

Chapter 8

POLYAMIDE-6 WITH PHENOTHIAZINE

CONTENTS

8.1	Introduction	234
8.2	Thermogravimetric Analysis	235
8.3	Differential Scanning Calorimetry	236
8.3.1	Pan Melt Blending	236
8.3.1.1	Melting Temperatures for first heating ramp of the powders at 5 °C/min	236
8.3.1.2	Crystallisation for first cooling ramp of the molten blend at 25 °C/min.	237
8.3.1.3	Melting Peak Temperatures for second heating ramp at 5 °C/min	239
8.3.1.4	Crystallisation Peak Temperatures for second cooling ramp at 25 °C/min	241
8.3.2	Ampoule Material	242
8.3.2.1	Melting Temperatures (First melt in DSC at 5 °C/min)	242
8.3.2.2	Overall Crystallinity	245
8.3.2.3	DSC Crystallisation Temperatures at 2 °C/min for remelted ampoule material.	246
8.3.2.4	Crystallinity from first crystallisation in the DSC	247
8.3.2.5	Phase Diagram from first heating and cooling ampoule material in DSC	248
8.3.2.6	Third Melting of materials/Second DSC Melt	249
8.3.2.7	Third Crystallisation of Materials/Second DSC Crystallisation	250
8.4	Fourier Transform Infrared Spectroscopy	251
8.5	Summary	251

8.1 Introduction

This chapter covers the melt blending of polyamide-6 with phenothiazine and provides the opportunity to make comparisons with those of polyamide-4,6 with phenothiazine and polyamide-6 with carbazole.

The combinations here differ from that with polyamide-4,6/phenothiazine because the polyamide repeat units are longer and differently constructed, polyamide-6 being a polyamide-n type rather than a polyamide-m,n. The melting temperature of phenothiazine is much closer to that of polyamide-6 than polyamide-4,6.

It differs from polyamide-6/carbazole in that now the second material melts before the polyamide-6 rather than after polyamide-6 melting. There may also be differences because the molecular shape and electron densities of the carbazole and phenothiazine do differ.

It will be shown in this chapter that generally the melting behaviour of the melt blends is similar to that in earlier chapters with polyamide-6, polyamide-6,9 and polyamide-6,12 combined with carbazole, but having reversed roles for the two materials.

A small amount of the polyamide will phase separate and crystallise separately in a phase uncontaminated with phenothiazine. That happens when the concentration of polyamide-6 is lower than 55% and it occurs whether the melt is being cooled quickly or slowly. This is to be seen also for polyamide-4,6 blended with either carbazole or phenothiazine.

8.2 Thermogravimetric Analysis

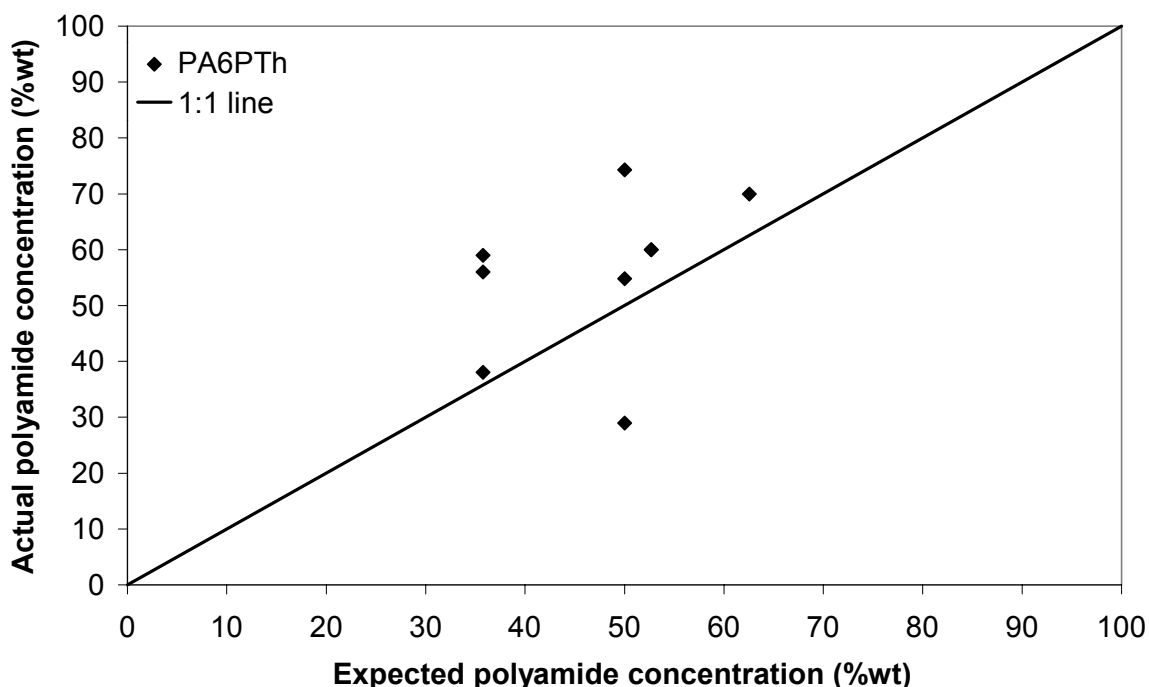


Figure 8-1 Actual versus Theoretical weight percentage polyamide in samples from polyamide-6/phenothiazine blends from ampoules.

Actual percentages of polyamide in samples from ampoules were determined by TGA. They differed in some cases from the percentages calculated from the masses of the constituent materials put into the ampoules. That difference would be due to local variations caused by phase separation, reorganisation during crystallisation or incomplete mixing in the melt, as mentioned in previous chapters. A comparison of the actual percentages of polyamide to those expected from the weights used in the ampoules is shown in Figure 8-1.

Several of the points are much more than 5% from the expected concentrations of polyamide based on weights used in making the ampoule material. The large differences from the expected seen in Figure 8-1 are much greater than seen in Sections 3.3.1 and 4.2.2 on general variability between samples and are real ones in concentration. The largest differences are encountered with one of the earlier ampoules before the furnace cooling had been optimised for consistency.

8.3 Differential Scanning Calorimetry

Polyamide-6 normally has a melting peak close to 223 °C with crystallisation peaks in the range 173-198 °C depending on crystallisation conditions, as mentioned in Chapter 4.

