# Compatibility Studies On Polystyrene/Poly (Vinyl Chloride) Blends By Dynamic Mechanical Analysis And Fourier Transformed Infra-Red Spectroscopy

**J. Y. Gyang[1],*, P. A. P. Mamza[1] and M. T. Isa[2]**

**[1]Department of Chemistry, Faculty of Physical Sciences, Ahmadu Bello University, Zaria, Nigeria**
**[2]Department of Chemical Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria**

*Corresponding author: josesygyang@gmail.com**
**Phone number: +2348088087004**

**ABSTRACT**
This study focused on the compatibility of the blends of PS/PVC. Polystyrene is brittle and unstable at elevated temperatures, but it is cheap and easy to process. Poly (vinyl chloride) has advantages of stability from ultra-violet rays, cheap and availability, flame retardant etc. The blends of PS/PVC were prepared at different compositions of 100/0, 0/100, 80/20, 60/40, 40/60 and 20/80. Two roll mill machine was used to compound the blends at $180^oC$, the compounded blends were compressed in hot moulds at $180^oC$ for five minutes under 4Pa pressure and the blend specimens produced from this process were kept for characterization. Samples from each composition were cut according to ASTM standards for DMA and FTIR to study the extent of their compatibility. FTIR spectrum for 80/20 composition showed the absence of C-Cl band, C-Cl band was also absent in the 60/40 spectrum, the spectrum for 40/60 showed the absence of =C-H aromatic stretching band, $CH_2$ band was absent in the 20/80 composition, the absence of these bands suggests chemical interactions of the two polymers. Glass transition temperature of 40/60 composition as observed on the storage modulus curve against temperature showed mutual shift of the $T_g$'s of PS and PVC towards each other. The FTIR and DMA results jointly showed that 40/60 PS/PVC blend is compatible.
**Keywords:** Compatibility, Polystyrene, Poly (vinyl chloride), Blends, DMA and FTIR.

## 1.0 INTRODUCTION
A polymer blend is a mixture of two or more polymers that have been blended together to create a new material with different physical properties (Grohens, *et al*., 2015). Polymer blending has attracted much attention as an easy and cost-effective method of developing polymeric materials that have versatility for commercial applications. In other words, the properties of the blends can be manipulated according to their end use by correct selection of the component polymers (Grohens, *et al*., 2015). Blending of polymers is considered as one of the simplest means of getting a variety of physical and chemical properties from the constituent polymers. The gain in better properties of polymers depends on their degree of compatibility or miscibility at a molecular level (Shivakumar *et al*., 2012 and Jin *et al*., 1998).
 Polymer blend is a macroscopically homogeneous mixture of two or more different species of polymers (Work *et al.,* 2004). Polymer blends and composites both have been of great commercial importance, polymer blends alone makes up currently over 30% of the polymer market. Blending of polymers is of great interest to researchers due to the fact that it represents an approach to the achievement of new combinations of desired properties without having to synthesize new polymers (Evstatiev *et al*., 2000).  The properties of a polymer mixture are determined mainly by the miscibility

of the components and the structure. This condition is fulfilled when strong specific intermolecular interactions exist between the components of a mixture (Aquino *et al.,* 2011). The production of blends usually requires little or no extra expenditure compared to new polymer synthesis (Khan *et al.*, 2008).

Polystyrene has the following properties; it is clear, transparent, can be easily fabricated, and possess high mechanical strength in addition to maintaining thermal properties. It is slightly brittle in nature and gets soften at $100^oC$ which sustains it to be used in formulations that require sterilization. At elevated temperatures, a mixture having low molecular weight compound and styrene will be formed as decomposition products (Arfin *et al.*, 2013). The principal limitations of polystyrene are its brittleness, limited mechanical stability at elevated temperature (glass transition temperature, $T_g$, of $100^0C$) (Mamza and Folaranmi, 1996) and its susceptibility to chemical attack.

Optical properties of Poly (Vinyl chloride)/polystyrene blends were studied by Saeed and Hassan, (2014). The absorption coefficient of the material was determined using UV-VIS. Spectrometer. They concluded that there was strong absorption between (200 – 290) nm. They also said that the 50% PVC / 50% PS blend showed the best optical properties and that the absorption coefficient, extinction coefficient, refractive index for (50% PVC / 50% PS) show significant change from samples in comparison with other blend samples.

Fang *et al.*, (2000) carried out a study on the morphology of poly (vinyl chloride)/polystyrene blends by electron microprobe analysis method. They concluded through their results that PVC and PS are incompatible.
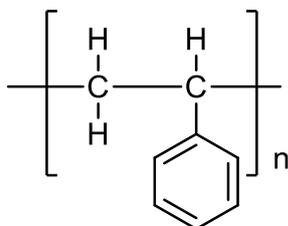


Structure of Polystyrene

Poly (vinyl chloride) (PVC) is one of the most commonly used thermoplastic materials in worldwide polymers. PVC has low cost, high performance and high possibility of producing a variety of products from different processing conditions and techniques Norazlina *et al.*, (2015). Poly (vinyl chloride) is extremely important with useful molecular structure and morphology in every area for example, it is used as thermoplastics due to its many valuable properties like low price, good process ability, chemical resistance and low flammability Kok *et al.*, (2008). The chemical resistance and good weatherability of PVC can be used to improve the susceptibility to chemical attack of PS and its brittleness. This work is aimed at studying the compatibility of PS/PVC blends at different compositions for household usage.

Dynamic Mechanical Analysis is a method recently used in the study of compatibility of polymer blends using glass transition temperature.
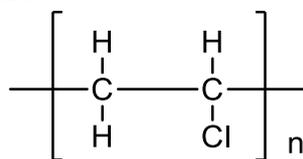


Structure of Poly (vinyl chloride)

## 2.0 MATERIALS AND METHOD
### 2.1 Materials
PS (grade: H-616, transparent) produced by Solarene, Korea was supplied by Shivlila polymer Ltd, Kano State, Nigeria. PVC (grade: K67) powder was supplied by Panar Ltd Sharada, Kano State, Nigeria. The materials were compounded in a two roll mill and compression moulded into sheets. The blended specimens were then cut according to ASTM D4065 for DMA characterization.

