Development of Altuglas PMMA resin For Automotive Lightening Lenses

A MAJOR PROJECT DISSERTATION SUBMITTED TO FACULTY OF TECHNOLOGY

OF

UNIVERSITY OF DELHI
TOWARDS THE PARTIAL FULFILLMENT OF THE
REQUIREMENT
FOR
THE AWARD OF THE DEGREE OF

MASTER OF ENGINEERING

IN POLYMER TECHNOLOGY

BY
RAKESH NAUTIYAL
10/poly/04

UNDER THE SUPERVISION OF

Dr. A.P. GUPTA
Mr.SANJAY CHOUBEY

DEPT. OF APPLIED CHEMISTRY & POLYMER TECHNOLOGY
DELHI COLLEGE OF ENGINEERING
(UNIVERSITY OF DELHI).
NEW DELHI- 110042

ACKNOWLEDGEMENT

This accomplishment shares the intelligence and diligence of many and therefore, I am beholden to all those of their benevolence.
My foremost thanks to Mr. Sanjay Choubey of his valuable guidance and intellectual cerebrations through out the work and also of providing every resource at his dispose to work with. Apart from providing facilities he has also been a motivational source for me. I am also indebted to the other members of Arkema Ltd.who had been very co-operative during my project work and also sincere thanks to Jay ushein people for R & D work at Gurgaon.

Above all I express my gratitude to Dr. A.P. Gupta Polymer science & technology, D.C.E, who has provided the basic intentions, instinct and opportunity to work at Arkema.

Perspicacious guidance and motivation of Prof. G.L. Verma have been the foundation of this work, of whom I am most indebted.

Rakesh Nautiyal
10/poly/04

DEVELOPMENT OF ALTUGLAS PMMA RESIN FOR AUTOMOTIVE LENSES

INDEX Page no.

ABSTRACT

The intention of the project has been to develop some kind of resin for automotive lightening lenses which have optimum properties like good impact resistance, high heat resistance, high optical properties, good melt flow etc.

So I have worked on existing grade of Altuglas resin, which have not optimum desired properties for automotive lightening lenses.
By blending of different grades of Altuglas Resin I have made single grade which have optimum properties desired for automotive lightening lenses.

INTRODUCTION

Acrylic Resins

The laboratory history of acrylics monomers began as early as 1843 when acrylic acid was first synthesized.

This was followed in 1865 by the preparation of ethyl methacrylate by Frankland and Duppa, while in 1877 Fitting and Paul noted that it has the tendency to polymerize. By 1900, most of the common acrylates had been prepared in laboratory and some work had also been done on their polymerization. In 1901, Dr Rohm, in Germany started systematic work in the acrylic field and later took an active part in the industrial development of the acrylic ester polymer in that country. Polymethyl acrylate was the first acrylic polymer to be produced industrially. It was marketed as the solution of the polymer in an organic solvent and was used mainly in lacquers and surface coatings. Later, Roland Hill studied methyl methaacrylate and its polymerization in detail, while Crowford developed an economic method of manufacturing the monomer.

Acrylics are thermoplastics and are widely used in such diverse industries as building, automotive lighting, sign appliance and aircraft. The term acrylics not only covers the polymers and resins

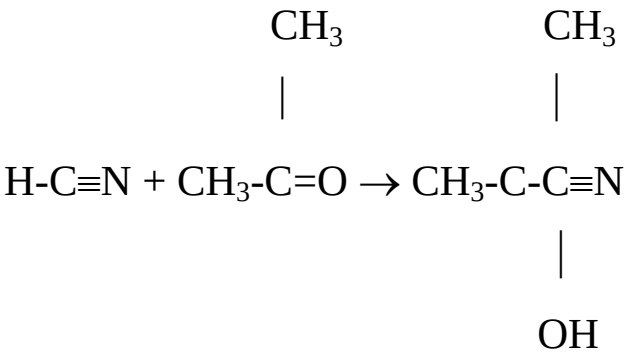
made from acrylics esters, but also include polymerisable derivatives of both acrylics and methaacrylic acids as well as the acid chlorides nitriles and amides.

Natural gas, compressed gas and acetone are the basic raw materials from which monomers for acrylics resins are produced. By combining the carbon, hydrogen, oxygen and nitrogen from the natural gas and air methanol and ammonia are obtained. These raw material and intermediates are then converted in several steps to MMA or other members of broad family of acrylics monomers polymerization is accompanied by adding organic catalyst and heat to the reactive mixture through either bulk, suspension or emulsion polymerization.

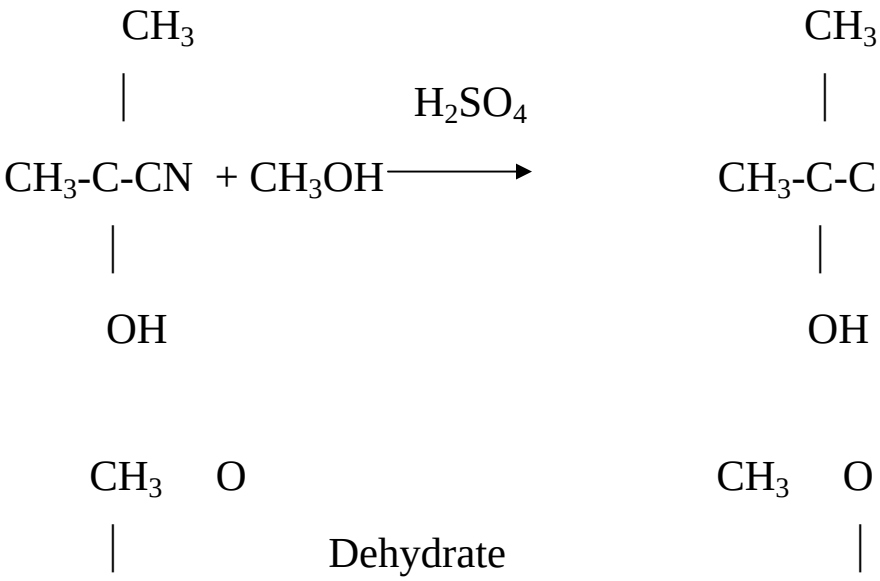
Backbone monomers:

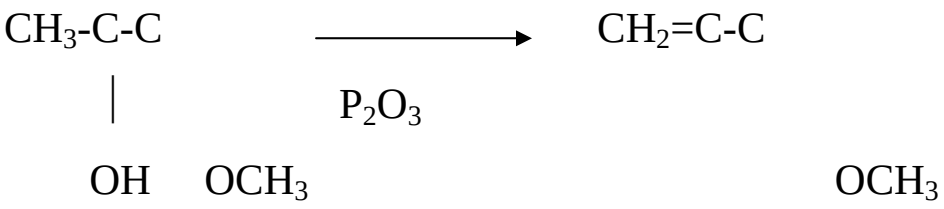
The principal building blocks for thermoplastic acrylics are methacrylate and acrylate esters. Methaacrylate esters differ in composition from the corresponding acrylate esters by the presence of methyl group substituted at the alpha carbon. Monomers used for coating s are usually based on methyl or ethyl esters but these are rarely higher than butyl as the polymer tends to become too soft when high esters are used.

Methylmethacrylate is a colourless volatile liquid b.p 101^0c; m.p 48.2^0c ; slightly soluble in water and most organic solvents. It is readily polymerized by light, heat, ionizing radiations and catalyst. It is copolymerised with other methaacrylate esters and many other esters. Methylmethacrylate monomer can be made in a multi-step process from acetone, hydrocyanic acid, sulfuric acid and methonal as follows-



Acetone cyanohydrin





Early production of acrylic esters monomers started with ethylene chlorohydrins and sodium cyanide. Following the Second World War one company developed a more economical continues catalytic process in which carbon monoxide, acetylene and alcohol are passed through a catalytic container containing nickel carbonyl and hydrochloric acid. The acrylate monomer produced depends on the choice of alcohol: methonal for example produces methyl acrylate monomer while butyl alcohol produces butyl acrylate monomer.

PMMA

Polyacrylates include a number of materials such as polymethyl methaacrylate (PMMA), polymethyl acrylate (PMA) and hydroxyethyle mathacylate (HEMA**).**

SPolymethyl methacrylate (PMMA) or poly (methyl 2-methylpropenoate) is the synthetic polymerof methyl methacrylate. This thermoplastic and transparent plastic is sold by the trade names Plexiglas, Perspex, Acrylite, Acrylplast, and Lucite and is commonly called acrylic glass or simply acrylic. The material was developed in 1928 in various laboratories and was brought to market in 1933 by the German Company Rohm and Haas (GmbH & Co. KG).

Properties

The material is often used as an alternative to glass . Differences in the properties of the two materials include:

- PMMA is lighter: its density (1190 kg/m^3) is about half that of glass.
- PMMA does not shatter.
- PMMA is softer and more easily scratched than glass. This can be overcome with scratch-resistant coatings.
- PMMA can be easily formed, by heating it to 100 degrees Celsius.

APPLICATIONS

Altuglas resins are used in many Industries, including:

- **Transportation and the automotive industry**

Automotive Lighting, Cluster Lenses, number plates, reflectors, Badges, co extruded body panel, interior and exterior trims, etc.

- **Building Construction**

Extruded panels for buildings, glazing and co extruded profiles For window frames, etc.

- **Lighting**

Light fittings, bowls, diffusers globes, etc…

- **Household and Domestic equipments**

Salad and mixing bowls, drinking glasses, bathroom accessories, etc.