8.3.1 Pan Melt Blending

8.3.1.1 Melting Temperatures for first heating ramp of the powders at 5 °C/min

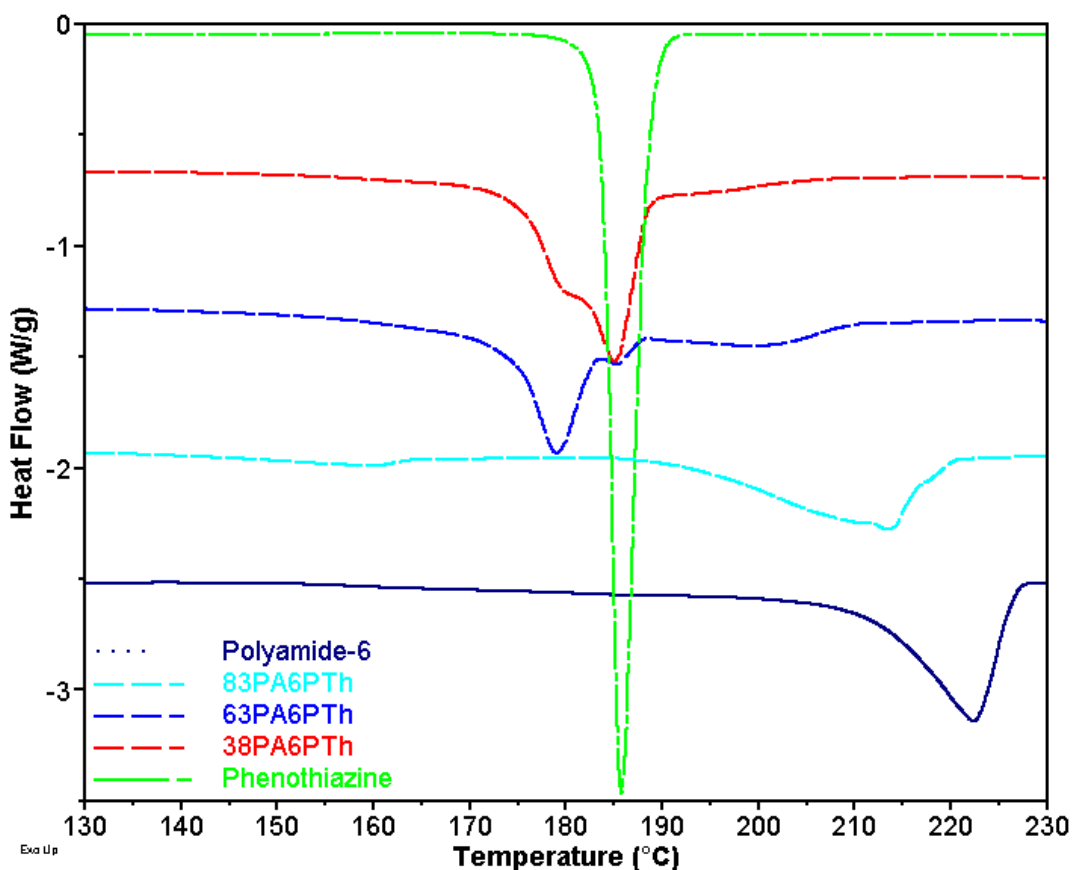


Figure 8-2 DSC thermograms during the first melting in the DSC at 5 °C/min of polyamide-6, phenothiazine and powder mixtures of the two.

Figure 8-2 shows the DSC thermograms of polyamide-6, phenothiazine and their mixtures taken as powder samples in DSC pans to the melt at 5 °C/min. These are described in detail below:

- a) Pure polyamide 6 powder melts in the same way as in Chapter 4 ie dependent upon the previous thermal history of the sample.
- b) The 83PA6PTh sample undergoes weak thermal activity (seen more clearly in Appendix A) in the region near 160 °C and caused by the small amount of phenothiazine present being absorbed into the amorphous structure of polyamide grains. This plasticises the amorphous polymer lowering its viscosity. The dissolution of polymer lamellae into the plasticised amorphous polyamide takes place slowly at temperatures lower than the normal polyamide-6 melting peak in what is a TLS peak for polyamide.
- c) The 63PA6PTh thermogram displays a eutectic peak 8 °C below the normal phenothiazine melting temperature. followed by a small peak at the phenothiazine melting temperature and a weak TLS peak for polyamide-6 which has a maximum at 200 °C and is complete by 209 °C. The fact that there is a peak at the phenothiazine melting temperature and a TLS peak afterwards shows that these two materials had difficulty in forming a solution at these temperatures and timeframe of the experiment or that the materials were in a region of phase space where phase separation occurs.
- d) Sample 38PA6PTh shows a similar style of behaviour but modified in the eutectic and TLS peak peaks by the lesser percentage of polyamide-6 and in the middle peak by the larger amount of phenothiazine being melted at the phenothiazine melting temperature.

The first melting of polyamide and diluent powders did not result in as easy dissolution of the materials into a eutectic melt as was seen in other material combinations. Either there was phase separation or the kinetics of dissolution were slow at the temperatures involved. The eutectic melts were encountered for polyamide concentrations less than or equal to 65% by weight and involved a depression of 8 °C below the normal diluent melting temperature.

8.3.1.2 *Crystallisation for first cooling ramp of the molten blend at 25 °C/min.*

Figure 8-3 below shows the DSC thermograms for the powder samples of Section 8.3.1.1 being cooled from the melt at 25 °C/min to room temperature.

- a) The first crystallisation of 83PA6PTh is a skewed main peak. It can be shown on closer examination to be a double peak, as can be seen in Appendix A. The first peak is a small amount of almost pure polyamide-6 crystallising, followed by crystallisation of polyamide-6 together with phenothiazine. The separate initial crystallisation of polyamide-6 points towards phase separation under the conditions of cooling rate and concentration used.

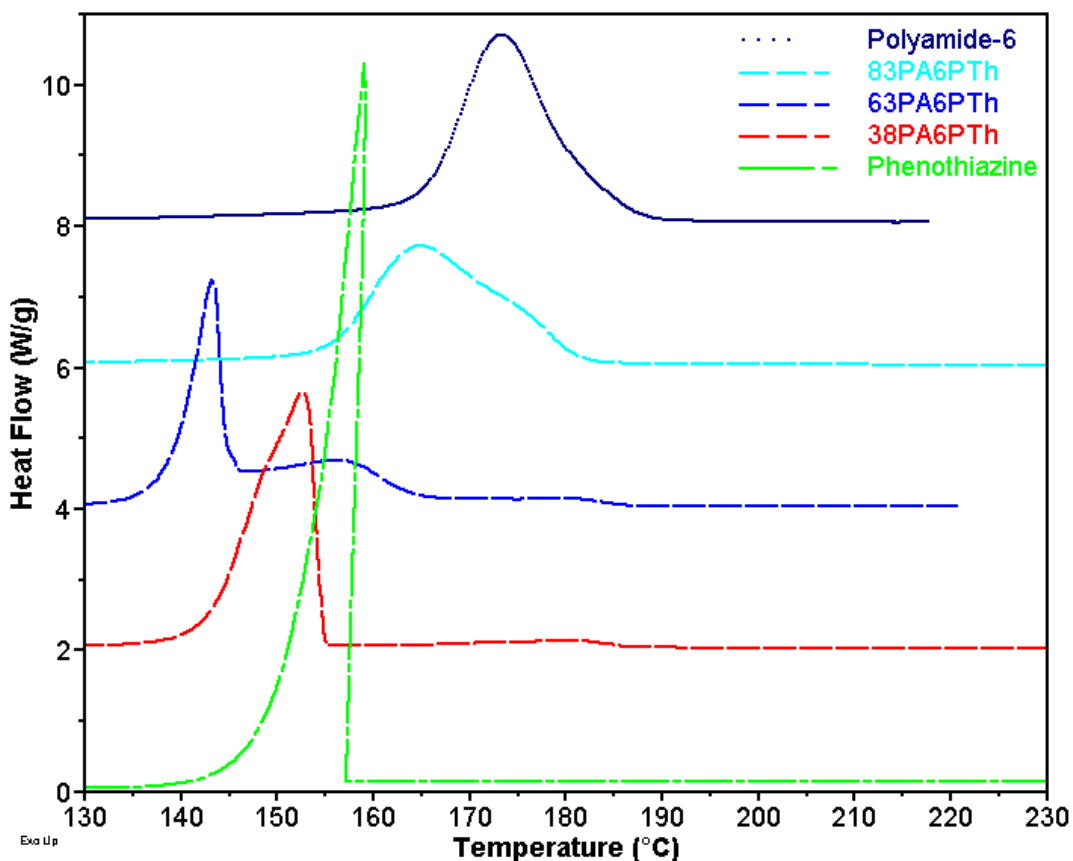


Figure 8-3 DSC thermogram for first crystallisation of pan blended polyamide-6/phenothiazine from the melt at 25 °C/min.