**2.2 Preparation of Blend Compositions**
The table below shows how the blend compositions were made in percentages

**Table 2.1 The Compositions of PS/PVC Blends**

| Compositions | Polystyrene (%) | Poly (vinyl chloride) (%) |
|:---:|:---:|:---:|
| 1 | 100 | 0 |
| 2 | 80 | 20 |
| 3 | 60 | 40 |
| 4 | 40 | 60 |
| 5 | 20 | 80 |
| 6 | 0 | 100 |

A total solid content of 100g was measured and used, using a digital weighing balance.

**2.3 Compounding and Compression Moulding of the Blends**
The compounding was done to ensure proper and thorough mixing of the polymer blends together. The two roll mill machine was used for the compounding process; it was heated to about $180^{o}$C to ease the melting of the polymers before they were finally introduced into the two roll mill machine. The compression moulding machine was used to compress the already mixed and cooled polymer blends, the materials placed in hot plates of 3mm thick and a dimension of 10x10mm were pressed at $180^{o}$C for five minutes under the pressure of 4Pa and the sheets produced from this process were kept for characterization.

**2.4 Fourier Transform Infra-Red (FTIR) Spectroscopy**
The FTIR machine model CARY 630 Agilent Technologies at Multi-User laboratory, Chemistry Department of Ahmadu Bello University Zaria. A blade was used to cut some pieces of the compressed blend samples for the test according to ASTM E168. Transmittance method was used with thirty (30) scans and background scans of sixteen (16), a resolution of eight (8) was used and the samples were scanned within the range of 4000 to 650cm$^{-1}$. This was used to investigate the functional groups of the individual polymers and the blends.

**2.5 Dynamic Mechanical Analysis (DMA)**
Dynamic mechanical properties of the blends of PS/PVC in this study were conducted in the strength of material laboratory, Department of Mechanical Engineering, Ahmadu Bello University, Zaria. NETZSCH DMA 242 machine was used, at frequencies of 2.5Hz, 5Hz and 10Hz, temperature range of $32^{o}$C – $150^{o}$C and a heating rate of 5.0K/min the glass transition temperature was determined from the onset of the storage modulus (E′) drop. The glass transition was used as a criterion for the polymer blends compatibility.

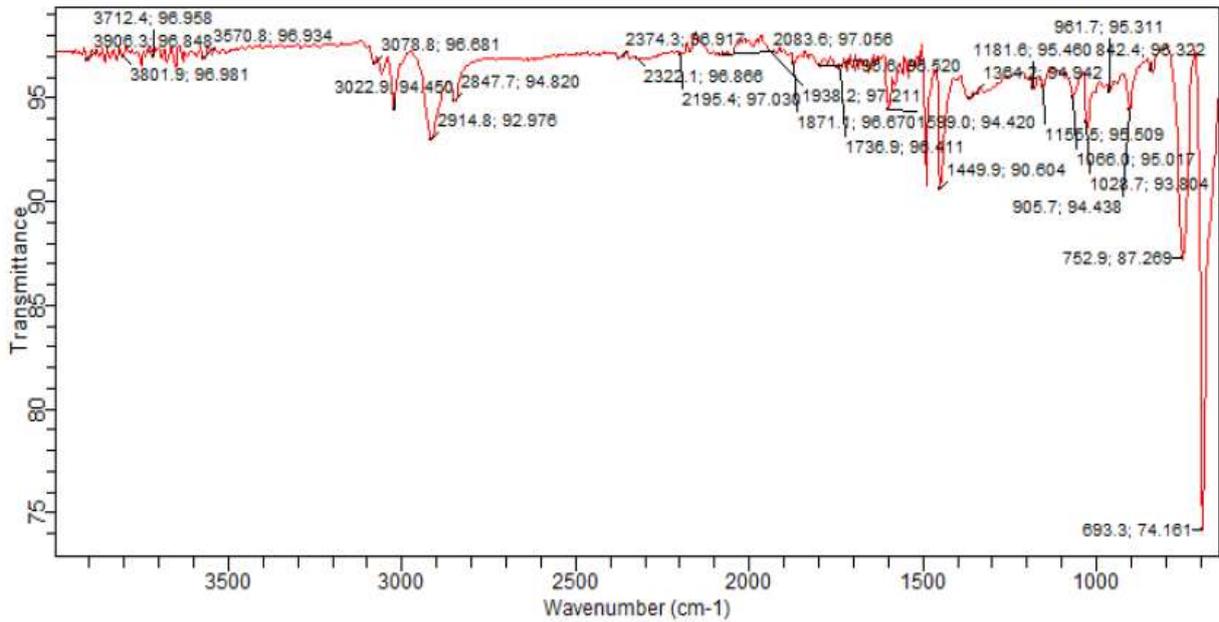## 3.0 RESULTS AND DISCUSSIONS
## 3.1 Fourier Transform Infra-Red