- **Medical/Hygiene**

Diagnostic test-cuvettes, blood pressure filters, toothbrushes

- Electronical-Optical

Projection TV's, light pipe, optical media, office machinecomponents, mobile phone lenses, DVD, light guide panelsfor LCD

In addition, there are many other specific applications Furniture, signs, displays and more.

Global Manufacturers

- ALTUGLAS

  Altuglas International
  C/o Arkema
  6,Cours Michelet-Cedex 52
  F-92064 Paris la defense 10

- ICI

  ICI Chemical& Polymers
  PO.Box-13,The heath,Runcom
  CheshireWA74QF,U.K

- LG

  www.lgmma.com

- SUMITOMO

  Head Office
  27-1,Shinkawa 2-Chome,Chuo-Ku
  Tokyo 104-8260
  JAPAN

- DEQUSSA

  www.deuqssa.com

- ASHAHI

  www.ashahichemical.com

- GSFC (INDIA)

  GSFC,Sikka Unit
  P.O. Motikhavdi ,Jamnager
  Pin-361140,Gujrat

PMMA IN AUTOMOTIVE

The new range of high-technology products developed by Altuglas fosters an important partnership with the automotive industry, using innovative material.

From standard to very high impact PMMA, Altuglas can be used in following Applications.

Rear light systems/reflectors
Decoration Trims

Number Plate Systems

Front Light Systems

Flash Light Systems

Badges, Lenses & Logos

Cluster Lenses

Glazing Parts

Light Guide Systems

Mirror Shells

Warning Triangles

Wind Shields & Sun Visors

Rear Light System/ reflectors

Grades in use:

- Altuglas V 825 T, V 825, V 040
- Altuglas V 920
- Altuglas HT 121.

Properties:

- High Temperature resistance
- Surface hardness
- Excellent optical properties
- UV resistance
- Colour ability

Number Plate System

Grades in use:

- Altuglas NP6
- Altuglas MI-7
- Altuglas MI-7T
- Altuglas HFI-7

Properties:

- High Impact resistance
- Transparency
- Second surface film for letters
- Excellent UV resistance
- Surface hardness
- High temperature resistance
- Easy processing

Front Light Systems

Main Applications:

Car and motorbike front light system

Grades in use:

- Altuglas MI-7
- Altuglas HT 121.

Properties:

- High Temperature resistance
- Excellent Surface hardness
- Good light transmission
- Excellent UV resistance

Flash Light Systems

Main Applications:

Car and motorbike front light system

Grades in use:

- Altuglas V 825 T, V 825, V 040
- Altuglas HT 121.

Properties:

- High Temperature resistance
- Excellent Surface hardness
- Optical properties
- Excellent UV resistance
- Colour ability

Badges, Lenses & Logos

Grades in use:

- Altuglas V 825, V 040
- Altuglas HT 121
- Altuglas HFI-7

Properties:

- High Temperature resistance
- Top Surface hardness
- Easy processing
- Impact resistance
- Second surface decoration
- Metalised highlight transmission

Wind Shields & Sun Visors

Grades in use:

- Altuglas HFI-10
- Altuglas HT 121
- Altuglas MI-7T, MI-7

Properties:

- Temperature resistance
- Impact resistance
- Surface hardness
- Easy processing
- UV resistance
- Optical properties

Cluster Lenses

Grades in use:

- Altuglas V 825, V 040
- Altuglas HT 121

Properties:

- High Temperature resistance
- Top Surface hardness
- Optical properties
- Impact resistance

Decoration Trims

Grades in use:

- Altuglas MI-7
- Altuglas HT 121

Properties:

- Good Temperature resistance
- Top Surface hardness
- Transmission
- High Impact resistance
- Gloss finish

Glazing Parts

Grades in use:

- Altuglas V 825 T, V 825, V 040
- Altuglas HFI-7
- Altuglas HFI-10
- Altuglas MI-7T, MI-7

Properties:

- High Temperature resistance
- Good impact resistance
- Stiffness
- Easy processing
- Optical properties

Light Guide System

Grades in use:

- Altuglas V 825, V 040
- Altuglas V 920
- Altuglas HT 121

Properties:

- Good Temperature resistance
- Easy processing
- Good surface hardness
- Stiffness

Mirror Shells

Grades in use:

- Altuglas MI-7T, MI-7

Properties:

- Good Temperature resistance
- Good impact resistance
- Top surface hardness
- Colour ability
- Gloss finish

Warning Triangles

Grades in use:

- Altuglas V 825 T, V 825, V 040

Properties:

- Excellent Temperature resistance
- Easy processing
- Excellent UV resistance
- Stiffness
- Colour ability

THE RANGE

Whenever there is a need for good looking, precise, tough, moulded parts we can find the ideal combination of performance properties and values in the Altuglas family of acrylic thermoplastic resin. Excellent optical clarity, unsurpassed weatherability and design flexibility.

These resins are available in many grades and colour to meet specific applications. Assemblies can be drilled, machined, engraved or embossed. Decorative coating can be sprayed, silk-screened, hot stamped, vacuum-metallized or chrome plated.

Exceptional optical clarity and resistance to ultraviolet-light degradation and discoloration make Altuglas acrylic resin the standard of the industry, These resins are virtually unaffected by alkalis, hydrocarbons, nonoxiding acids, saltwater, photographic or battery solution

Thus Altuglas resins are available in a complete range of transparent, translucent, opaque or custom colours in varying grades of melt flow and heat resistance.

Different product range

Product	Selection Guideline
Altuglas VS	Very high flow
Altuglas VM	Medium heat resistance, high flow
Altuglas V 920 T	General purpose injection moulding Resin with high flow.
Altuglas V 825 T	High heat resistance
Altuglas V 045/ V 044	Extrusion grade with high heat resistance, with / without lubrication.
Altuglas V 046	General purpose lubricated extrusion grade with high heat resistance.

Table-1

GENERAL PROPERTIES

General properties	Test method ASTM DIN ISO	Units	Standard grade Altuglas V 920T	Altuglas V 825T	Altuglas V 046	Impact resistance Altuglas DRT
Density	D-792 53479 1183	G/cm^3	1.18	1.19	1.18	1.15
Water absorption	D-570 53495 62	%	0.3	0.3	0.3	0.36
Mould shrinkage	D-955	%	0.2-0.6	0.2-0.6	0.2-0.6	0.2-0.8

Table -2

MECHANICAL PROPERTIES

Mechanical properties	Test method ASTM DIN ISO	Unit	Standard grade Altuglas V 920T	Altuglas V 825T	Altuglas V 046	Impact resistance Altuglas DRT
Tensile strength	D-638 53455 527-2	Mpa	70	70	70	38
Elongation at break	D-638 53455 527-2	%	6	6	6	40
Flexural strength	D-790 53452 178	Mpa	103	103	103	62
Flexural modulus	D-790 53452 178	Mpa	3300	3300	3330	1700
Compressive Strength	D-695 53454 604	Mpa	110	117	117	45
Rockwell hardness	D-785		M-96	M-97	M-96	M-46
Impact resistance (charpy,unnotched)	53453 179-1	Kj/m^2	11	11	11	60
Impact resistance (charpy, notched)	53453 179-1	Kj/m^2	2	2	2	7
Impact resistance (lzod,notched)	D-256 180/1a	Kj/m^2	1.8	1.8	1.8	6.3

Table-3

OPTICAL PROPERTIES

Optical properties	Test method ASTM DIN ISO	Units	Standard grade			Impact resistance
			Altuglas V 920T	Altuglas V 825T	Altuglas V 046	Altuglas DRT
Refractive **Index B**	D-542 53491 R-489		1.49	1.49	1.49	1.49
Light transmittance	D-1003 5036	%	92	92	92	90
Haze	D-1003 5036	%	0.5	0.5	0.5	2

Table-4

ELECTRICAL PROPERTIES

Electrical properties	Test method ASTM DIN ISO	Units	Standard grade			Impact resistance
			Altuglas V 920T	Altuglas V 825T	Altuglas V 046	Altuglas DRT
Dielectric **strength**	D-149 53581	MV/m	19.7	19.7	19.7	15
Dielectric Constant 50 HZ	D-150 53483		3.7	3.7	3.7	3.9
Dissipation factor 1 MHZ	D-150 53483		0.04	0.04	0.04	0.04
Surface resistivity	D-527 53482	ohm	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$
Volume resistivity	D-527 53482	ohm.cm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$

Table-5

THERMAL PROPERTIES

Thermal Properties	**Test method** **ASTM DIN ISO**	**Units**	**Standard grade**			**Impact resistance**
			Altuglas V 920T	Altuglas V 825T	Altuglas V 046	Altuglas DRT
Vicat softening **Temperature**	D-1525 53460 306B5	^{0}C	103	108	101	100
HDT: 1.80 Mpa	D-648 53461 75-2	^{0}C	95	100	92	88
Melt flow index	D-1238 53735 1133	G/10mm	6	2.8	2	0.8
Coefficient of linear expansion	D-696 53752A	$10^{-6}/^0$k	65	65	65	100

Table-6

FLAMMABILITY

Flammability	**Test method** **ASTM DIN ISO**	**Units**	**Standard grade**			**Impact resistance**
			Altuglas V 920T	Altuglas V 825T	Altuglas V 046	Altuglas DRT
Fire resistant	UL/94	CLASS	HB	HB	HB	HB

Table-7

Testing method for different properties of Altuglas resins

Mechanical properties

Tensile Tests (ASTM D-638 , ISO 527-2)

Tensile elongation and tensile modulus measurement are among the most important indication of strength in the material. Tensile strength in a broad sense is a measurement of ability of the material to withstand forces that tend to pull it apart and to determine to what extent that material stretches before breaking. Tensile modulus, an indication of the relative stiffness of a material, can be determined from stress-strain diagram. Different type of plastic material are often compared on the basis of tensile strength, elongation and tensile modulus data.