- b) The cooling ramp for 63PA6PTh shows some initial crystallisation of polyamide-6 followed by the crystallisation of a polyamide-6/phenothiazine phase between the crystallisation temperatures of the constituent materials, and concluding with the crystallisation of phenothiazine. The first peak is showing phase separation at those high temperature/concentration conditions. There is apparently the possibility at lower temperatures for polyamide-6 and phenothiazine to crystallise at the same time with phenothiazine in the inter-lamellar space. The last peak of this thermogram is sharp with a steeply rising face but is decidedly not as “spiky” as pure phenothiazine.

That lesser spikiness points to solidification of some polyamide-6 combined with crystallising phenothiazine embedded within the remaining amorphous mix. The lead-in to the last peak shows that there is an attempt to begin crystallisation of residual polyamide-6 that by this stage has been suppressed from crystallisation by nearly 30 °C. The polyamide-6 depression of the phenothiazine crystallisation is by approximately 15 °C.

- c) The cooling thermogram of 38PA6PTh is similar to the two samples immediately above in that there is an initial small crystallisation of polyamide-6 because of phase separation. The main peak is actually a double peak with (mainly) phenothiazine crystallising followed by the depressed crystallisation of polyamide-6 together with some phenothiazine.

The three polyamide-6/phenothiazine pan blended samples all have crystallisation of a small amount of polyamide-6 at the normal polyamide-6 crystallisation temperature. These can indicate an incompatibility between the two materials at that temperature/cooling rate, pointing to phase separation occurring. That crystallisation of small amounts of the polyamide was seen in polyamide-4,6/carbazole and polyamide-4,6/phenothiazine combinations of previous chapters.

All three PA6PTh samples also have solidification of the two materials together at temperatures below the polyamide-6 crystallisation temperature and are depressed more with higher levels of phenothiazine.

The crystallisation of phenothiazine takes place independently and occurs with the crystallisation of some polyamide-6 included in it. This occurs in the same way as seen in Figure 4-5 with pan samples for the polyamide-6/carbazole combination in Chapter 4 and leading to a sharp non-spiky peak.

8.3.1.3 *Melting Peak Temperatures for second heating ramp at 5 °C/min*

The DSC thermograms for the remelting at 5 °C/min of samples originally melted in pans from the powders are displayed in Figure 8-4.

- a) The first faint melting at 160 °C in 83PA6PTh has become fainter in the repeat heating run of the sample. The main peak has become a single,

slightly rounder, peak and lies at marginally higher temperatures. These changes are due to the two materials being in more intimate molecular contact and to the slight loss of some phenothiazine.

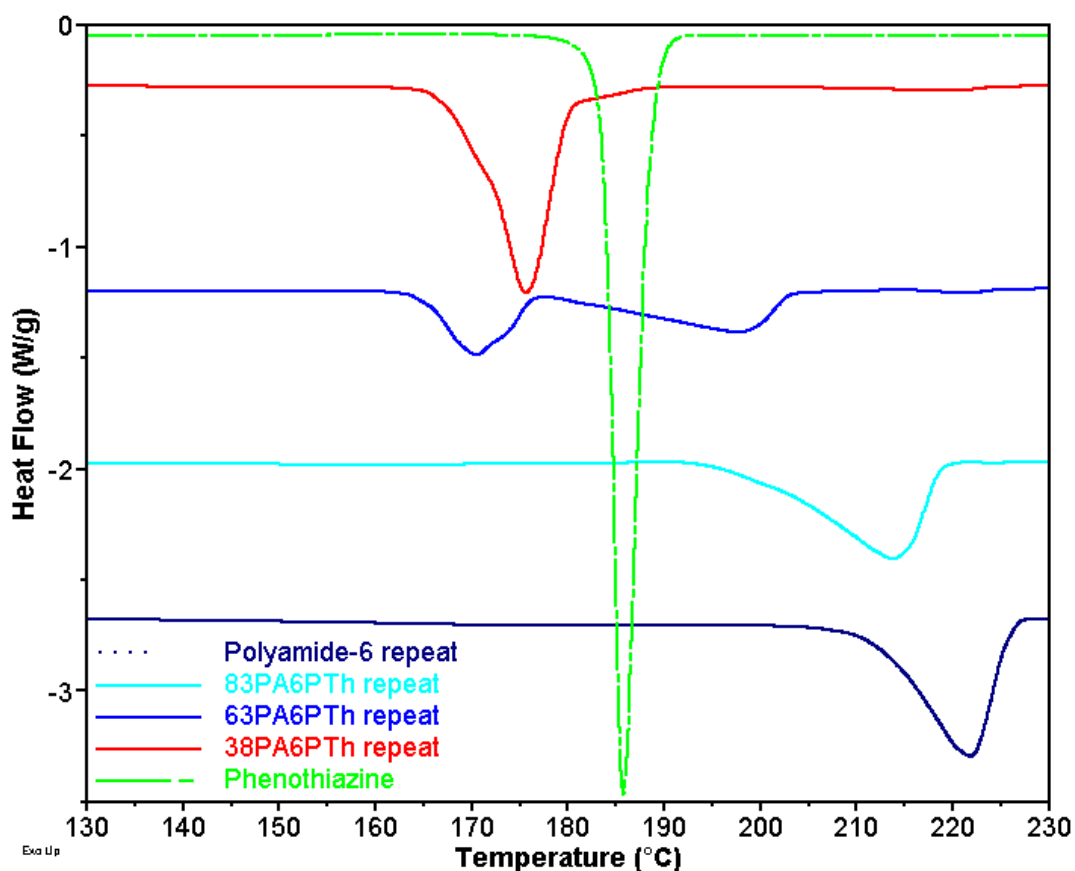


Figure 8-4 DSC thermogram at 5 °C/min of second melt of polyamide-6/phenothiazine materials previously melt blended powders then crystallised in pans.

- b) It was mentioned in the preceding section that the 63PA6PTh sample had crystallised into three phases, a polyamide-6, a polyamide-6/phenothiazine and a very phenothiazine-rich polyamide-6/phenothiazine portion. The previous double main melting peak from 8.3.1.1 has dropped to a lower temperature on reheating and is now 15 °C below the phenothiazine melting temperature. The TLS dissolution of polyamide-6 evident in the first melting has now moved to slightly lower temperatures and is complete by just over 200 °C. This is most likely due to the better mixing of the materials from the previous crystallisation. There is a slight melting peak at the polyamide-6 melting temperature indicating a small amount of pure polyamide existed in the structure that is being remelted.

c) The 38PA6PTh sample has reduced the peak temperature of the original main melting (double) endotherm by over 10 °C upon remelting. The melting is a triple peak with the two main phases mentioned in the crystallisation description now melting again and followed by a small, TLS peak shoulder on the higher temperature side. There is a slight melting peak at the polyamide-6 melting temperature that represents the melting of the small near-pure polyamide-6 portion seen during crystallisation.

The melting of some fractions at 8-10 °C lower seen in this set of thermograms is due to the better mixing of the two materials. The results are best seen in the light of the earlier difficulties in achieving the phenothiazine powder dissolution in the polyamide-6/phenothiazine solution. That was seen from the separate peaks at exactly the phenothiazine melting temperatures in Figure 8-2. Very small melting peaks at the polyamide-6 melting temperature for all three samples shows that there is reluctance in dissolving the polyamide-6 phase into the high temperature solution at temperatures above 200 °C.