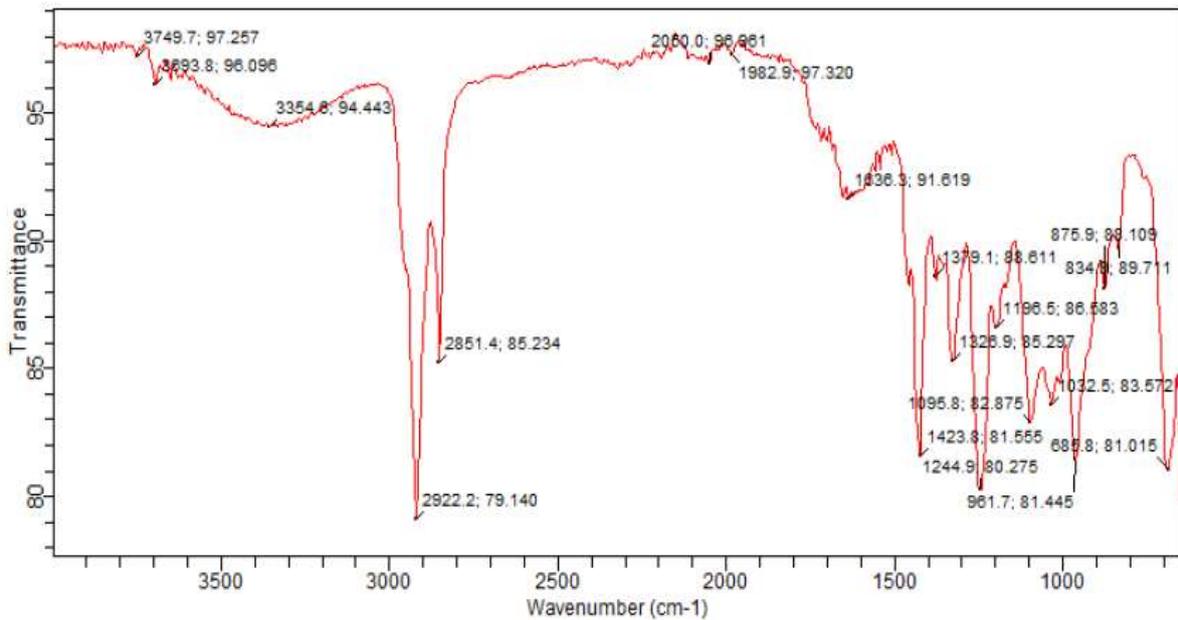**Figure 3.1 FTIR Spectrum of Pure PS**
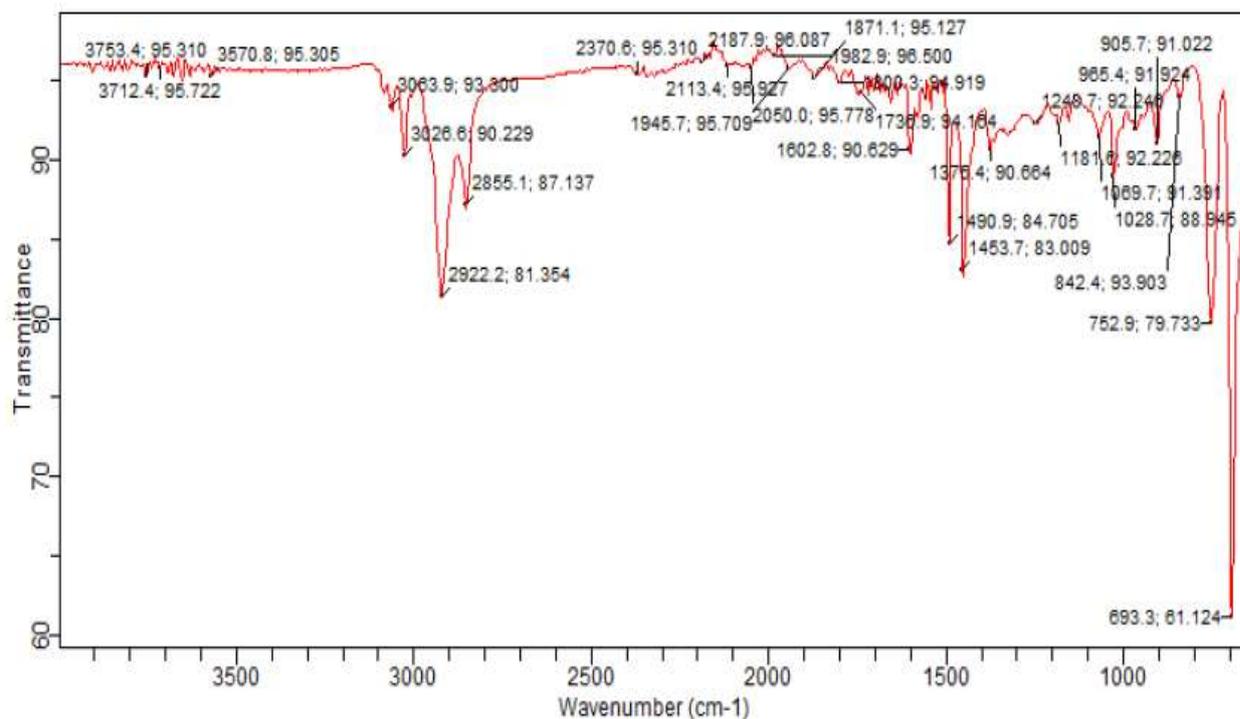


**Figure 3.2 FTIR Spectrum of Pure PVC**

**Figure 3.3 FTIR Spectrum of 80/20 PS/PVC Blend**

The 80/20 PS/PVC composition is presented in figure 3.3. The $CH_2$ bending peak with medium intensity was seen at a wavelength of $1453cm^{-1}$ for the PS and PVC. A peak was seen at a wavelength of $2855cm^{-1}$ indicating C-H bond. The peak appearing at $1490cm^{-1}$ wavelength indicates the aromatic C=C bond in PS. There are two peaks on $693\ cm^{-1}$ and $752\ cm^{-1}$ all within the C-Cl range, but these peaks were also present on the FTIR spectrum for the pure PS, therefore, these peaks cannot be assigned to C-Cl stretch, =C-H aromatic stretch appears at a wavelength of $3063cm^{-1}$. The absence of the C-Cl peak suggests that there is an intermolecular interaction that took place at that functional group (Kaniappan and Latha, 2011); this implies compatibility of 80/20 PS/PVC composition.