Apparatus:

The tensile testing machine of a constant-rate-of crosshead movement is used .It has a fixed or essentially stationary member carrying grip and a movable member carrying a second grip. Self-aligning grips employed for holding the test specimen between the fixed member and the movable member prevent alignment problems .A controlled-velocity drive mechanism is used. An extension indicator is used to determine the distance between two

designated points located within the gauge length of the test specimen as the specimen is stretched. Stress elongation, modulus, energy and statistical calculations are performed automatically and presented on visual display or hardcopy printout at the end of the test.

Test Specimens and Conditioning:

Test specimen for tensile test are prepared in many different ways. Most often they are either injection moulded or compression moulded. The

specimens are conditioned using standard conditioning procedures. Since

The tensile properties of some plastics change rapidly with small changes in temperature it is recommended that test be conducted in the standard laboratory atmosphere of $23+\_\ 2\ ^{0}c$

Conditioning is defined as the process of subjecting a material to a stipulated influence or combination of influence for a stipulated period of time. Three basic reasons for conditioning specimens are:

1. To bring the material to equilibrium with normal or average room condition.
2. To obtain reproducible results regardless of previous history or exposure.

3. To subject the material to abnormal condition of temp. and humidity in order to predict its service behaviour

Test procedures:

The speed of testing is the relative rate of the motion of the grip or test fixture during the test. There are basically five different testing speed specified in the ASTM D 638 standard. The most frequently employed speed of testing is 0.2 in./min. If the test speed is not given appropriate speed that causes rupture between 30 sec and 5 min should be chosen. The test specimen is positioned vertically in grip of the testing machine to prevent any slippage .As the specimen elongates the resistance of specimen increases and is detected by load cell. This load value (force) is recorded by the instrument. Some machine also record the maximum (peak) load obtained by the specimen. The elongation of the specimen is continued until a rupture of specimen is observed load value at break is also recorded.

The tensile strength at yield and at break (ultimate tensile strength) are calculated.

Tensile strength= force (load)(lb) p/cross section area (sq.in.)

Tensile strength at yield (psi)=maximum load recorded(lb) /crosssection area(sq.in.)

Tensile strength at break (psi)=load recorded at break (lb) /cross section area(sq.in.)

Flexural test (ASTM D-790, ISO 178)

Flexural strength is the ability of the material to withstand bending force applied perpendicular to its longitudinal axis. The stresses induced by the flexural load are a combination of compressive and tensile stress. Many polymer do not break under flexure even after large deflection that makes determination of the ultimate flexural strength impractical for many polymers. Flexural **modulus** is a measure of the stiffness during the first or initial part of the bending process. The flexural modulus is represented by the slope of the initial straight-line portion of the stress-strain curve and is calculated by dividing the change in the stress by the corresponding change in strain.

There are two basic methods that cover the determination of flexural properties of plastics. Method 1 is a three point loading system utilizing center loading on a simple support beam Method 2 is a four point loading system utilizing two load points equally spaced from their adjacent support point with a distance between load point of one-third of the support span.

Apparatus:

The machine used for tensile testing is also used for flexural testing The upper or lower portion of the movable crosshead can

be used for flexural testing .The dual purpose load cell that indicates the load applied in tension as well as in compression facilitates testing of the specimen in either tension or compression. The machine used for this purpose should operate at a constant rate of crosshead motion over the entire range and error in the load-measuring system should not exceed(1 % of the maximum load expected to be measured

The loading nose and support must have cylindrical surfaces.A strain guage type of mechanism is used to measure deflection in the specimen.

Test specimen and conditioning:

The specimen used for flexural testing are bars of rectangular cross-section and are cut from sheets, plates or molded shapes. The common practice is to mold the specimen to the desired finished dimensions.The specimen of size 1/8*1/2*4 in. are the most commonly used.

Test procedure and Calculations:

The test is initiated by applying the load to the specimen at the specified crosshead rate. The deflection is measured either by a gauge under the specimen in contact with it in the center of the support span or by the measurement of the motion of the loading nose relative to support. A load-deflection curve is plotted if the determination of flexural modulus value is desired

The maximum fiber stress is related to the load and sample dimension and is calculated using following equation:

$$\text{Method 1 } S=3PL/2bd^2$$

Where S=stress (psi): P=Load (lb): L=length of span (in.): b=width of specimen (in.): d=thickness of specimen (in.)

Flexural strength is equal to the maximum stress in the outer fibres at the moment of break this value can be calculated by using the above stress equation by letting load value P equal the load at moment of break.

The maximum strain in the outer fibers, which also occur at mid span, is calculated using following equation

$$r=6Dd/L^2$$

Where r=strain (in./in.): D=deflection (in.): L=length of span (in.): d=thickness of specimen (in.)

Compressive properties (ASTM D 695)

Compressive properties describe the behavior of the material when it is subjected to a compressive load at a relatively low and uniform rate of loading. Compressive test provide a standard method of obtaining data for research and development, quality control, acceptance or rejection and special purposes. Compressive properties include modulus of elasticity; yield strength, deformation beyond yield point, compressive strength, compressive strain and slenderness ratio.

Apparatus:

The universal testing machine used for tensile and flexural testing can also be used for testing compressive strength of various

materials. A deflectometer or a compressometer is used to measure any change in distance between two fixed points on the test specimen at any time during the test.

Test specimen and Conditioning:

Recommended specimens for this test are either rectangular blocks measuring ½*1/2*1 in. or cylinder ½ in. in diameter and 1 in. long. Specimen may be prepared by machining or molding.

Procedure:

The specimen is placed between the surfaces of the compression tool , making sure that the end of the specimen are parallel with the surface of compression tool .The test is commenced by lowering the movable crosshead at a specified speed over the specimen. The maximum load carried by the specimen during the test is recorded .The stress-strain data are also recorded either by recording load at corresponding compressive strain or by plotting a complete load-deformation curve with an automatic recording device. Compressive strength is calculated by dividing the maximum compressive load carried by the specimen during the test by the original minimum cross-sectional area of the specimen .The result

is expressed in lb/in.^{2} Modulus of elasticity or compressive modulus is also represented by the slope of the initial straight-line portion of the stress-strain curve and is calculated by dividing the change in stress by the corresponding change in strain.

Rockwell Hardness (ASTM D 785)

The Rockwell hardness test measures the net increase in depth impression as the load on an indenter is increased from a fixed minor load to a major load and then returned to a minor load .The hardness numbers derived are just numbers without units. Rockwell hardness are always quoted with a scale symbol representing the indenter size , load , and dial scale used .The hardness scale in order of increasing hardness are R , L , M , E , and K scales .The higher the number in each scale , the harder the material. There is a slight overlap of hardness scale and therefore it is quite possible to obtain two different dial readings on different scales for the same material.

Test Apparatus and Specimen:

Rockwell hardness is determined with an apparatus called Rockwell hardness tester .A standard specimen of ¼ in. minimum thickness is used . The specimen can either be molded or cut from a sheet and must have parallel flat surfaces.

Test procedures:

The specimen is placed on the anvil of the apparatus and minor load is applied by lowering the steel ball onto the surface of the specimen .The minor load indents the specimen slightly and assures good contact .The dial is adjusted to zero under minor load and major load is applied within 10 sec. By releasing the trip lever. After 15 sec. Major load is removed and the specimen is allowed to recover for an additional 15 sec. Rockwell hardness is read directly off the dial with the minor load still applied.

Impact properties

The impact properties of the polymeric material are directly related to the overall toughness of the material. Toughness is defined as the ability of the polymer to absorb applied energy. The area under stress-strain curve is directly proportional to the toughness of the material. The higher the impact energy of the material, the higher the toughness and vice versa. Impact resistance is the ability of the material to resist breaking under a shock loading or ability to resist the fracture under stress applied at high speed.

Apparatus and Test Specimen:

The testing machine consists of a heavy base with a vice for clamping the specimen in place during the test. A pendulum-type hammer with an anti friction bearing is used. Additional weights can be attached to the hammer for breaking tougher specimens. The pendulum is connected to the pointer and a dial mechanism that indicates the excess energy remaining in the pendulum after breaking the specimen. The dial is calibrated to read the impact values directly in in-lb or ft-lb. A hardened steel-striking nose is attached to the pendulum. The test specimen can be prepared either by molding or cutting them from a sheet. Izod test specimen are

½*1/2*1/8in. the most common specimen thickness is 1/8in. but 1/4in. is preferred since they are less susceptible to bending and crushing. A notch is cut into a specimen very carefully by milling machine. The recommended notch depth is 0.100in.

Izod test

The specimen is clamped into position so that the notched end of the specimen is facing the striking edge of the pendulum. The pendulum hammer is released, allowed to strike the specimen. If the specimen do not

break , more weights are attached to the hammer and the test is repeated until failure is observed. The impact values are read. The impact strength is calculated by dividing the impact values obtained from the scale by the thickness of the specimen. The reversed notch impact resistance is obtained by reversing the position of the notched specimen in the vice. Notching of the test specimen drastically reduces the energy loss due to deformation and can generally be neglected. Tough plastic materials that have izod impact higher than 0.5 ft-lb/in. of notch seem to expend very little energy in tossing the broken end of the specimen. For relatively brittle material having an izod impact less than 0.5 ft-

lb/in. of notch the energy loss due to toss factor represent a major portion of the total energy loss.