8.3.1.4 Crystallisation Peak Temperatures for second cooling ramp at 25 °C/min

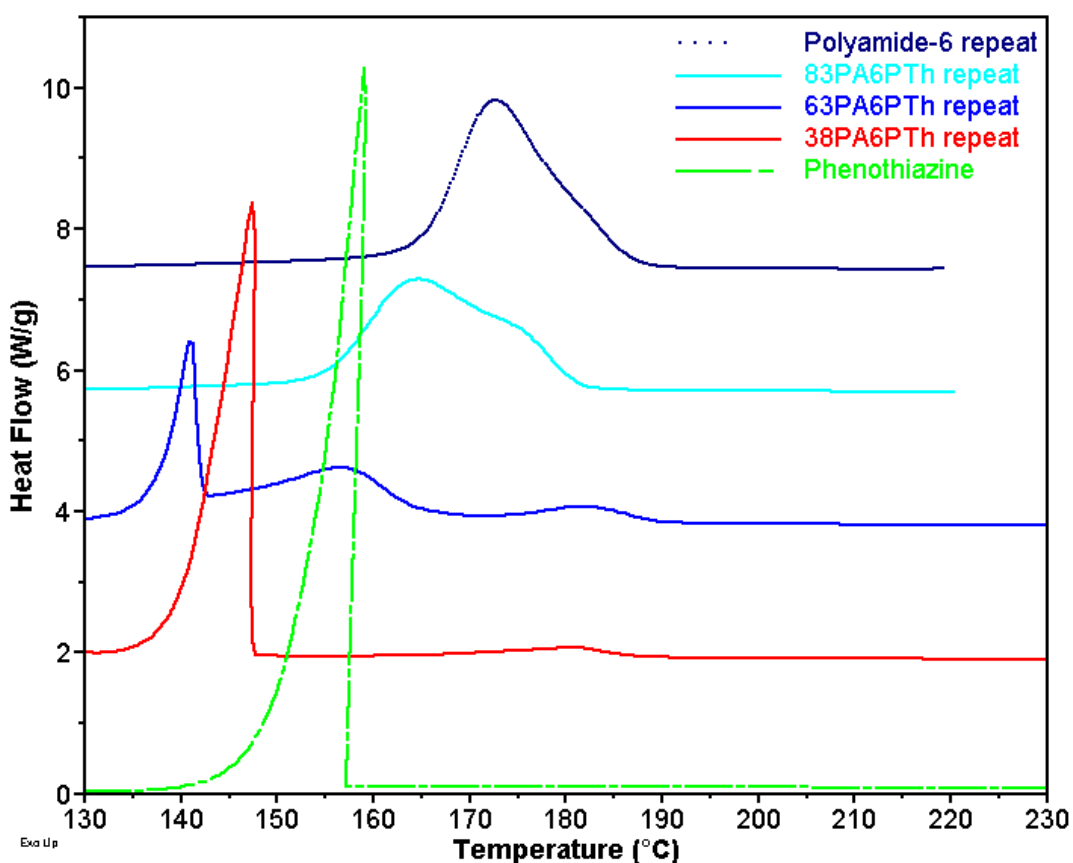


Figure 8-5 DSC thermograms of the second crystallisation of pan blended polyamide-6/phenothiazine samples in the DSC, cooling at 25 °C/min.

Figure 8-5 shows the thermograms of the pan blended samples during their second crystallisation cycle at 25 °C/min.

- a) Sample 83PA6PTh is virtually identical in re-crystallisation to the original crystallisation.
- b) The first two crystallisation endotherms for sample 63PA6PTh are quite similar to the original ones on first crystallisation of the pan blended samples. An observable difference is the slightly larger size of the two peaks, meaning that the sample is more crystalline although no explanation is available for this. The main phenothiazine-based peak is slightly smaller and is some 3 °C lower in temperature due to the evaporative loss of phenothiazine.
- c) The re-crystallisation of 38PA6PTh takes place, as before, with a barely visible crystallisation of some polyamide-6 due to phase separation. The peak is followed, during the cooling, by a single main peak for phenothiazine at lower temperatures. The peak is slightly more “spiky” showing that there is less polyamide-6 incorporated in that crystalline phase. The crystallisation temperature is depressed a further 6 °C to make it 11 °C below the pure phenothiazine crystallisation temperature.

All three blends again show some crystallisation of polyamide-6 during the re-crystallisation from the melt. The indications, again, are that there is limited compatibility between the two materials, resulting in liquid-liquid phase separation of polyamide-6 from the diluent in the melt at higher temperatures. There does appear to be more compatibility between the two materials at lower temperatures resulting in some crystallisation of phenothiazine together with polyamide-6 at the 25 °C/min cooling rate.

8.3.2 Ampoule Material

8.3.2.1 Melting Temperatures (First melt in DSC at 5 °C/min)

The thermograms in Figure 8-6 show the heating curves (at 5 °C/min) from melting samples formed originally in ampoules for the first time in the DSC.

Thermograms from ampoule samples in Figure 8-6 were obtained in the DSC after the samples were crystallised in ampoules at a slow rate. The results are reasonably in agreement with the thermograms from the second melting of the pan blended samples despite the latter having been crystallised at the

much faster 25 °C/min. The descriptions of this set of data will be partially grouped because of the number of thermograms in total and the obvious broad similarity of some of them. It should be remembered that the percentages of polyamide in the actual sample measured in the DSC may differ by a small amount from those of the TGA measurements. This is because different samples had to be used for TGA and DSC, although taken from next to each other in the bulk ampoule sample. That means, for example, 61PA6PTh used in the DSC may have had slightly less polyamide-6 than 60PA6PTh.