Figure 3.4 presents the FTIR spectrum for the 60/40 composition of PS/PVC blend. $693cm^{-1}$ and $752cm^{-1}$ band appeared as was seen on the FTIR spectrum for pure PS and could not be assigned
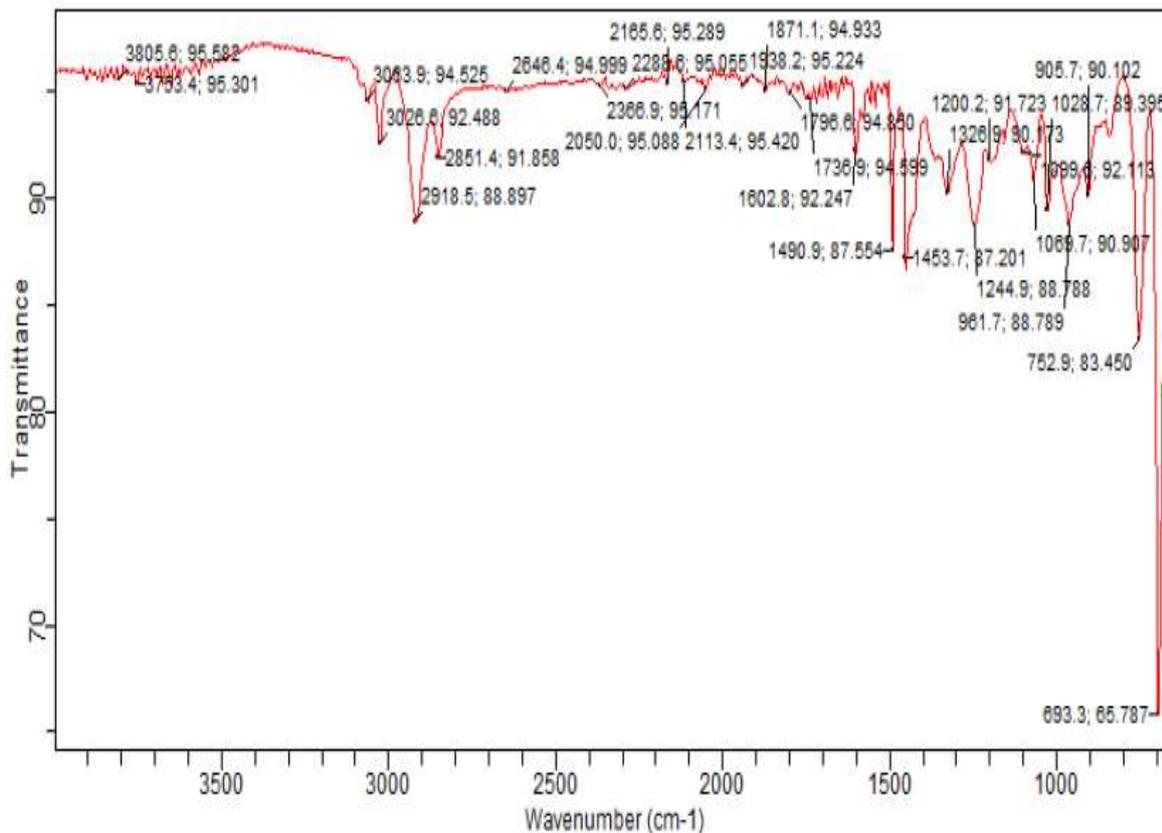
**Figure 3.4 FTIR Spectrum of 60/40 PS/PVC Blend**

to any functional group. $1453cm^{-1}$ peak is assigned to $CH_2$, and $2851cm^{-1}$ is assigned to C-H group, while the aromatic =C-H and C=C groups were represented with $3063cm^{-1}$ and $1490cm^{-1}$ respectively. There is no band appearing for the C-Cl group, this signifies that a possible interaction might have taken place on that functional group implying compatibility of the blend at 60/40 composition of PS/PVC.