Charpy impact test:

This test is conducted in a very similar manner to the izod impact strength test. The only difference is the positioning of the specimen. In this test the specimen is mounted horizontally and supported unclamped at both ends. Only the specimens that break completely are considered acceptable. The charpy impact strength is calculated by dividing the indicator reading by the thickness of the specimen. The results are reported in ft-lbf/in. of notch for notched specimens and ft-lbf/in. for unnotched specimens.

OPTICAL PROPERTIES

Refractive Index (ASTM D 542, ISO 489)

Refractive index is the fundamental property of transparent material. The refractive index also known as the index of refraction is defined as the ratio of the velocity of light in a vacuum to its velocity in transparent medium.

Index of refraction=sin of angle of incidence/sin of angle of refraction

Two basic methods are most commonly employed to determine the index of refraction. The first method known as refractometric method require the use of refractometer. The alternate method calls for the user of the microscope with a magnification power of at least 200 diameters. The method is generally preferred over the microscopic method since it is much more accurate.

Refractometric method:

The Abbe refractometer most widely used to determine the index of refraction. The test also require the source of white light and a contacting liquid that will not attack the surface of the plastic. The

contacting liquid must also have a higher refractive index than a plastic being measured. A test specimen of any size can be used as long as it conveniently fits on the face of the fixed half of the refractometer prism.

The test is carried out by placing a specimen in contact with a prism using a drop of contacting liquid. The polished edge of the specimen is kept towards the light source. The refractive index is determined by moving the index arm of refractometer so that the field seen through the eyepiece is half dark. The compensator is adjusted to remove all colours from the field. Next index arm is adjusted using the vernier to coincide the dark and light portion of the field at the intersection of the cross hairs. The value of the index of refraction is read for sodium D lines.

Luminous Transmittance And Haze (ASTM D 1003)

Luminous transmittance is defined as the ratio of the transmitted light to the incident light. The value is generally reported in percentage of light transmitted. Haze is the cloudy appearance of an otherwise transparent specimen caused by light scattered from within the specimen or from its surface. Haze is defined as percentage of transmitted light which is passing through a specimen deviates from the incident beam by forward scattering.

Haze is normally caused by surface imperfection, density change, or inclusions that produce light scattering.

Test Procedure:

This procedure employs an integrating sphere hazemeter. The test specimen must be large enough to cover the aperture but smaller enough to be tangent to the sphere wall. The test is conducted by taking four different consecutive readings and measuring the photocell output as follows:

T_1=specimen and light trap out of position, reflectance standard in position
T_2=specimen and reflectance standard in position, light trap out of position
T_3=light trap in position, specimen and reflectance standard out of position
T_4=specimen and light trap in position, reflectance standard out of position

The quantities represented in each reading are incident light , total light transmitted by specimen , light scattered by instrument and light scattered by

instrument and specimen, respectively. Total transmittance Tt and diffuse transmittance Td are calculated as follows:

$$T_t=T_2/T_1$$

$$T_d=[T_4-T_3\,(T_2/T_1)]/T_1$$

The percentage of haze is calculated as follows:

$$\text{Haze percentage}=T_d/T_t \ast 100$$

ELECTRICAL PROPERTIES

Dielectric Strength (ASTM D 149)

The dielectric strength of an insulating material is defined as the maximum voltage required to produce a dielectric breakdown. It is expressed in volt per unit of thickness. Three basic procedures have been developed to determine dielectric strength of an insulator. The first procedure is known as short-time method. In this method the voltage is increased from zero to breakdown at uniform rate.

The second method is known as slow rate-of-rise method. The test is carried out by applying initial voltage approx equal to 50% of the breakdown voltage.

The step-by-step method requires applying initial voltage equal to 50% of the breakdown voltage and then increasing the voltage in equal increments and holding for specified time periods until the specimen breakdown.

Dielectric strength (V/mil)=Breakdown voltage(V) / Thickness (mil)

Dielectric Constant (ASTM D 150)

The dielectric constant of an insulating material is defined as the ratio of charge stored in an insulating material placed between two metallic plates to the charge that can be stored when the insulating material is replaced by air.

Dielectric constant =Capacitance, material as dielectric / Capacitance, air as dielectric

The dielectric constant test is simple. The test specimen is placed between the two electrodes and the capacitance is measured. Next the test specimen is replaced by air and the capacitance is again measured. The dielectric constant value is determined from the ratio of the two measurements.

Dissipation Factor (ASTM D 150)

In all electrical applications it is desirable to keep the electrical losses to a minimum. Electrical losses indicates the inefficiency of an insulator. The dissipation factor is a measure of such electrical inefficiency of the insulating material. The dissipation factor

indicates the amount of energy dissipated by the insulating material when the voltage is applied to the circuit. The dissipation factor is defined as the ratio of the conductance of a capacitor in which the material is the dielectric to its susceptance or the ratio of its parallel reactance to its parallel resistance.

Thermal Properties

Heat Deflection Temperature (HDT) (ASTM D 648)

Heat deflection is defined as the temperature at which a standard test bar deflects 0.010 in. under a stated load of either 66 or 264 psi. Heat deflection temperature is a single point measurement and does not indicate long-term resistance of plastic materials.

Apparatus And Test Specimens:

The apparatus for measuring heat deflection temperature consist of an enclosed oil bath fitted with a heating chamber and automatic heating controls that raise the temperature of the heat transfer fluid at a uniform rate

A cooling system is also incorporated to fast cool the heat transfer medium for conducting repeated test. The specimen are supported at steel supports that are 4 in. apart with a load applied on the top of the specimen vertically and midway between the supports. The contact edge of the support and of the piece by which pressure is applied is rounded to a radius of ¼ in. A mercury thermometer is used for measuring temperature. The unit is capable of applying 66 or 264-psi fiber stress on specimen by means of a dead weight.

Test procedure:

The specimen is positioned in the apparatus along with temperature and deflection measuring devices and the entire assembly is submerged into the oil bath kept at room temperature. The load is applied to a desired value. Five minutes after applying the load the pointer is adjusted to zero and the oil is heated at the rate of 0.2^0c/min the temperature of the oil at which the bar has deflected 0.010 in. is recorded as the heat deflection temperature at the specified fiber stress.

Vicat Softening Temperature (ASTM D 1525, ISO 306)

The vicat softening temperature is the temperature at which a flat-ended needle of 1 mm^2 circular cross section will penetrate a thermoplastic specimen to a depth of 1 mm under a specified load using a selected uniform rate of temperature rise. This test is very similar to a deflection temperature under the load test and its usefulness is limited to quality control, development and characterization of materials. The data obtained from this test is also useful in comparing the heat-softening qualities of thermoplastic materials.

The test apparatus designed for deflection temperature under load test can be used for the vicat softening temperature test with minor modification. The flat test specimen is molded or cut from a sheet with a minimum thickness and width of 0.12 and 0.50 in. respectively.

The test is carried out by first placing the test specimen on specimen support and lowering the needle rod so that the needles rest on the surface of the specimen. The temperature of the bath is raised at the rate of 50 or 120^0 c/hr uniformly. The temperature at which needle penetrates 1 mm is noted and reported at the vicat softening temperature.

Melt Flow Index (ASTM D 1238, ISO 1133)

The melt index also known as melt flow rate (MFR), test measures the rate of extrusion of a thermoplastic material through an orifice of specific length and diameter under prescribed condition of temperature and load. This test is primarily used as a means of measuring the uniformity of the flow rate of the material. The reported melt index value help to distinguish between the different grades of a polymer. A high molecular weight material is more resistant to flow than a low molecular weight material

Test Procedure:

The melt index apparatus is preheated to a specified temperature. The material is loaded into the cylinder from the top and specified weight is placed on a piston. The material is allowed to flow through a die. The initial extrudate is discarded because it may contain some air bubbles and contaminants. Depending on the material or its flow, cuts for the test are taken at different time intervals. The extrudate is weighted and melt index values are calculated in grams per 10 min.

An alternate method for making the measurement for materials with a high flow rate involves automatic timing of the piston travel by some electrical or mechanical device. The melt index value is calculated by using the following formula:

$$\text{Flow rate}=(426*L*d)/t$$

Where L=length of calibrated piston travel (cm)

d= density of resin at test temperature (g/cm^3)

t=time of piston travel for length L(sec)

WEATHERING PROPERTIES

The increased outdoor use of plastic has created a need for a better understanding of the effect of the environment on plastic materials. The environmental factors have on appearance and properties. The severity of damage depends largely on the nature of the environment, geographic location, type of polymeric material and duration of exposure. The major environmental factors that seriously effects plastics are-

1. Solar radiations – UV, IR, X-rays
2. Microorganisms, bacteria, fungus and mold
3. High humidity
4. Ozone and oxygen
5. Water vapor, liquid or solid
6. Thermal energy
7. Pollution: industrial chemicals

UV Radiations:

All types of solar radiations have some sort of detrimental effect on plastics. Ultraviolet radiations is the most destructive of all radiations.

The energy in UV radiations is strong enough to break molecular bonds. This activity in polymer brings about thermal oxidative degradation which results in embrittlement, discoloration and overall reduction in physical and electrical properties. One of the best methods of protecting the plastics against UV radiations is to incorporate UV absorbers or UV stabilizers into the plastic materials. The UV absorbers provide preferential absorption to most of the UV light thus the polymer is protected from harmful radiations through these organic and inorganic absorbers.

Ultraviolet stabilizers inhibit the bond rupture by chemical means or dissipate energy to lower levels that do not attack the bonds.