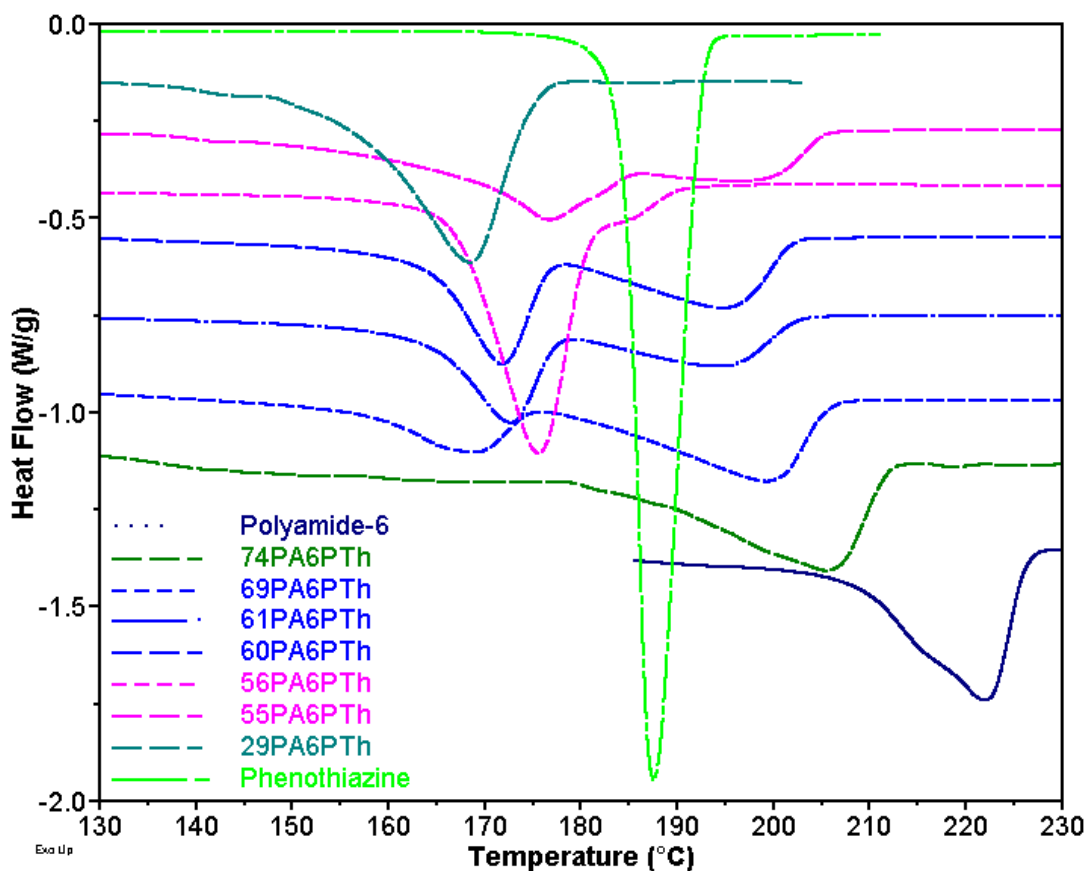


Figure 8-6 DSC thermograms of polyamide-6/phenothiazine samples from ampoules in their first melt in the DSC at 5 °C/min.

Samples 69PA6PTh, 55PA6PTh and 29PA6PTh were from ampoules 17 and 18. These were made before the furnace process had been set up for best consistency. In fact, samples 69PA6PTh and 29PA6PTh are both from the same ampoule. The results have been included, but with the recognition that they are not entirely representative of the ampoule melt blending process generally used for ampoule data in the thesis.

- a) The polyamide-6 sample has a double peak with a shoulder for the melting/re-crystallisation of the metastable material into the stable form

- before the main melting peak. The position of the shoulder is typical of the cooling rate used in the furnace for the ampoule.
- b) 74PA6PTh is similar to the pan blended 83PA6PTh except that, with a lower polyamide level, there is more depression of the main melting peak temperature.
 - c) The three samples with polyamide concentration in the range 60-70% show similar thermal performance to the pan blended 63PA6PTh sample although the first peak for 69PA6PTh begins at slightly lower temperatures than the other two of this group. An average of the three would be very close in peak temperatures and peak heights to the pan blended 63PA6PTh sample on its second melting ramp. This is despite the cooling ramps differing strongly between pan and ampoule samples in their previous thermal treatments.
 - d) There are no concentration equivalents in the pan blended samples to the 56PA6PTh and 55PA6PTh samples from ampoules. The two samples together show a transition from the thermograms of the previous three and the sample 29PA6PTh to be described below. The 56PA6PTh thermogram is reasonably similar to the ampoule samples with concentrations between 60 and 70% polyamide. The pan blended 38PA6PTh sample in Section 8.3.1.3 had a first melting peak at the same temperature as both these samples and had displayed a small TLS dissolution of the polyamide once the temperature of the saturated solution was increased. The smaller size of the first peak and larger size of the second peak for 55PA6PTh compared to 56PA6PTh reflect actual differences in polyamide levels more than the 1% from TGA measurements. The overall slightly lower crystallinity of the 55PA6PTh sample is, most likely, because the sample was from Ampoule 17 made before the furnace cooling of the ampoule samples had been completely refined.
 - e) The 29PA6PTh sample has a main peak with no further evidence of dissolution of polyamide-6. A comparison with the pan blended 38PA6PTh shows that the polyamide-6 concentration at saturation for 180 °C must be between 29 and 38%. There is a very small peak at 145 °C near the temperature of a fainter peak barely visible with

55PA6PTh. The origin of this is unclear and there is no equivalent one with the 38PA6PTh pan blended sample at its second melting. It was mentioned earlier that these were from early ampoules where the cooling profile had not been fully refined, so it is possible that that may have contributed to the differences.

These thermograms of ampoule-formed samples in their first pass through a DSC cycle are quite consistent with the pan blended polyamide-6/phenothiazine samples at their second ramp. They show the polyamide-6/phenothiazine melt at depressed melting temperatures. This is followed, for concentrations of the polyamide above 35%, by dissolution of excess polyamide-6 in the saturated solution. In principle, the behaviour is similar to that seen with several polyamides and carbazole, but with reversed roles.

One specific curiosity in the thermograms is the varying temperature of the first peaks with this series of thermograms. The 29PA6PTh and 69PA6PTh samples with the low first melting temperatures both come from ampoule 18. That ampoule had been fired in the furnace before the furnace profile had been completely refined. There could be an effect from that cooling ramp on re-melting temperatures. That does not explain the melting temperature differences between samples 56PA6PTh and 60PA6PTh.

8.3.2.2 Overall Crystallinity

The percentages of polyamide were used with the total enthalpy of the first melting heating ramp to calculate the overall crystallinity of ampoule samples in the same manner as in earlier chapters. The results are plotted below in Figure 8-7. This represents the crystallinity of the samples as they were taken from the ampoules.

The overall crystallinity in Figure 8-7 obtained from the first melting in the DSC of ampoule material shows a rapid drop in crystallinity of the sample to approximately 40% at polyamide levels of 30% or higher. There is a relatively constant crystallinity for polyamide concentrations above that. The non-linear overall relationship means that the blending process is adversely affecting crystallinity and shows that there is some interaction between the materials leading to a non-zero free energy of mixing.

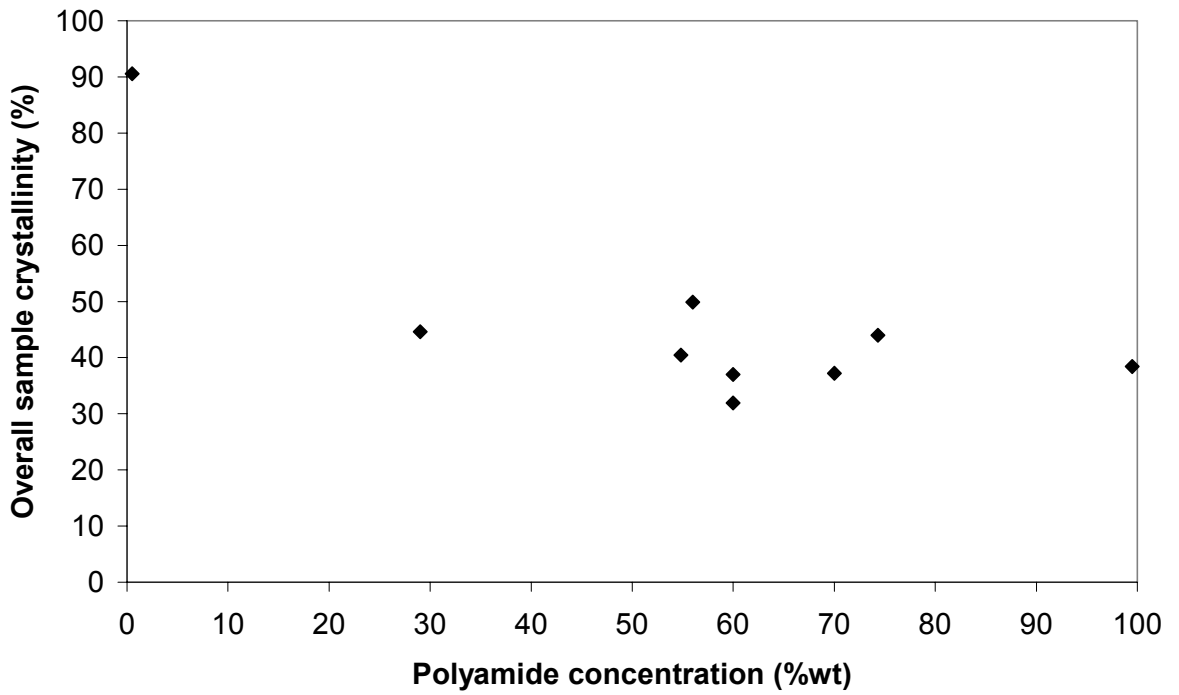


Figure 8-7 Overall crystallinity of polyamide-6/phenothiazine ampoule samples determined from TGA and total first DSC melting enthalpy.