The 40/60 composition of PS/PVC is represented on figure 3.5. $745cm^{-1}$ shows the peak for C-Cl group, $1461cm^{-1}$ is assigned to $CH_2$ bend, $2851cm^{-1}$ is for the C-H stretch, there is no band for =C-H aromatic stretch, $1543cm^{-1}$ is assigned to C=C aromatic. The absence of any peak within $3000cm^{-1}$ to $3100cm^{-1}$ for =C-H aromatic stretch signifies compatibility for this composition of PS/PVC blend.
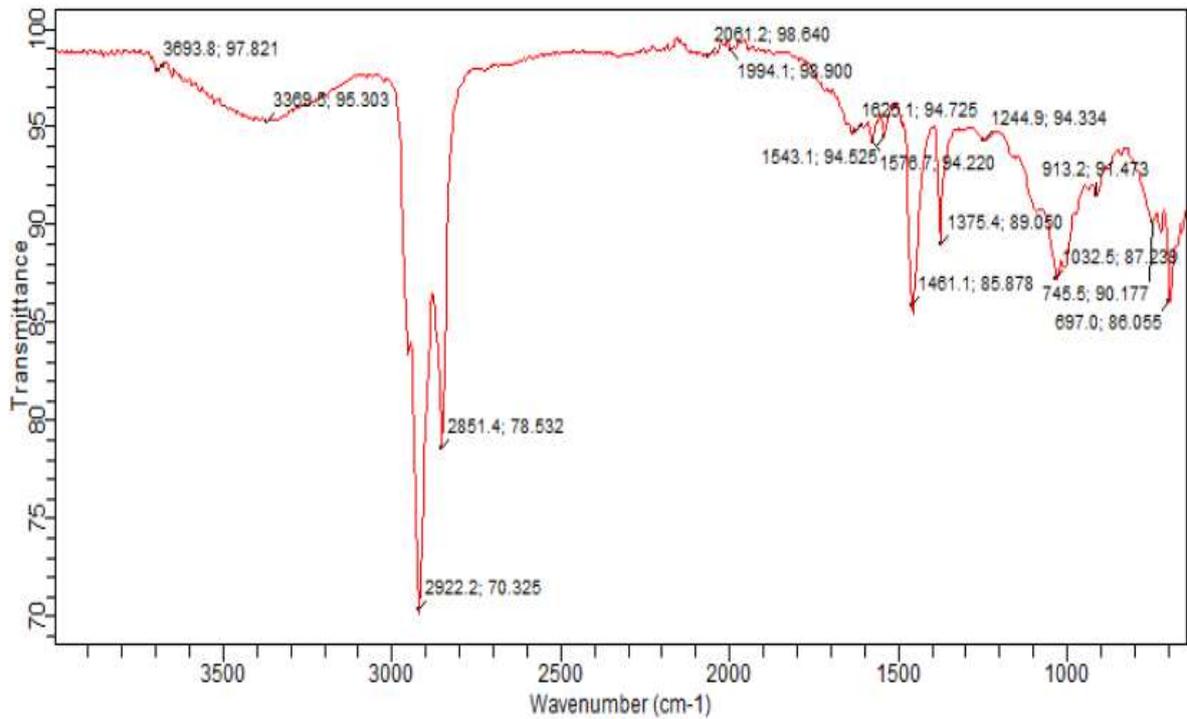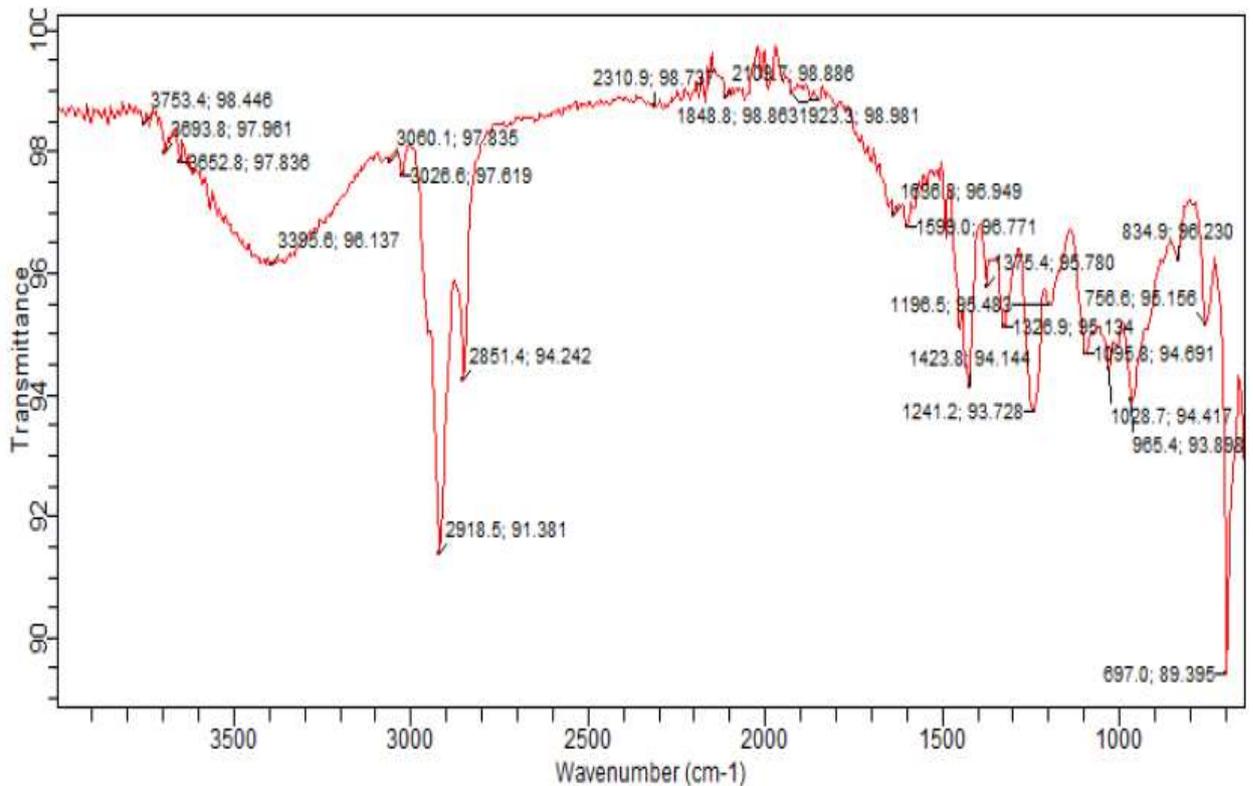
**Figure 3.5 FTIR Spectrum of 40/60 PS/PVC Blend**



**Figure 3.6 FTIR Spectrum of 20/80 PS/PVC Blend**

Figure 3.6 presents the FTIR result for 20/80 PS/PVC blend. 745cm$^{-1}$ is assigned for the C-Cl group, 3060cm$^{-1}$ is assigned for the =C-H aromatic stretch, 1599cm$^{-1}$ is assigned for the C=C aromatic group,

C-H stretch has a peak at 2851cm$^{-1}$, there is no peak for the CH$_2$ i.e. between 1480cm$^{-1}$ and 1440cm$^{-1}$, therefore it also signifies some level of interaction between the two polymers at this composition implying compatibility. All the compositions for the PS/PVC blend appears to be compatible based on the results from the FTIR.
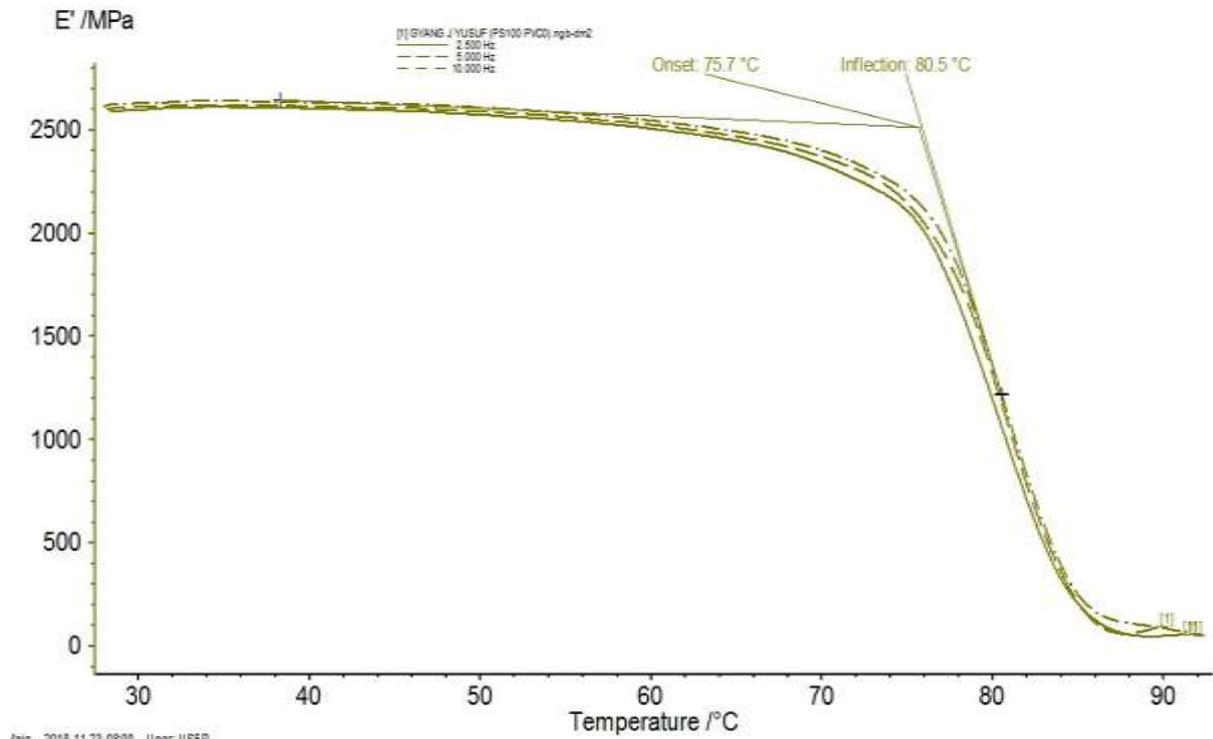