Accelerated Weathering Test:

Accelerated tests are often used to expedite screening the sample with various combinations of additive levels and ratios. A variety of light source are used that include carbon arc lamps, xenon arc lamps, fluorescent sun lamps and mercury lamps. Modern instruments have direct specimen spray on the front and backside of specimen. There are three major accelerated weathering tests:

- Exposure to carbon arc lamps
- Exposure to xenon arc lamps
- Exposure to fluorescent UV lamps

Exposure of plastics to Fluorescent UV lamps (ASTM G 53, ISO 4892)

This method is meant to stimulate the deterioration caused by sunlight and dew by means of artificial ultraviolet light and condensation. Ultraviolet light of wavelength between 290 and 350 nm is more efficient portion of sunlight that is damaging to plastic. The test apparatus basically consist of a series of UV lamps, a heated water pan and test specimen racks. The temperature and operating time are independently controlled both for UV and the

condensation effect. The test specimen are mounted on specimen racks with the test surface facing the lamp. The test conditions are selected based on requirements and programmed into the units. The specimen are removed for inspection at the predetermined time to examine color loss, crazing, chalking and craking.

Scratch Hardness Test

Scratch hardness is the oldest form of hardness measurement and was first developed by mineralogist back in 1822 F.Mohs evaluated comparative scratch hardness of many materials. However the mohs scale though convenient to apply is essentially qualitative in nature.

Pencil hardness tester:

Rating the hardness of an organic finish according to the hardness of lead pencil that will just scratch it was described by Wilkinson and Gardner studied the method using pencils sharpened different shapes: sharp cones, rounded cones, and chisels. He found the principal source of error lay in the character of a point. Gardner built a device to hold eight pencils at one time at an angle of 450 to the panel, but found that it was impossible to align all pencils uniformly. Modern production has overcome this problem and several companies offer the pencil hardness gage composed of eight mechanical drawing lead holders permanently mounted in a circular array on a plastic cylinder.

In this test, pencil leads of increasing hardness value one forced against a coated surface in precisely defined many until one lead

marks the surface, surface hardness is defined by the hardest pencil grade which fails to mark organic coating surface.

Today pencils are available in about 14 grades of hardness ranging from softest 6B to hardest 6H. The range in hardness from softest to hardest as follows:6B, 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, and 6H.

PROCESSABILITY

The processing characteristics of a material are a function of its formulation and the processing condition employed.

Injection Moulding Process:
Start up temperature for reciprocating Screw machine

Injection Condition	**^{0}C**
Rear	200-220
Center	215-235
Front	225-245
Nozzle	225-240
Mould Temp.	80-90
Material Temp.	240-250

Processing parameters

Moulding Defects and Remedies:

Defects	Remedies
Short shot (mould not filled) or rippled surface, usually in an area farthest from gate	1. Adjust feed to minimum consistent cushion. 2. Increase injection pressure. 3. Increase injection speed. 4. Increase back pressure. 5. Increase screw speed to give higher melt temp. 6. Raise cylinder temp. 7. Increase mould temp.for very thin large area part.
Weld line, knit lines resulting from separation and rejoining of the melt in mould	1. Increase injection pressure. 2. Adjust injection speed. 3. Increase back pressure 4. Increase screw speed to give higher melt temp. 5. Raise cylinder temp 6. Increase mould temp.for very thin large area part. 7. Ensure that the vents are adequately sized and clear. 8. Use short sprue with an extended nozzle.
Splash, tear drops, mica surface, splay marks, silver streaks, flow lines caused by escaping volatile material or moisture.	1. Increase injection pressure. 2. Increase back pressure. 3. Reduce screw speed. 4. Adjust injection speed. 5. Increase feed zone temp. 6. Increase mould temp. 7. Dry the material more thoroughly.

Sink marks caused by the back flow of material or shrinkage of part.	1. Increase injection pressure 2. Increase injection forward time. 3. Reduce screw speed. 4. Reduce nozzle and metering zone temp. 5. Increase feed zone temp. 6. Adjust back pressure. 7. Increase mould temp. 8. Reduce cooling time in mould. 9. Enlarge gates and runners.
Cold slug caused by cooling of the melt in the nozzle.	1. Increase nozzle temp. 2. Reduce injection speed. 3. Put cold slug well in mould opposite sprue bushing.
Warping caused by uneven forces trying to relax in the hot part.	1. Increase mould closed time. 2. Adjust injection forward time. 3. Increase ram speed. 4. Use differential mould temp. 5. Raise cylinder temp. 6. Increase nozzle and metering zone temp. 7. Cool parts in water at 40 to 50 ^{0} C.
Burning or trapping air in the mould caused by insufficient venting to the cavities.	1. Decrease injection speed & injection pressure. 2. Decrease clamping pressure. 3. Adjust mould temp. 4. Decrease cylinder temp. 5. Check venting of the cavity. 6. Relocate gate.

Burning or trapping air in the cylinder	1. Increase back pressure. 2. Reduce screw speed. 3. Reduce feed zone temp. 4. Use machine with larger cylinder shot size.
Internal bubbles in thick moulded parts caused by insufficient packing and/or excessive shrinkage.	1. Increase injection forward time. 2. Increase injection pressure. 3. Reduce cooling time in mould. 4. Decrease injection speed. 5. Adjust back pressure. 6. Reduce cooling time in water bath. 7. Increase temp. Of water bath. 8. Decrease nozzle and metering zone temp. 9. Increase feed zone temp.
Crazing, minute surface fractures	1. Clean mould surface in area of crazing. 2. Increase injection speed. 3. Modify injection forward time. 4. Decrease injection pressure. 5. Increase mould temp. & decrease gate size.
Delamination	1. Increase mould temp & /or cylinder temp. 2. Eliminate contamination.

Experimental Work

Objective: -

To develop a material for automobile lightening lenses which have optimum properties like high heat resistance, high impact resistance, optical properties, low hazing property.

Experiment no.-1

Work done:

Definite amount of standard grade Altuglas resin & impact resistant Altuglas resin is added.
Standard grade Altuglas resin taken is V 825 T (90%)
Impact resistant Altuglas resin taken is DRT (10%)

Observation:

Properties	V 825 T (90%)	DRT (10%)	Modified Grade
Density	1.19	1.15	1.18
Mould shrinkage	0.2-0.6	0.2- 0.8	0.2-0.7
Tensile strength	70	38	65
Elongation at break	6	40	15
Hardness	**M-97**	**M-46**	**M-89**
Impact resistance (unnotched)	11	60	20
Impact resistance (notched)	2	7	3.5
Haze	0.5	2	1.0
Dielectric strength	19.7	15	18.5
VST ^{0}C	108	100	105
HDT 1.8 Mpa	100	88	95
Melt flow index	2.8	0.8	2.2

