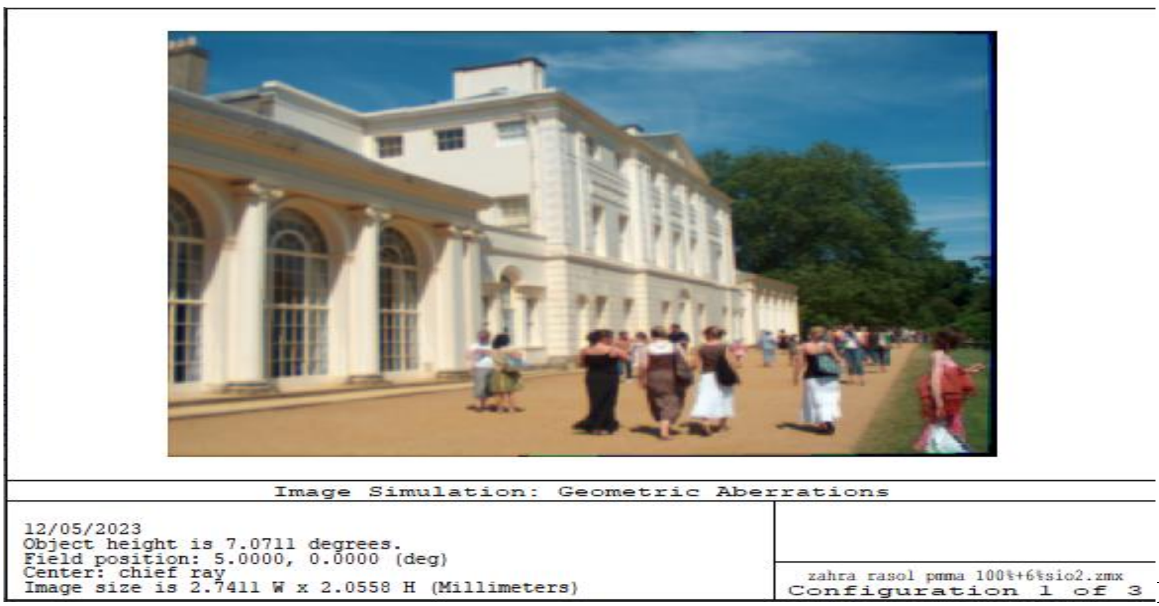

Figure **(14) represents pmma+5%sio2**.

Conclusions:

The images resulting from the test can be distinguished by the naked eye from one image to another and through the results of image analysis it was shown that the sample pmma + 3% sio2 is the best result and to confirm this another program such as matlab can be used to determine which of these images is the best.

When adding a nano material to the polymer, it is considered an impurity which affects the reduction of permeability but in return a high refractive index was obtained.

The program gave a note on the presence of geometric aberration. The polymer powder used reduced the chromatic aberration due to the increase in the refractive index and a decrease in its value.

The refractive index of the green color was used only because it is considered the center of the wavelengths.

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