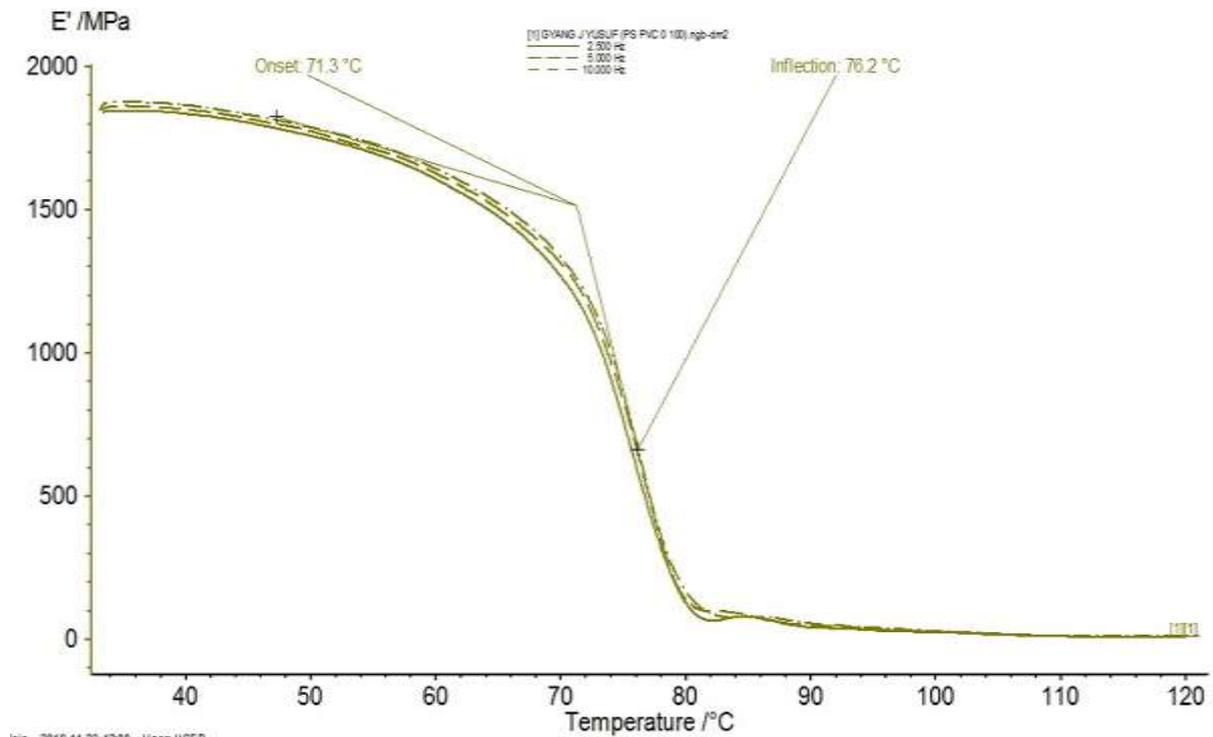**Figure 3.7 Storage Modulus Vs Temperature of Pure PS**



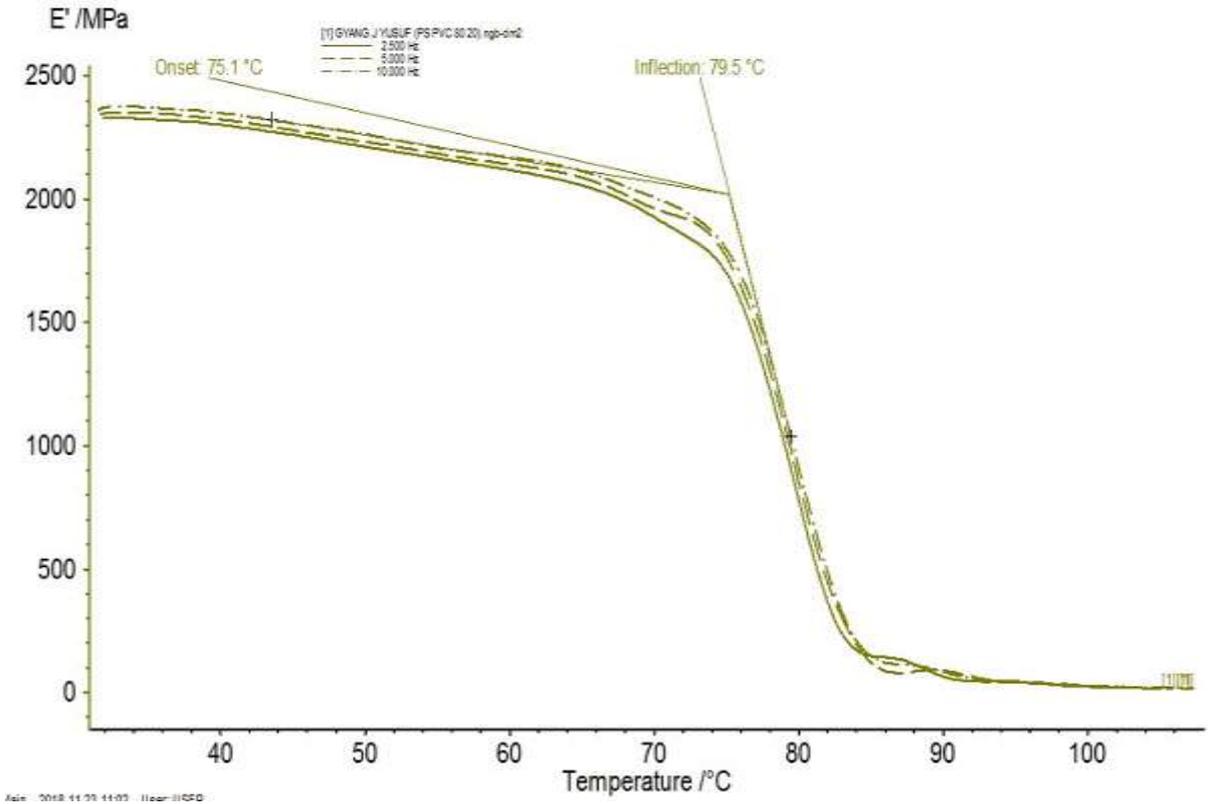**Fig. 3.8 Storage Modulus Vs Temperature for Pure PVC**