Table-8

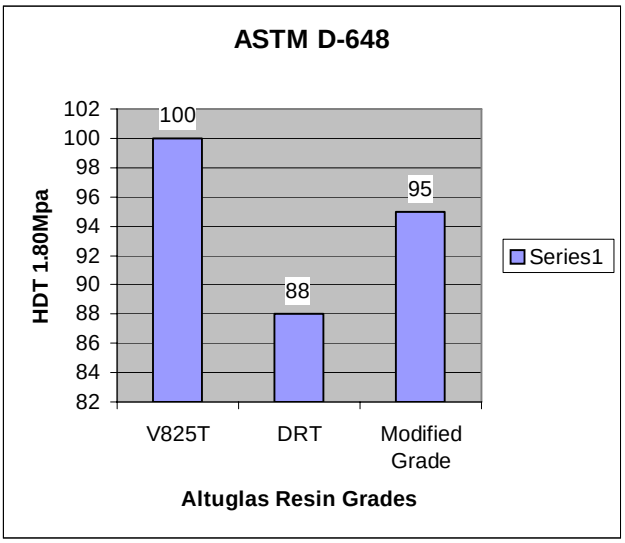


Fig. 1

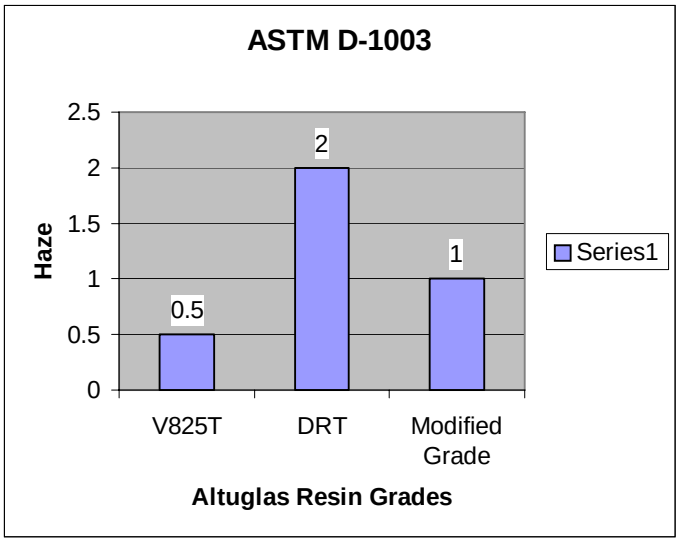


Fig. 2

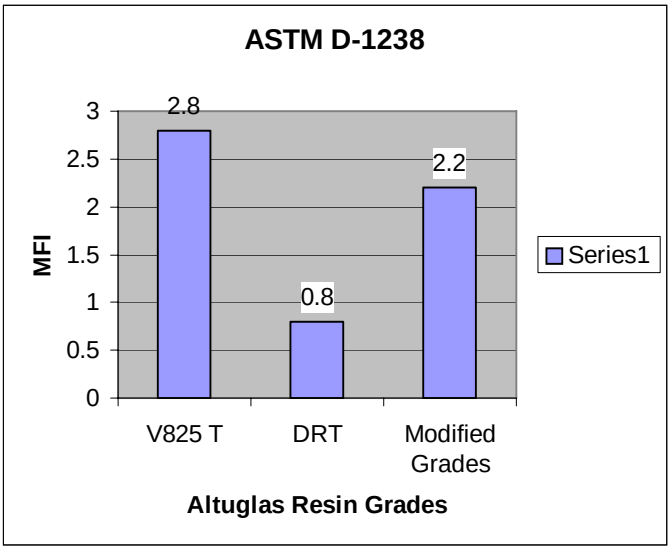


Fig. 3

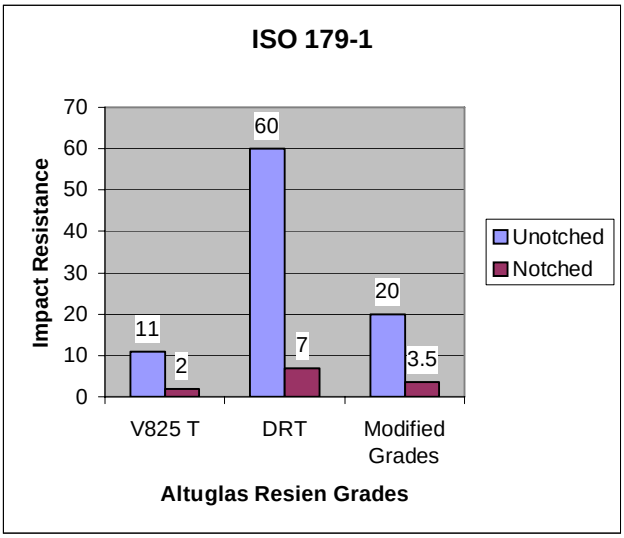


Fig. 4

Experiment no.-2

Work done:

Definite amount of standard grade Altuglas resin & impact resistant Altuglas resin is added.
Standard grade Altuglas resin taken is V 825 T (80%)
Impact resistant Altuglas resin taken is HFI-7 (20%)

Observation:

Properties	V 825 T (80%)	HFI-7 (20%)	Modified Grade
Density	1.19	1.17	1.18
Mould shrinkage	0.2-0.6	0.2- 0.6	0.2-0.6
Tensile strength	70	48	60
Elongation at break	6	25	12
Hardness	**M-97**	**M-65**	**M-83**
Impact resistance (unnotched)	11	35	14
Impact resistance (notched)	2	3	2.4
Haze	0.5	1.5	0.9
Dielectric strength	19.7	17.7	18.0
VST ^{0}C	108	90	100
HDT 1.8 Mpa	100	83	92
Melt flow index	2.8	11	5.0

Table-9

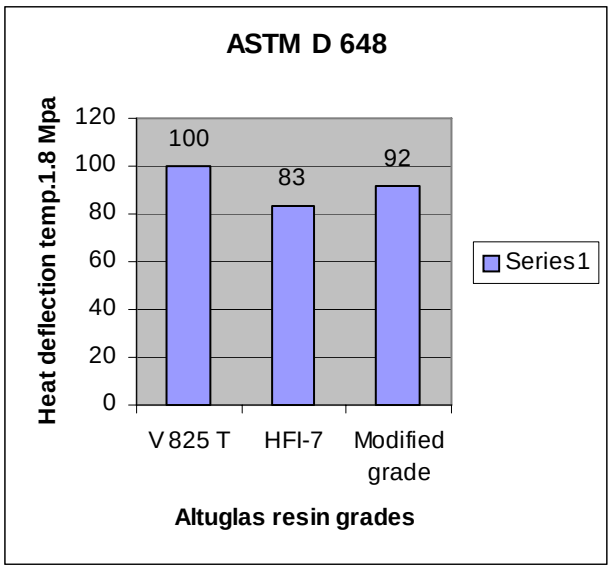


Fig.5

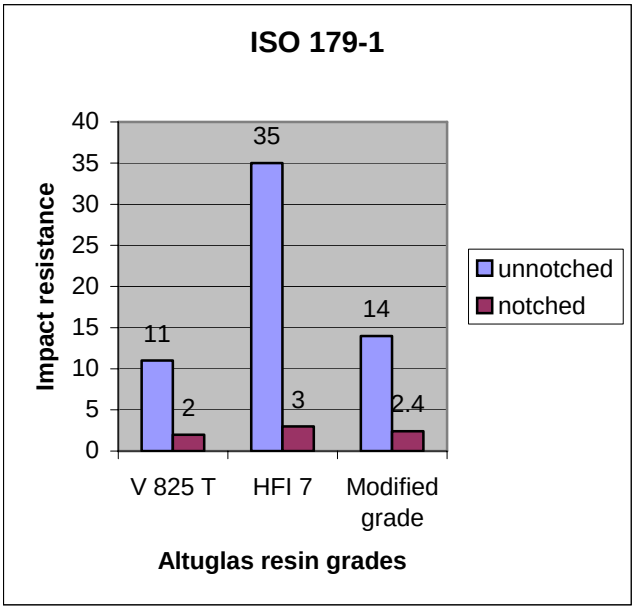


Fig.6

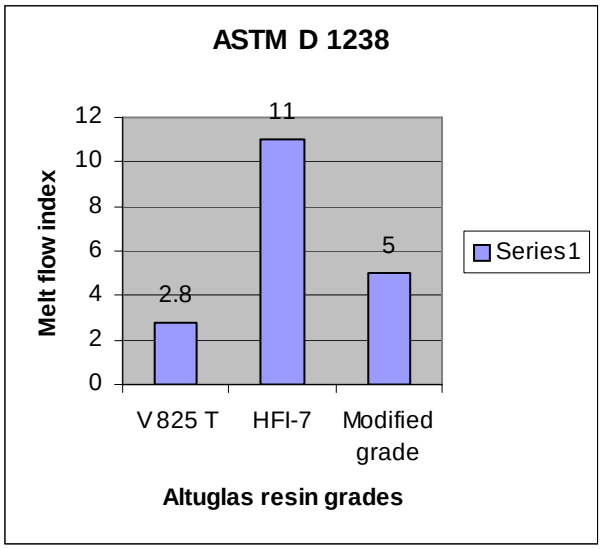


Fig.8

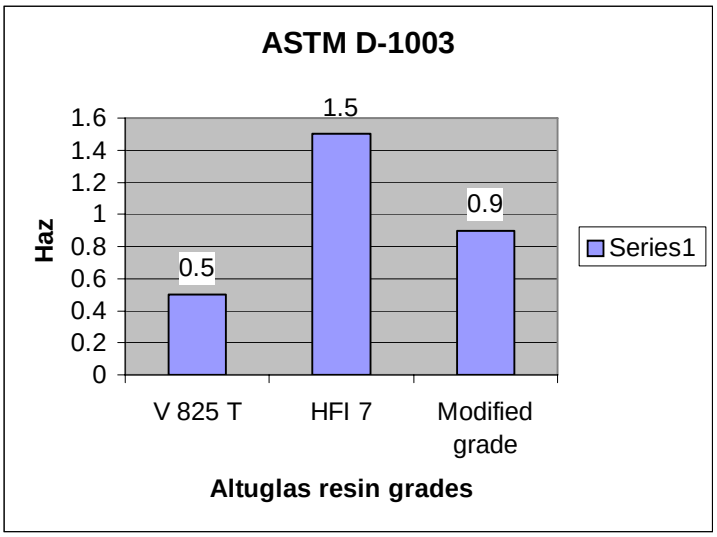


Fig.7

Experiment no.-3

Work done:

Definite amount of standard grade Altuglas resin & impact resistant Altuglas resin is added.

Standard grade Altuglas resin taken is V 825 T (90%)

Impact resistant Altuglas resin taken is HFI-7 (5%) & DRT (5%)

Observation:

Properties	V 825 T (90%)	HFI-7 (5%)	DRT (5%)	Modified Grade
Density	1.19	1.17	1.15	1.16
Mould shrinkage	0.2-0.6	0.2- 0.6	0.2-0.8	0.2-0.7
Tensile strength	70	48	38	67
Elongation at break	6	25	40	10
Hardness	M-97	M-65	M-46	M-85
Impact resistance (unnotched)	11	35	60	16
Impact resistance (notched)	2	3	7	2.6
Haze	0.5	1.5	2	0.7
Dielectric strength	19.7	17.7	15	18.5
VST ^{0}C	108	90	100	102
HDT 1.8 Mpa	100	83	88	94
Melt flow index	2.8	11	0.8	3.8

