Short Review on Thermal and Mechanical Properties of Polymers

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Abstract: In recent years the importance about the use of the polymeric materials in various fields has been growing fastly.The thermal and mechanical properties plays a important role in determining their glass transition temperature (T_g), degradation temperature, melting temperature, crystallinity, tensile strength, stress, elongation at break, stiffness, hardness, toughness, embrittlement etc. The aim of this review is to understand how these properties changes with the different preparation methods, reaction conditions including temperature, pressure and catalyst. The current review also highlighted on characterization techniques for measurements of these properties.

Index Terms: *DSC, Tg, Stress, Strength*

INTRODUCTION:

There is a demand for synthesis of new polymeric materials which are able to functionalize in order to give desired thermal and mechanical properties for different applications. A new class of materials that is polymer composites gives large engineering applications. Thermosetting Polymers are high-molecular-weight polymers possessing highly cross-linked network structure along with useful properties, and this type of materials received considerable research interest for various applications. This review highlights background of thermal properties of thermosetting polymers and there, glass transition temperature, thermal stability, thermoset polymers such as epoxy resin polyester, phenol-formaldehyde urea formaldehyde resin. Natural graphite powder compounded with low density polymers to improve thermal stability. Thermosetting polymers are the class of polymer obtained from cross-linking of thermosetting resin or condensation polymerization techniques and cross-linking agent like sulphur, ZnO for natural rubber along with an initiator are used. three-dimensional network structure is obtained through the cross-linking. These polymers cannot be remoulded or rechaped due to the formation of an irreversible chemical bond. So thermosetting polymers are havaing high melting temperature and high mechanical properties

THERMAL PROPERTIES OF POLYMERS:

While thermal analysis using Differential Scanning Calorimetry (DSC) the amorphous region of the polymer, at lower temperature, the molecules of the polymer frozen state, where the molecules can vibrate but are not able to move. All molecular vibration almost in frozen condition and polymer behaves like a glass this state of the polymer is called as the glassy state. In this state, the polymer is hard, rigid and brittle, similar to glass. Therefore it is called the glassy state. This glassy state shows brittle nature similar to a crystalline solid with molecular disorder as a liquid. If further when polymer is heated then polymer chains are away from each other, and the polymer becomes soft and flexible like a rubber. This state is called the rubbery state. The temperature at which polymer molecules becomes hard and brittle and above which behave like a glass is known as glass transition temperature.(Tg) Note that the glass transition occurs only in the amorphous region, and the crystalline region remains unaffected during the glass transition in semicrystalline polymeric materials.

MELTING POINT (T_M) AND GLASS TRANSITION TEMPERATURE (Tg):

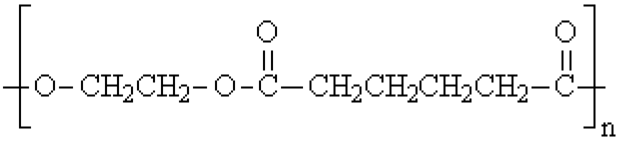
Tg is the property of the amorphous region of the polymer and on the other hand crystalline region is characterized by the melting point. The transitions are described first and second order transitions. Tg is the second order transition, whereas the Tm is the first order transition The value of T_g is not unique because the glassy state is not in equilibrium. T_g depends on several factors such as molecular weight, crystallinity, presence of bulky group on side chain, addition of plasticizer etc. T_g of some standard polymers are shown below.

Table1: Glass Transition Temperature of some polymers

Name of Polymers	T_g (^{0}C)
Polyvinly Chloride	87
Polystyrene	100
Polyl-lactide	60
Nylon	66
Low Density Polyethylene	-120
Polycarbonate	150
Polyethylene terephthalate	69

FACTORS AFFECTING ON GLASS TRANSITION POLYMERS:

The glass transition temperature depends on the mobility of polymer chain



$$\left[-O-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-CH_2CH_2CH_2CH_2-\overset{O}{\overset{\|}{C}}- \right]_n$$

Fig 1: Poly(ethylene adipate)

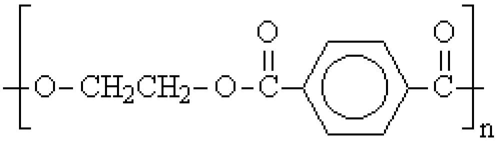
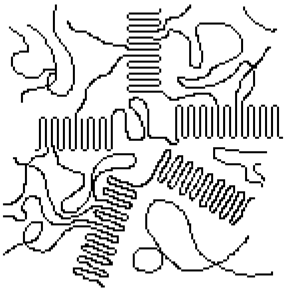


Fig 2: Poly(ethylene terephthalate) (Source Google)

In above two figures Tg of Poly(ethylene adipate) is -70^{0}C and Poly(ethylene terephthalate) is 69 ^{0}C. This is due to bulky group (benzene) present in the polymer structure. It restrict the rotation aroud the carbon carbon bond.