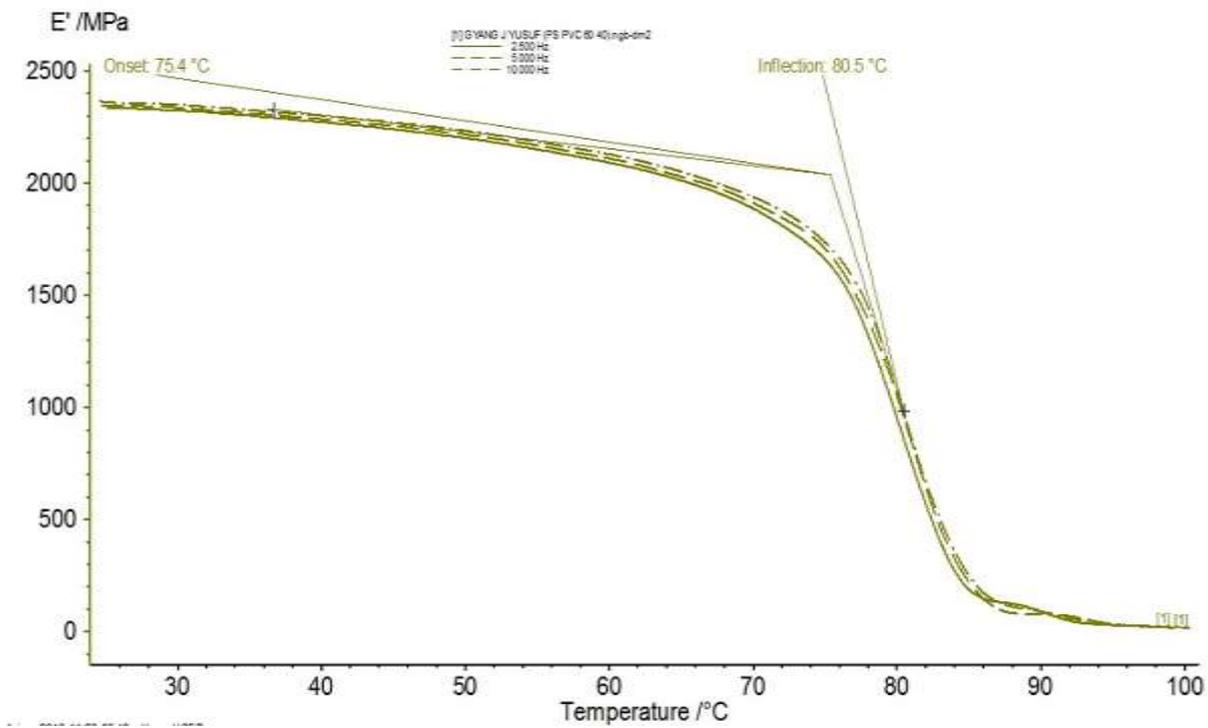**Fig. 3.9 Storage Modulus Vs Temperature of PS/PVC 80/20**



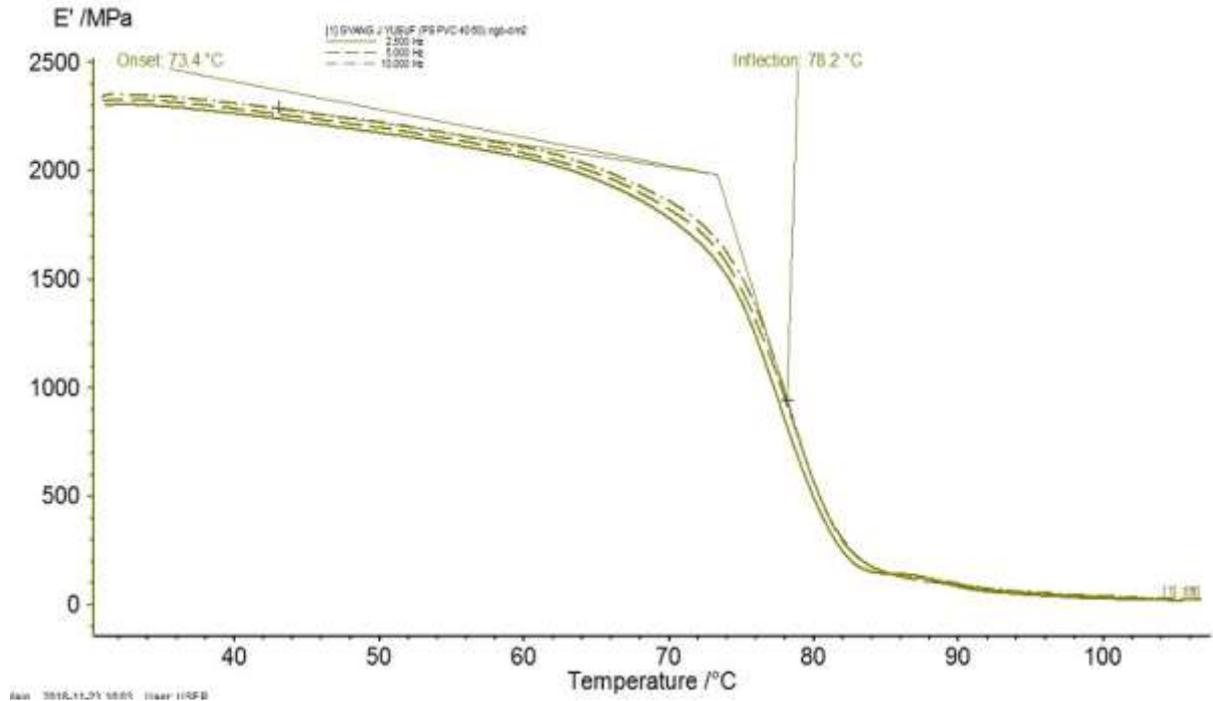**Fig. 3.10 Storage Modulus Vs Temperature of PS/PVC 60/40**