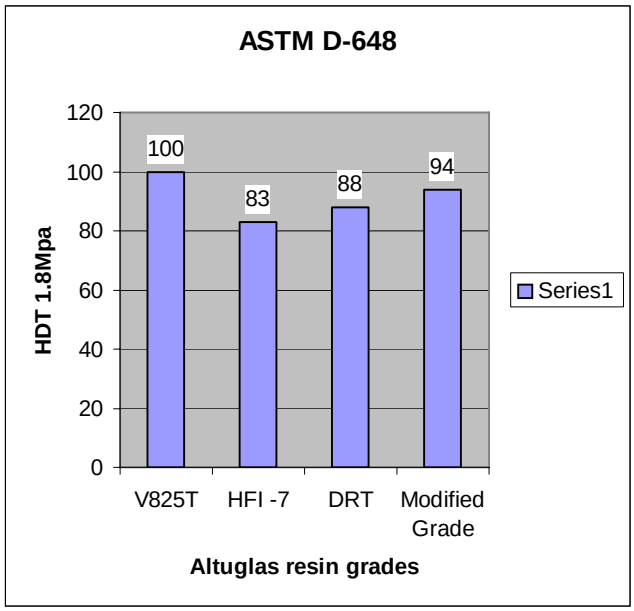


Fig.9

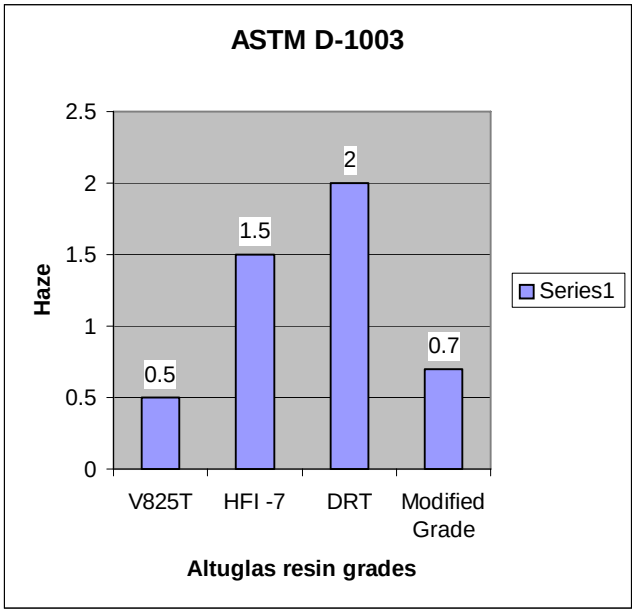


Fig.10

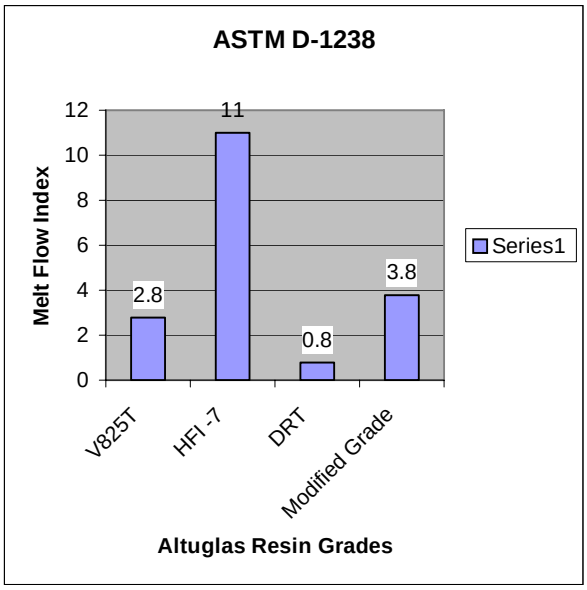


Fig.11

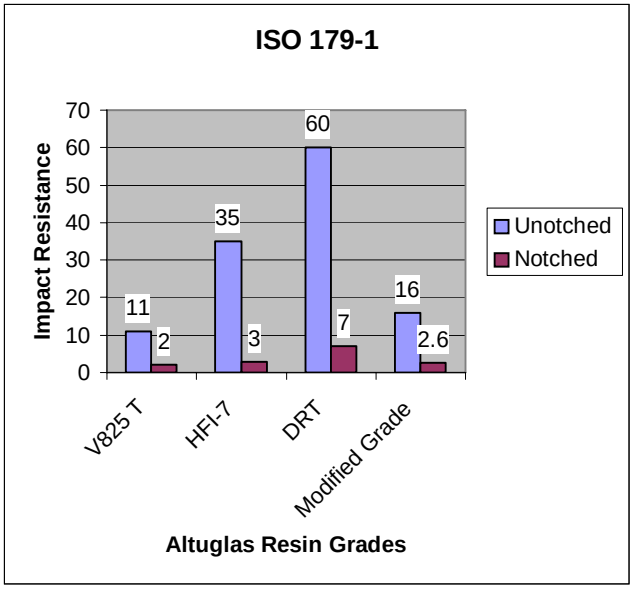


Fig.12

Experiment no.-4

Work done:

Definite amount of standard grade Altuglas resin & impact resistant Altuglas resin is added.
Standard grade Altuglas resin taken is V 825 T (80%)
Impact resistant Altuglas resin taken is HFI-7 (10%) & DRT (10%)

Observation:

Properties	V 825 T (80%)	HFI-7 (10%)	DRT (10%)	Modified Grade
Density	1.19	1.17	1.15	1.18
Mould shrinkage	0.2-0.6	0.2- 0.6	0.2-0.8	0.2-0.7
Tensile strength	70	48	38	64
Elongation at break	6	25	40	14
Hardness	**M-97**	**M-65**	**M-46**	**M-87**
Impact resistance (unnotched)	11	35	60	18
Impact resistance (notched)	2	3	7	3.3
Haze	0.5	1.5	2	0.6
Dielectric strength	19.7	17.7	15	16.7
VST ^{0}C	108	90	100	103
HDT 1.8 Mpa	100	83	88	93
Melt flow index	2.8	11	0.8	4.5