Crystallinity:



Fig; 3 Crystalline and Amorphous region of polymer molecule (Source Google images)

The well ordered arrangement of polymeric chains shows crystalline region of polymers and unordered arrangement region shows amorphous region of polymer chains. The parallel arrangement is due to the strong intermolecular force of attractions among the chains and amorphous region show weak intermolecular attacraction between them. If percentage of crystallinity is high, high is the Tg of polymers.

Plasticizers

Plasticizers are low molecular weight materials added to polymers to increase the flexibility of chains and reduce the intermolecular cohesive forces between the polymer chains which result decrease in glass transition temperature..

Molecular Weight:

Tg is also affected by the molecular weight of the polymer, T_g is increased with the molecular weight. The molecular weight (high or low)is related to the glass transition temperature by the Fox–Flory Equation

EXPERIMENTAL METHODS FOR THERMAL PROPERTIES:

Differential scanning calorimetric (DSC) measurements were made on a Perkin-Elmer thermal analyzer model DSC-Q10 in a nitrogen atmosphere. The measurements were run from –40 to 250 0C at a heating rate of 10 0C/ min and a cooling rate of 100 0C/ min.

RESULTS:

DSC characterization Result of polyethylene polymers.

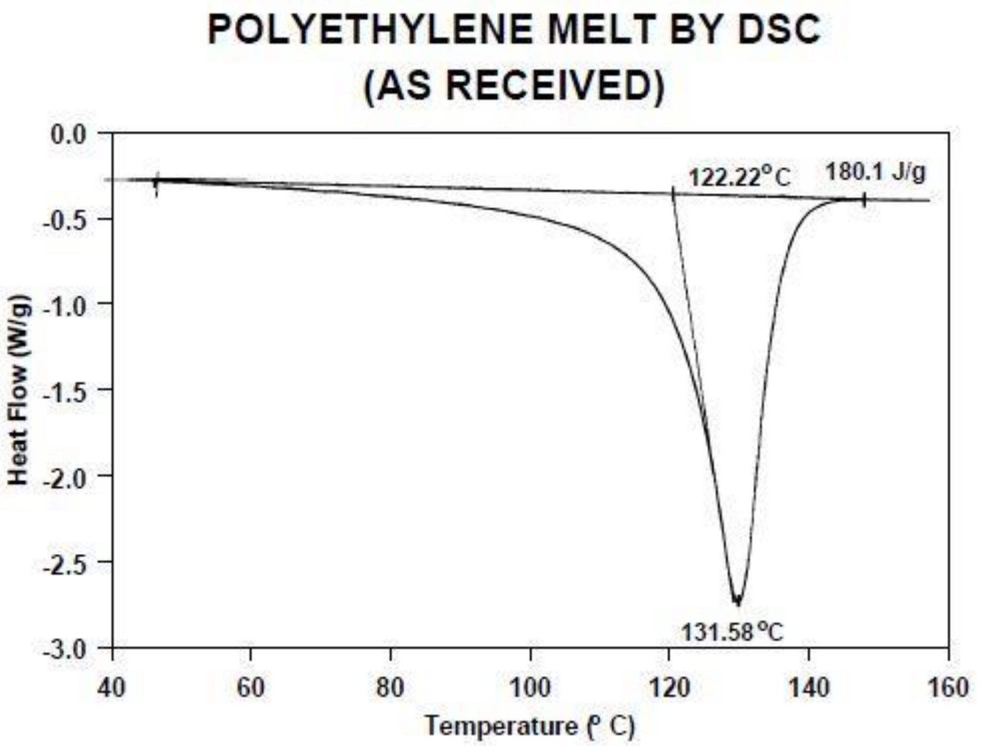


Fig: 4: DSC of Polyethylene (Source: AZO Materials)