8.3.2.3 DSC Crystallisation Temperatures at 2 °C/min for remelted ampoule material.

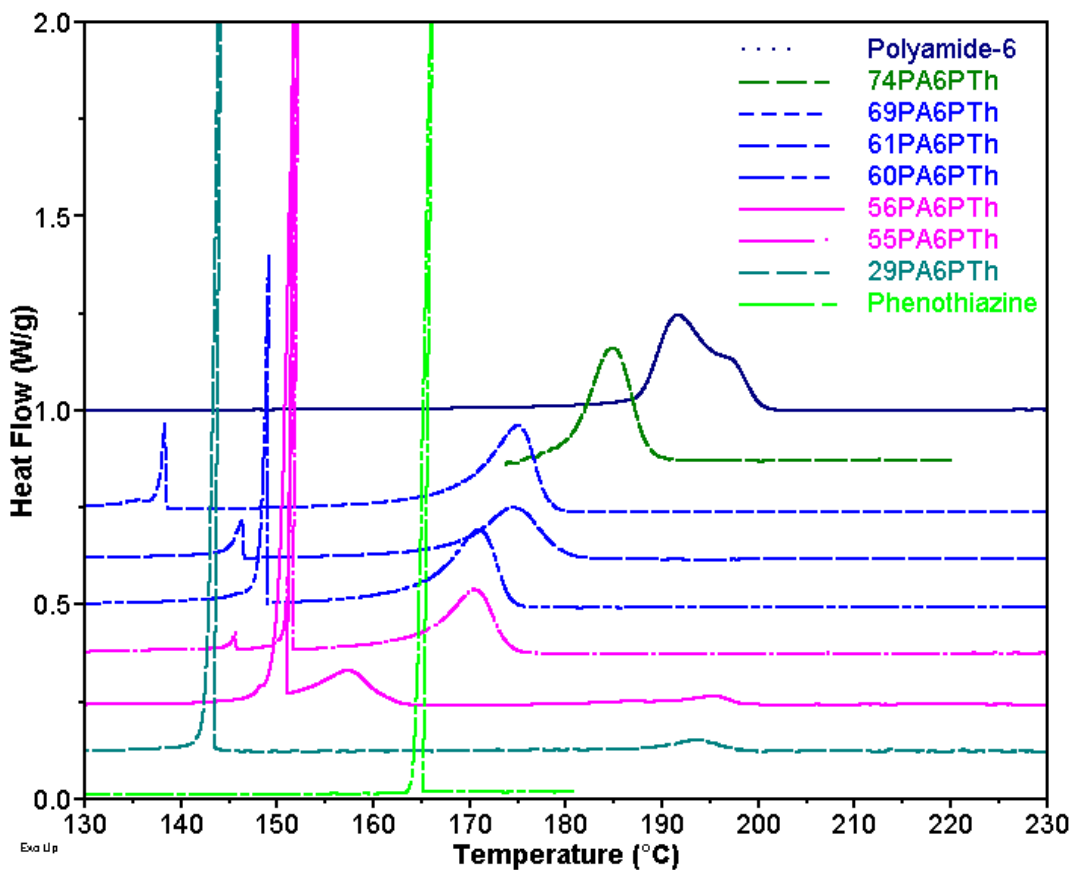


Figure 8-8 DSC thermograms of the first crystallisation in the DSC at 2 °C/min of polyamide-6/phenothiazine ampoule samples.

Figure 8-8 shows the thermograms of the crystallisation of material melt-blended in ampoules, taken to the melt in the DSC and now being crystallised at 2 °C/min.

The two polyamide-6/phenothiazine samples with the highest percentages of phenothiazine have small peaks at exactly the same temperature as polyamide-6 crystallisation. This shows phase separation of polyamide-6 from the rest of the solution at the cooling rate of 2 °C/min. Similar crystallisation of polyamide occurred with the pan blended samples during cooling at 25 °C/min during their second crystallisation ramp, as described in Section 8.3.1.4. The crystallisation of polyamide-6 at moderate to low polyamide levels is thus occurring regardless of whether the melt is cooled quickly or slowly. It points to incompatibility of the polyamide-6 in the solution at medium to low polyamide concentrations when temperatures are near 200 °C. There is a difference between fast and slow cooling at higher polyamide levels in that the polyamide does not phase separate and crystallise out at the slower cooling rate, unlike with the faster cooled pan blended samples.

An overall trend of increasing depression of the polyamide-6 crystallisation can clearly be seen from the thermograms as the level of phenothiazine is made higher. This shows some interaction between the two materials and the fact that no polyamide-6 crystallises separately under this slower cooling rate. The bulk of the polyamide-6 crystallising in these later stages can be depressed by up to 35 °C.

Phenothiazine crystallisation depression is quite variable between 12 and 25 °C.

8.3.2.4 *Crystallinity from first crystallisation in the DSC*

The crystallinity of phenothiazine and polyamide can be calculated as in earlier chapters and is displayed in Figure 8-9. This is determined from the first cooling ramp in the DSC although it does have some limitations because of the evaporative loss of phenothiazine to varying degrees from the samples.

The crystallinity of the phenothiazine, as with the crystallisation depression, is very variable but reduces to zero above approximately 75% polyamide-6. The variability has also been seen with several other polyamide/diluent

combinations, but only those with the melting temperature of the polyamide higher than that of the diluent. The crystallinity of the non-phenothiazine portion has a maximum between 60 and 70% polyamide that is higher than that of the pure polyamide.