Table-11

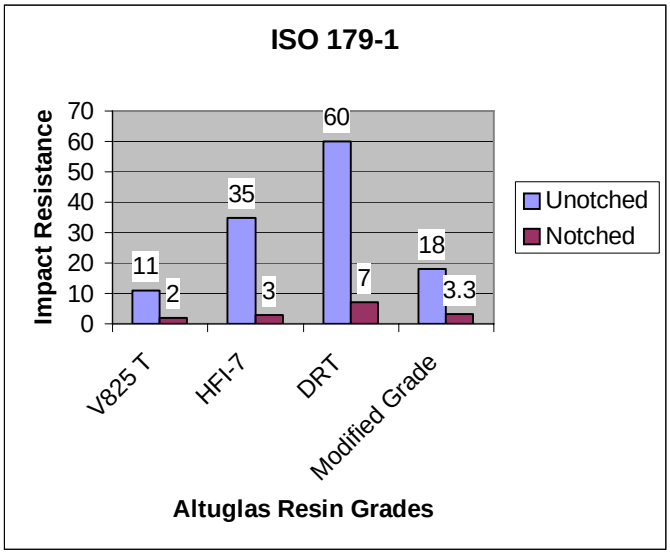


Fig.13

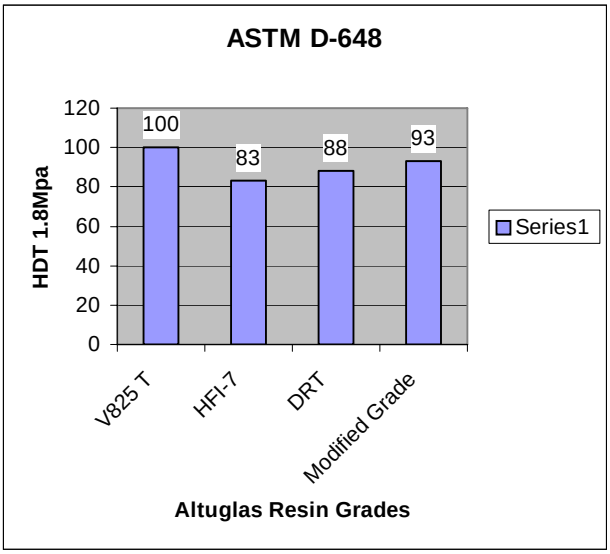


Fig.14

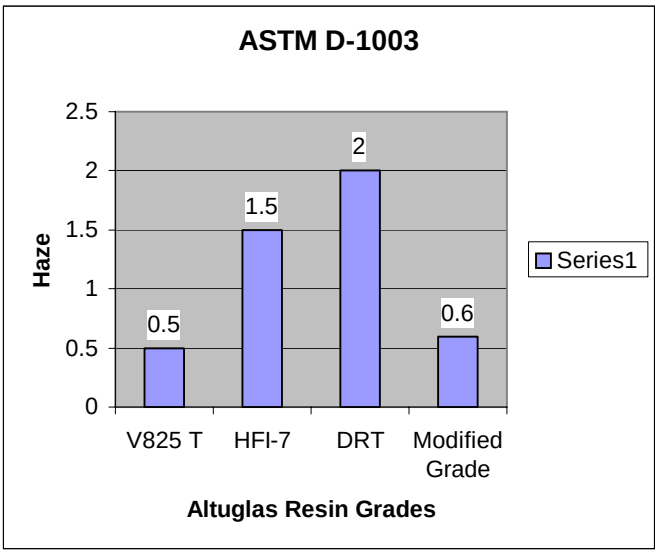


Fig.15

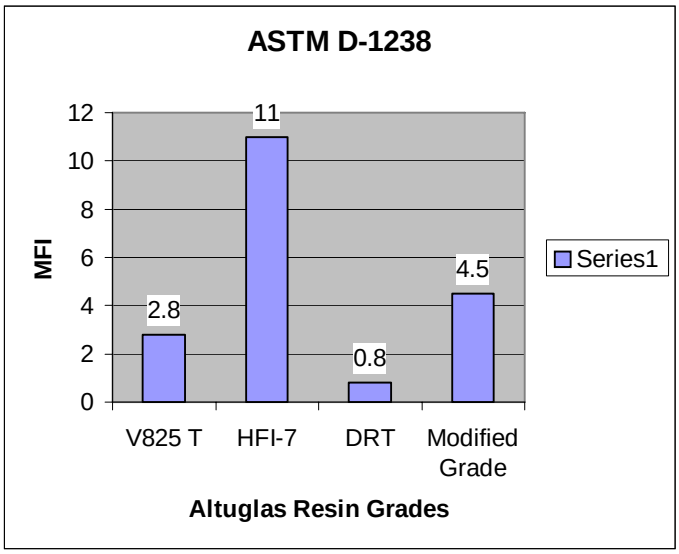


Fig.16

RESULT

Fig.17

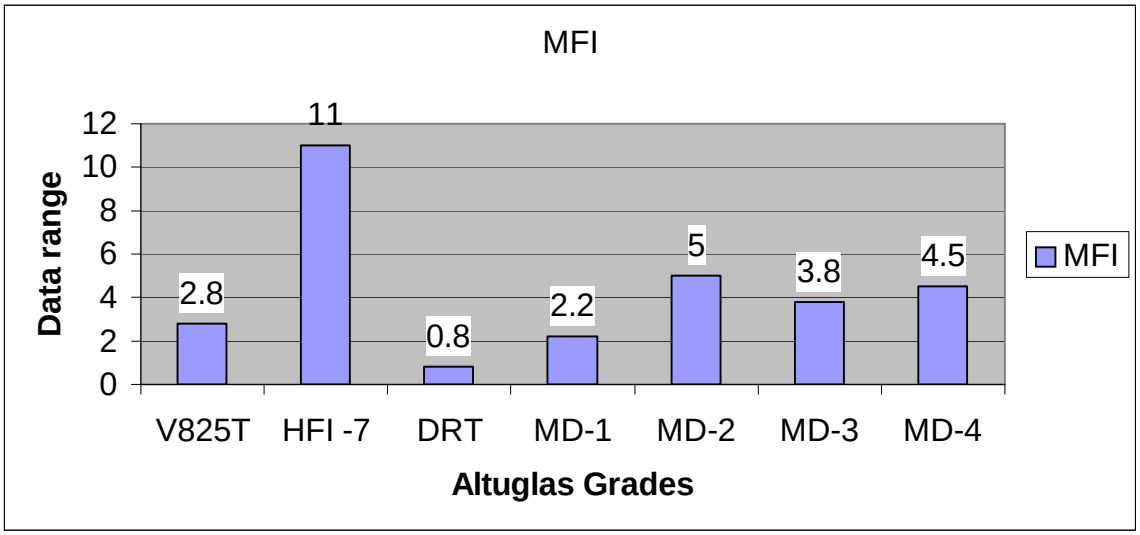


Fig-18

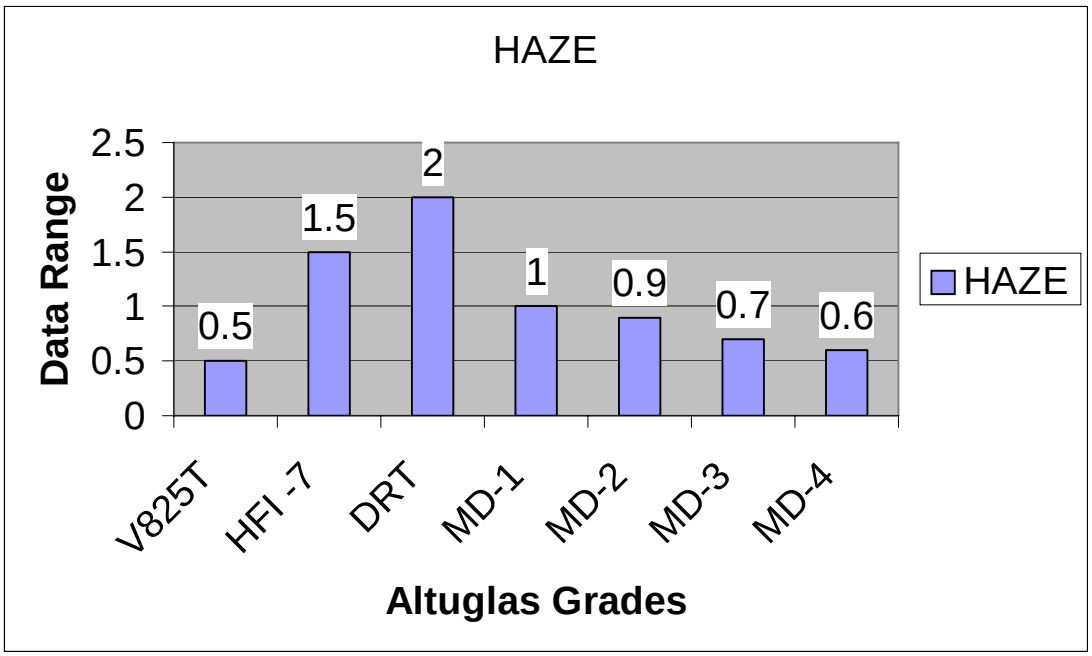


Fig-19

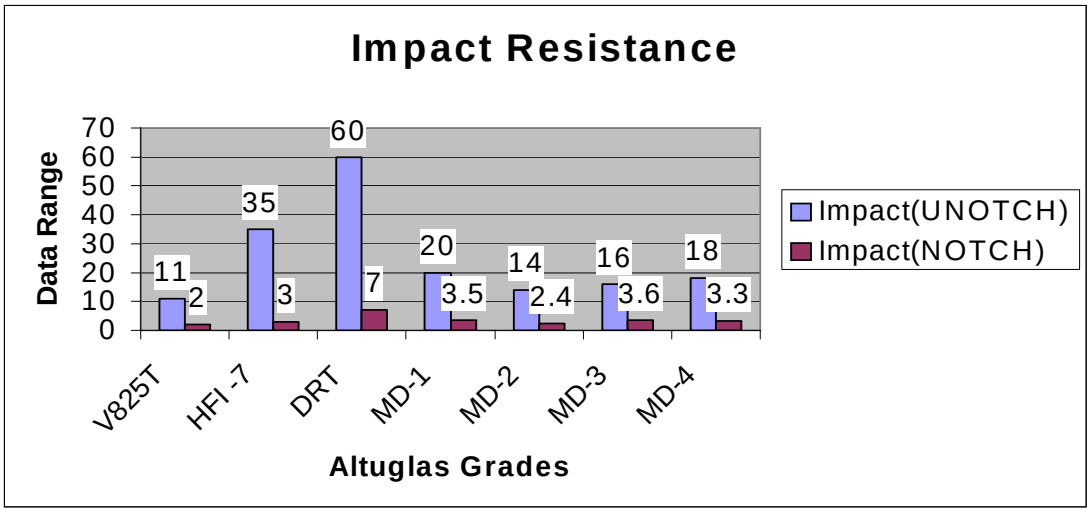
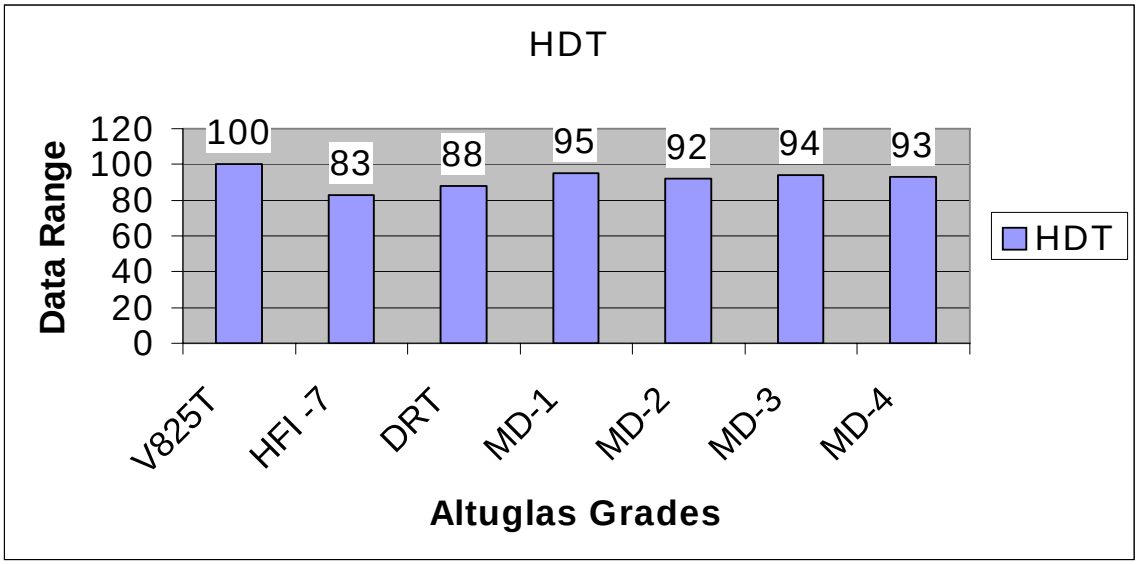


Fig-20



It was found that MD-4 (Modify grade) is the best with optimum properties for the application of automotive lenses.

Scope of the work

- This work gives an idea to design a grade for specific product by blending of different grades of same engg.polymers.

- To analysis the properties variation by blending of different grades of same engg.polymers.

BIBLIOGRAPHY

1. Plastic Materials by J.A. Brydson
2. Physical chemistry of materials by A. Tager
3. Handbook of testing technology by V. Shah
4. Encyclopedia of Polymer science and Technology by Nicholas P. Cheremisinoff
5. Synthetic Resin Technology by EIRI Consultants&Engineers.
6. By Internet links

**** http://en.wikipedia.org/wiki/Image:PMMA-repeat.png

***** http://en.wikipedia.org/wiki/Image: Methyl-methacrylate-skeletal.png

***** http://www.swicofil.com/products/278polymethylmethacrylate.html

7. By Altuglas technical manual