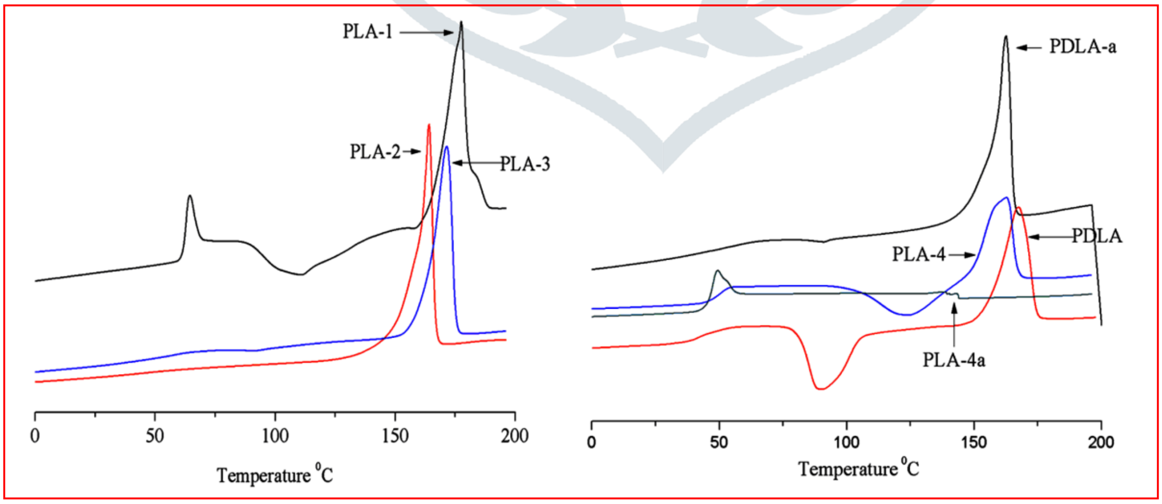


Fig 5 Differential Scanning Calorimetry (DSC) of poly(lactide)s synthesized using cloisite modified catalyst showing melting points

MECHANICAL PROPERTIES:

It is important to know the basic mechanical properties of the polymers before its actual application in various fields; these properties are stretch, how hard and soft and elongation at break etc. Composites materials meet these properties (like stiffness, tensile strength) for different engineering applications.

Factors affecting on strength of polymers:

1)Strength

Molecular weight: Increase in molecular weight increases the strength of the polymers up to certain limits and beyond that no change in strength.

Crystallinity: Hight crystallinity increases the strength because of strong intermolecular force of attraction within the polymeric chains.

Cross Linking: Crosslinking restricts the molecular motion of the polymeric chains and increases the strength of the materials.

2) Elongation at Break: It is the strain present in the materials on its break point. It is percentage change in the length of the material before it break.

RESULTS:

Following graph shows change in stress strain mechanical properties with the addition of Biochar as a filler. Author observed that addition of 1 wt% of Biochar materials not improved the stress strain properties. However it shows modification of ductile properties increases over addition of 2 to 4 wt% biochar materials.

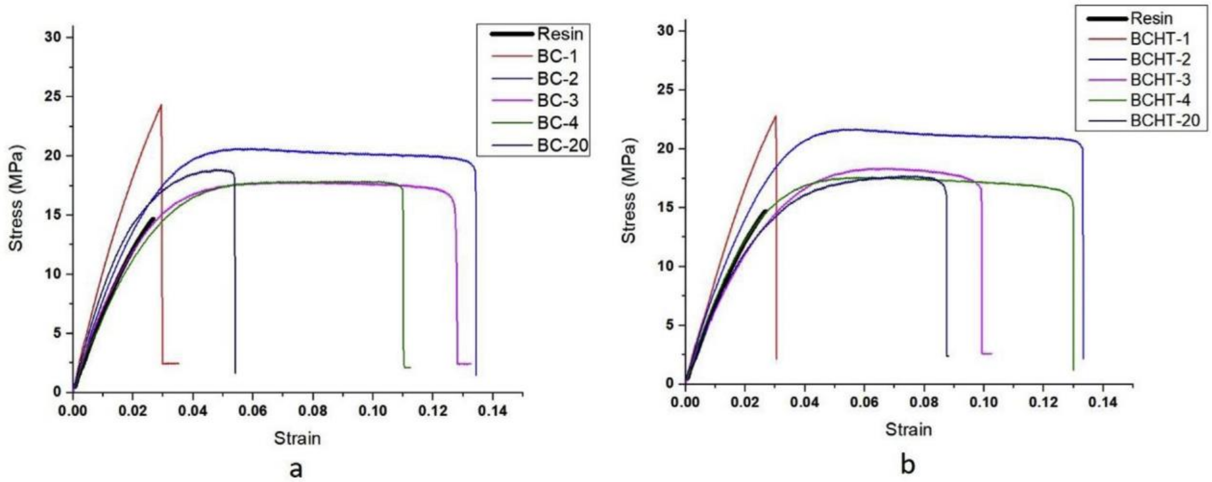


Fig: 6 Stress-strain curve comparison (Sorce:Mauroand etal group research article).

Table 2: Mechanical properties of PLA composites

Material	Elongation at Brek (%)	Flexural Strength (Mpa)
Net PLA	12.3	63.34
10 % cellulose	91.8	9
30% cellulose	95.3	8.4

(Souece Intal S and etal grou research article)

Data from table 2 shows change in elongation at break and fluxeral strength changes due to addition of cellulose.

CONCLUSION:

Thermal and mechanical properties are different for different polymers. Generally melting temperature of polymer increases with the addition of filler as a compounding of polymer. Glass transition temperarure should be in low range for the application at room temperarure, specially cold countries. A mechanical property varies with physical properties of polymers like molecular weights.fluxeral properties can be improved with adition of different wt% foreign materials.

ACKNOWLEDGMENT:

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