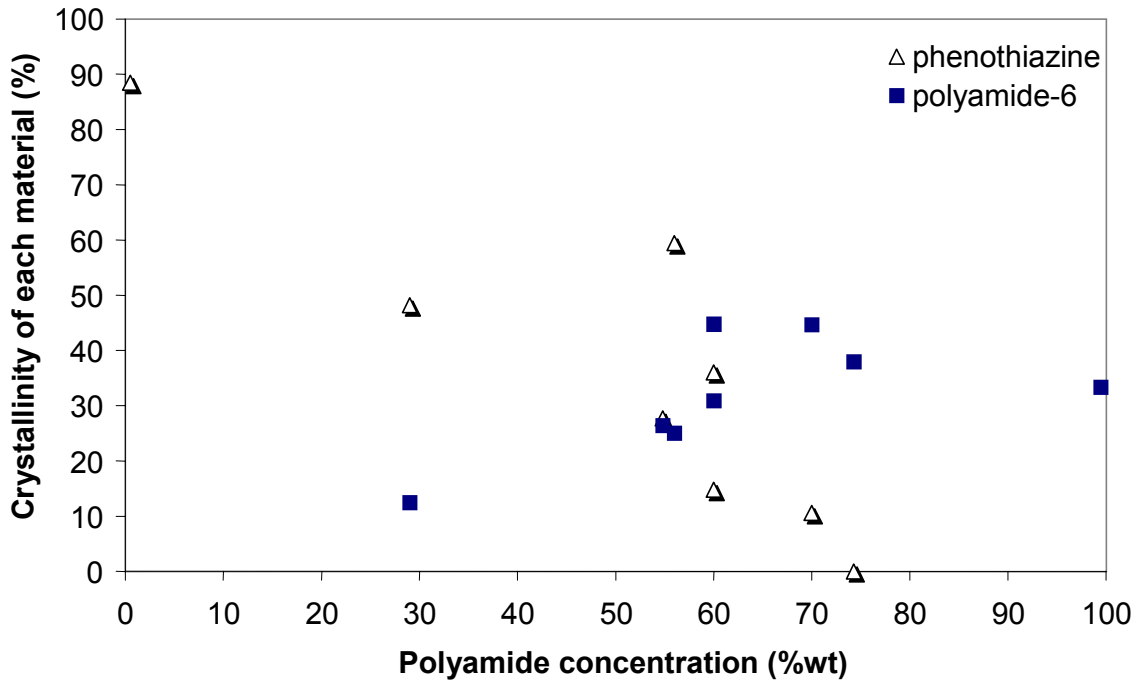


Figure 8-9 Crystallinity of phenothiazine and Non-phenothiazine parts from crystallisation of polyamide-6 blend from the melt in the DSC.

8.3.2.5 Phase Diagram from first heating and cooling ampoule material in DSC

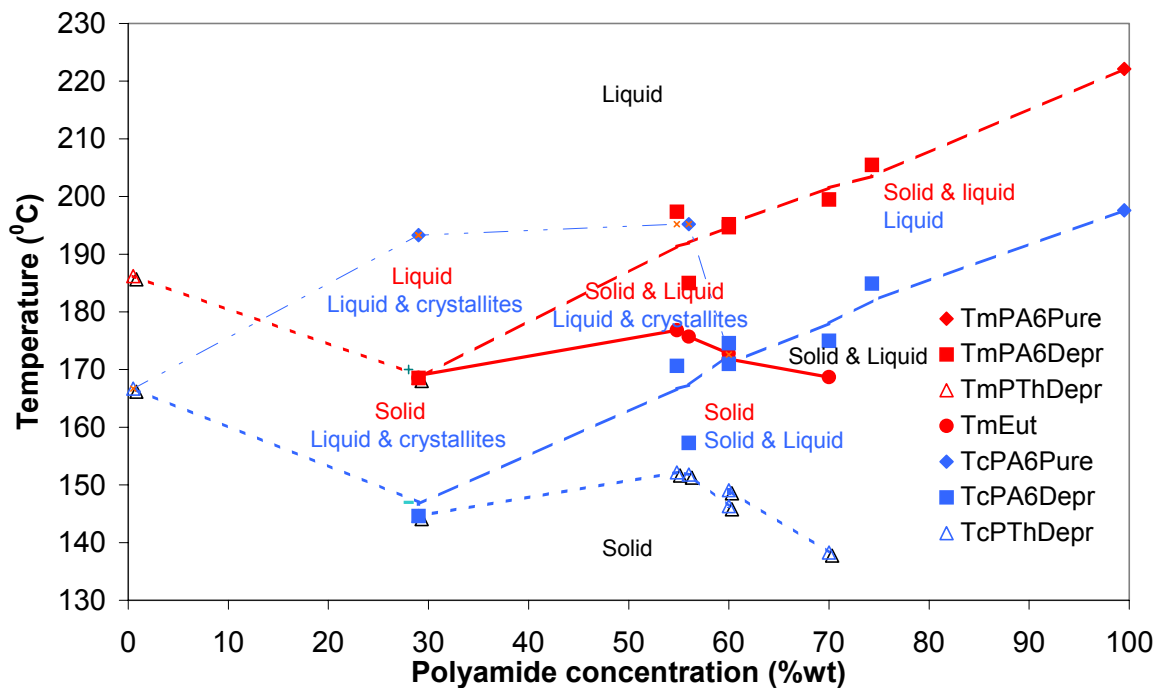


Figure 8-10 Non-equilibrium phase diagrams for polyamide-6, phenothiazine and their blends showing Flory-Huggins style depression of the peak temperatures

The non-equilibrium phase diagrams in Figure 8-10 show Flory-Huggins style crystallisation depressions of the polyamide by the diluent and vice versa. The melting phase diagram appears to have a near horizontal first melting transition above 30% polyamide concentration which could be eutectic melting.

There is also some crystallisation of small amounts of nearly pure polyamide at temperatures very close to the normal polyamide-6 crystallisation temperature. That was also found with both polyamide-4,6/diluent blends but not with the polyamide-6, polyamide-6,9, or polyamide-6,12/carbazole blends where the polyamide crystallisation temperature is lower than the diluent one.

8.3.2.6 Third Melting of materials/Second DSC Melt

The ampoule samples in pans from the first DSC runs were passed through a repeat melt/crystallisation cycle in the DSC as was done in earlier chapters. Figure 8-11 below shows the DSC thermograms of the melt portions of the repeat DSC runs.

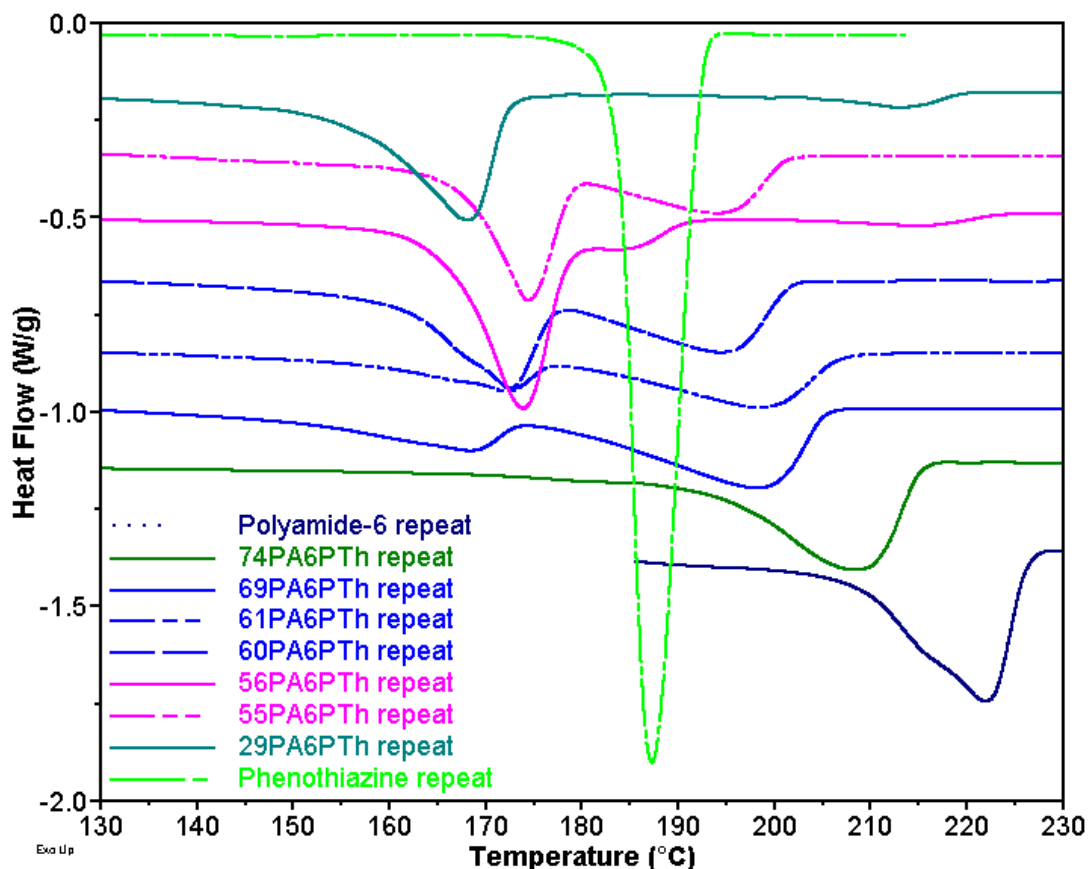


Figure 8-11 DSC thermograms of the second melt at 5 °C/min in DSC of polyamide-6/phenothiazine ampoule material.