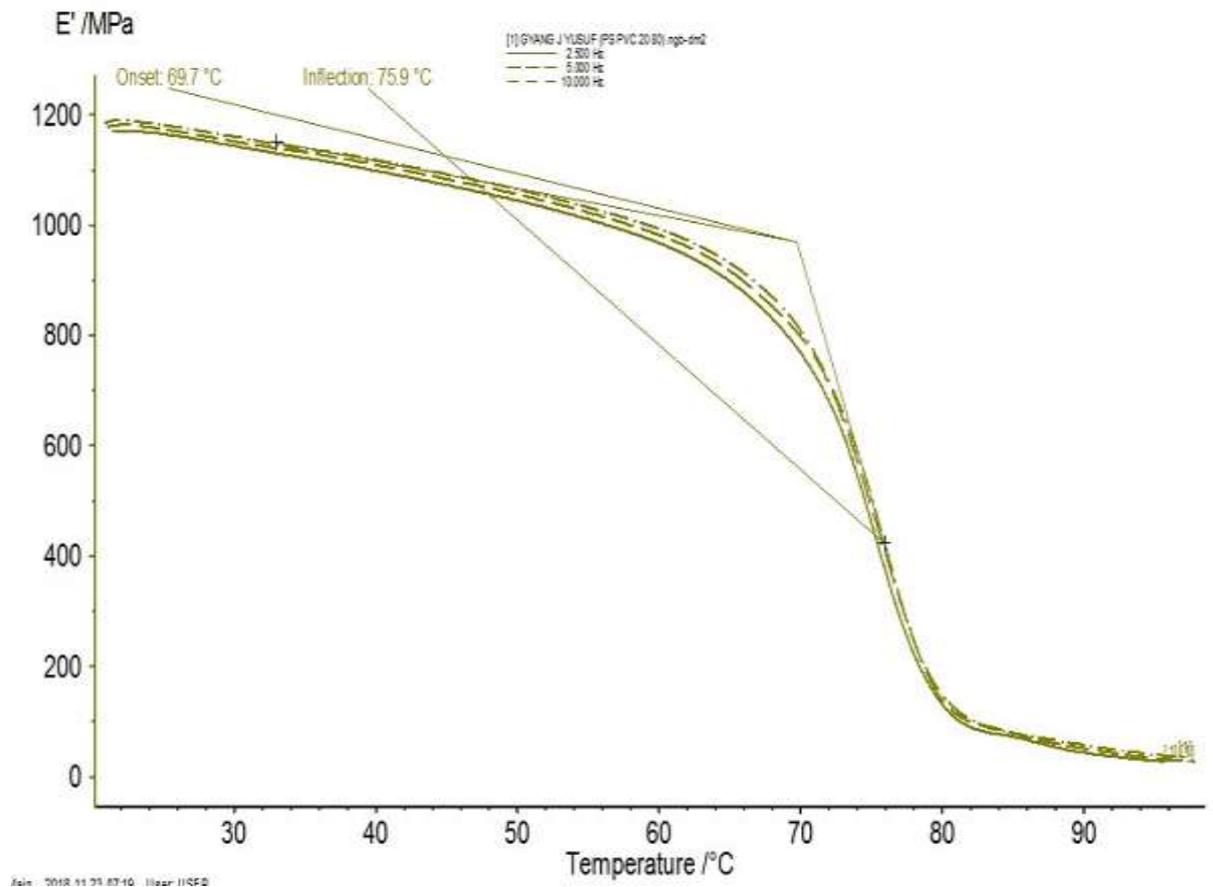**Fig. 3.11 Storage Modulus Vs Temperature of PS/PVC 40/60**



**Fig. 3.12 Storage Modulus Vs Temperature of PS/PVC 20/80**

**3.2 DMA for the PS/PVC Blends**

The plots of storage modulus against temperature for the different PS/PVC blends are presented on figures 3.7 to 3.12. PVC appears to reduce the glass transition temperature ($T_g$) of PS in the 80/20 and 60/40 PS/PVC compositions, the $T_g$ of polystyrene decreased from 75.7$^o$C to 75.1$^o$C which is not significant enough to observe meaningful change in the properties of the blend. Similar observation has been made for the 60/40 composition, the glass transition temperature of PS decreased from75.7$^o$C to 75.4$^o$C in the blend, which is also not significant enough to change the physical properties of the blend. On the other hand, PS increased the glass transition temperature of PVC (71.3$^o$C) in the 80/20 and 60/40 PS/PVC compositions of the blends to 75.1$^o$C and 75.4$^o$C respectively, this does not actually show any sign of compatibility in the two compositions of the polymer blends. PS and PVC have their glass transition temperatures shift significantly towards each other in the 40/60 PS/PVC composition of the blend, this composition can be said to be more compatible. The 20/80 PS/PVC composition of the blend showed a glass transition temperature lower than those of the two polymers involved; 69.7$^o$C, this glass transition temperature made the blend to become more rubbery than the two individual polymers, but in terms of compatibility, the composition is incompatible.

**4.0 CONCLUSION**

Based on the results of this study, PS/PVC blends could be said to be compatible based on the FTIR spectra, but the 40/60 composition was the most compatible as confirmed by DMA; therefore, the 40/60 PS/PVC is the only composition that is confirmed to be compatible by the two methods used in this research.

**ACKNOWLEDGEMENT**

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