Some evaporation of phenothiazine will have taken place in between the first and second DSC runs of the ampoule samples. The effect will be greater than in the pan blended samples because of the protracted times spent at high temperatures due to the slower cooling ramp used with these samples.

Small differences are seen between the first melt in the DSC and the second one. The first melting peaks with this DSC run are smaller and the second peaks are larger than with the first DSC run. These factors are due to the evaporation of some phenothiazine. Less of the polyamide can be dissolved before a saturated solution is reached. There is more left to dissolve into the solution only when higher temperatures have been reached.

There are melting peaks also evident at the normal polyamide-6 melting temperature in the cases of the 56PA6PTh and 29PA6PTh samples. This is the small amount of polyamide-6 seen to crystallise as a pure polyamide-6 phase in the previous section.

8.3.2.7 Third Crystallisation of Materials/Second DSC Crystallisation

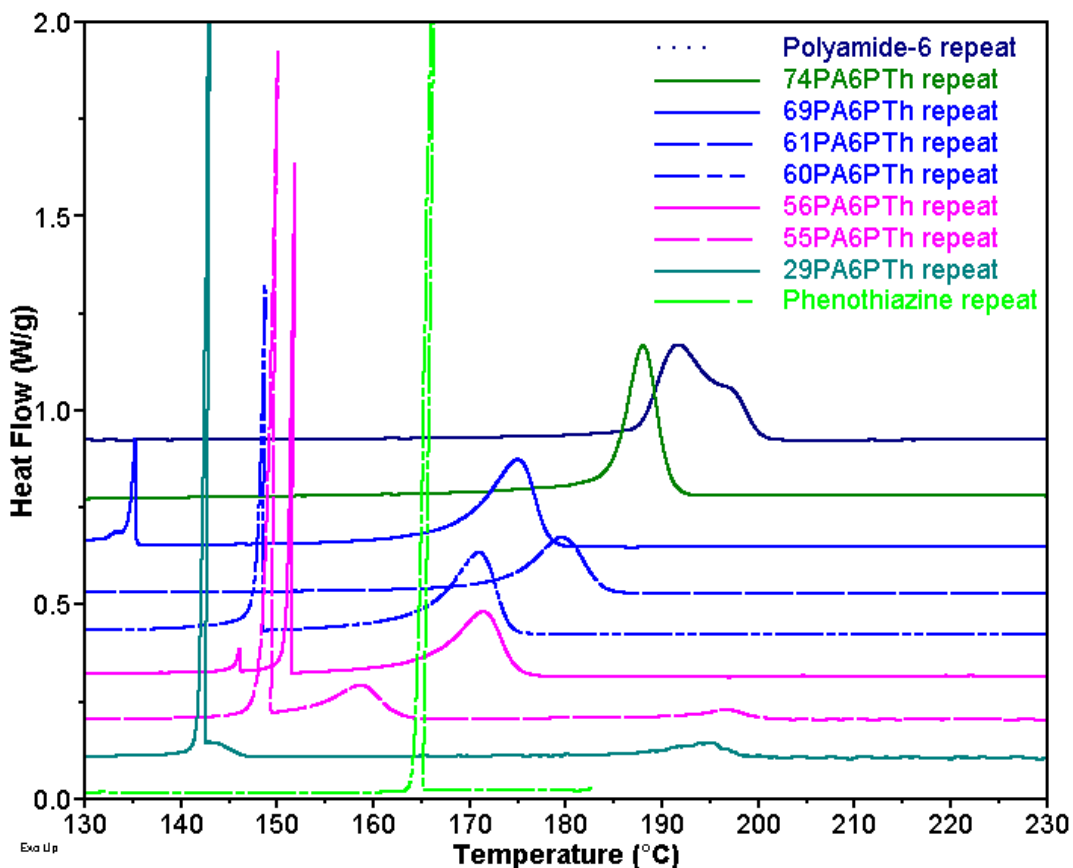


Figure 8-12 Thermograms of the second crystallisation at 2 °C/min in a DSC polyamide-6/phenothiazine ampoule material.

Figure 8-12 depicts the thermograms from the second crystallisation in the DSC at 2 °C/min of samples originally formed in ampoules.

The small differences to be seen in Figure 8-12 compared to the first DSC run Figure 8-8 are due to the loss of some phenothiazine by evaporation. 74PA6PTh and 61PA6PTh stand out most noticeably in this respect. This latter has lost enough phenothiazine to result in no separate phenothiazine crystallisation “spike” in the range 135-165 °C. The only other significant change is the 29PA6PTh sample has lost enough phenothiazine that there is now a separate, approximately Gaussian, crystallisation of polyamide-6/phenothiazine peaking at 143 °C. This means that there is polyamide-6 solidified with the phenothiazine in a phase depressed 50 °C below the normal polyamide-6 crystallisation temperature.

8.4 Fourier Transform Infrared Spectroscopy

FTIR was carried out on ampoule samples in the Mid Range IR with photoacoustic and in the Near IR with DRIFT to search for hydrogen bond interactions between the two materials. A close inspection of the results in both ranges did not show any such interaction. Results may be seen in Appendix D on CD.

8.5 Summary

The results in this chapter have demonstrated similar effects in dissolution/melting and in crystallisation to those seen in some earlier chapters, sometimes with the roles of polyamide and diluent reversed because melting temperatures are in reverse order. The lower melting material has melted at depressed temperatures, dissolving some of the higher melting material until the solution became saturated. The higher melting material then required higher temperatures before more could be dissolved into the saturated solution.

Another observation common with polyamide-4,6/carbazole and polyamide-4,6/phenothiazine blends was some polyamide melting and crystallising exactly at the normal polyamide melting temperatures. This shows reduced compatibility of the polyamide-6 in polyamide-6/phenothiazine solutions at high temperatures. The crystallisation of pure polyamide-6 was occurring at fast and slow cooling rates when the level of polyamide was medium to low. It only occurred at fast cooling rates when the level of polyamide-6 was moderate to high, showing that the two materials could be marginally

compatible at high temperatures if the polyamide-6 level was sufficiently high.

In addition to the overall common factors, a part of the phenothiazine melted at exactly the normal phenothiazine melting temperature in the same way as seen strongly with polyamide-4,6/phenothiazine in Chapter 7. The difference here was the presence of double peaks at both phenothiazine depressed and at normal phenothiazine melting temperatures. The melting at normal phenothiazine melting temperatures constituted the majority of the double peak for the highest level of phenothiazine with pan blended samples. These curves indicate that dissolution/melting temperature depression is taking place up to a certain level of phenothiazine and then phenothiazine does not continue melting until the temperature has been raised further. At that stage the temperature is too low to dissolve more polyamide. That situation differs from the various polyamides combined with carbazole where the lower melting material completely melted at a depressed temperature and went into dissolution of the higher melting material as the temperature was raised sufficiently.

This combination of a polyamide with phenothiazine showed with FTIR that there was no hydrogen bond interaction between the polyamide-6 and phenothiazine as for polyamide-4,6/phenothiazine and all the polyamide/carbazole combinations.