| RTI PAST PERFORMANCE | |
|---|---|
| RTI Tracking Number: | 1403A11 Date: 3/26/2014 |
| Core Task: | Metallurgical Testing, Thermogravimetric Analysis, Chemical Analysis, Metallurgical Testing |
| Analytical Techniques | Hardness/ DSC/TGA/FTIR/SEM/EDS |

Four water valve samples were received for analysis and were identified as follows:

Sample 1403A11-001A: – Good Part from Stock
Sample 1403A11-001B: – Failed claim # 00514820T
Sample 1403A11-001C: – Failed claim #BVXD20000352T
Sample 1403A11-001D – Un-welded parts

The scope of the analysis was to characterize the parts for compositional differences by Differential Scanning Calorimetry (DSC), Thermal Gravimetric Analysis (TGA), EDS (Energy Dispersive X-ray Spectroscopy) for qualitative identification of elements with atomic number greater than five, and FTIR (Fourier Transform Infrared Spectroscopy) for identification of organic functional groups as well as to observe under magnification the failed weld area for possible root causes of weld failure. The results of the analysis are discussed below.

**Analysis Data and Results:**

The parts were observed under magnification for possible contaminates, un-welded areas, or any notable defects in the parts. Figures 1, 2, 3 and 4 are images of the parts at 20X magnification. Figure 1 represents the post at the weld location prior to sonic welding. Figure 2 represents the stock part collar after cutting in half and pulling away from the post. This image shows a rough area where the material was welded to the post. No notable contamination or un-welded areas were found to be present. Figure 3 represents the failed post after wiping the black dirt away from the weld area. This image shows a rough area that was welded with dirt in the textured area of the broken weld. The black material/dirt is believed to be present from part use after the weld failed since this black material was present on the recess of the failed part as well. Figure 4 represents the failed collar after being sliced for observation of the weld area. This image shows the weld line that had failed as well as excess lose polymer/filler material that is believed to have been formed during the sonic welding process of the parts.

Portions of each sample around the weld area of the post and collar of both the good stock samples and a failed sample were cut and isolated for thermal analysis. The thermal graphs for both DSC and TGA can be seen in Figures 5 to 16. The DSC analysis was used to determine the glass transition temperature of the polymer and TGA was used to determine the weight percentage of organic and inorganic material in the polymer composite material. The results are shown in Table 1 below.

**Table 1: Thermal Properties**

| Sample Name | % Organic | % Char | % Inorganic | Glass Transition ($^{o}$C) |
|---|---|---|---|---|
| **1403A11-001A Post** | 35.4 | 24.0 | 40.6 | 110.7 |
| **1403A11-001A Collar** | 35.2 | 27.4 | 37.0 | 114.8 |
| **1403A11-001A Excess weld** | 49.2 | 19.3 | 31.2 | 86.6 |
| **1403A11-001B Post** | 37.0 | 25.3 | 37.4 | ND |
| **1403A11-001B Collar** | 32.6 | 28.0 | 39.1 | 133.9 |
| **1403A11-001B Excess Weld** | NA | NA | NA | 151.1 |
| **1403A11-001D Post** | NA | NA | NA | 95.2 |

The failed part was found to have a higher glass transition temperature that indicates the polymer composite has become brittle over time most likely due to environmental stress.

Each portion of the stock and failed sample around the welded area were isolated for ATR/FTIR to determine the nature of the material. Figure 17 represents the FTIR spectra of the post of the good stock part around the weld area. Figure 18 represents the FTIR library match of the post of the good stock part indicating it to be polyphenylene sulfide with silica filler. Figure 19 represents the FTIR spectra of the collar portion of the stock part indicating polyphenylene sulfide with silica filler. Figure 20 represents the FTIR spectra of the excess material of the stock part indicating polyphenylene sulfide with lesser amounts of silica filler. This would indicate that excess polymer was produced during the welding process. Figure 21 represents the FTIR spectra of the failed post portion of Sample 1403A11-001B indicating polyphenylene sulfide with lesser amounts of silica filler. Figure 22 represents the FTIR spectra of the failed collar portion of Sample 1403A11-001B indicating polyphenylene sulfide with silica filler. The bulk material of both the stock part and the failed part were found to be silica filled polyphenylene sulfide.

SEM/EDS analysis was performed on the inside portion of the collar at the weld interface of Samples 1403A11-001A (stock good part) and 1403A11-001B (failed part). Figures 23 and 24 represent the SEM images of the weld interface. The SEM image of the failed collar weld appears to be slightly smoother at the weld break that can be representative of a brittle failure. EDS analysis of the weld interface is shown in Figures 25 and 26. EDS of the failed weld indicates the presence of potassium not found to be present in the stock weld sample. This would indicate possible environmental stress due to a potassium rich material. Although we can not know the nature of the potassium material if it were an alkali material such as potassium hydroxide the base material PSS has limited suitability to this type of material and would fail over time.

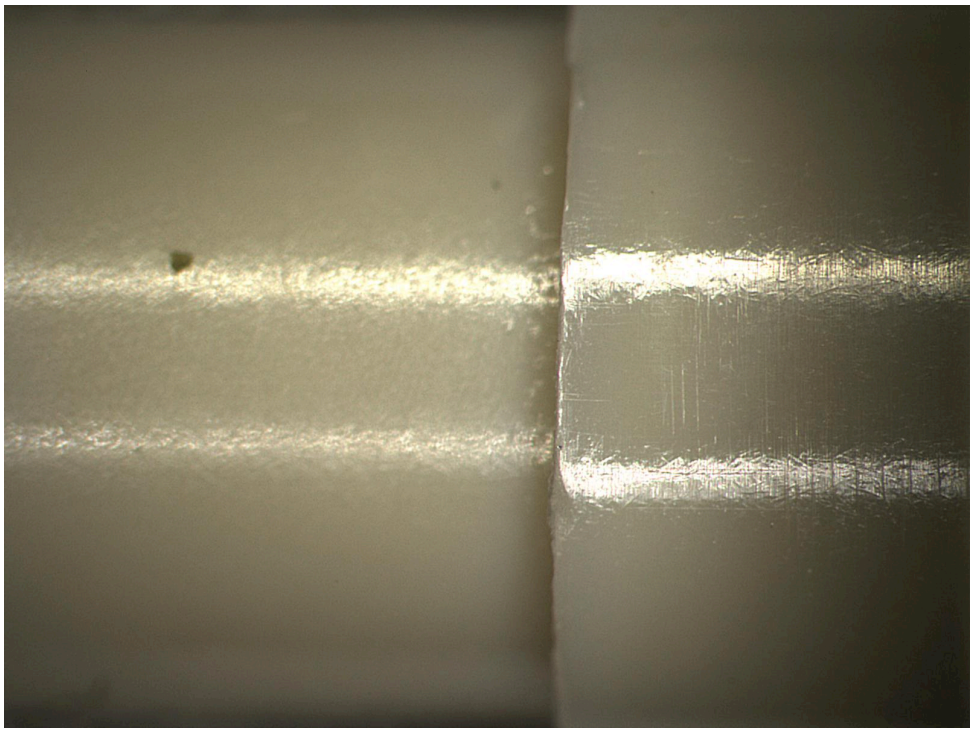

**Figure 1: Sample 1403A11-001D Post Un-welded**

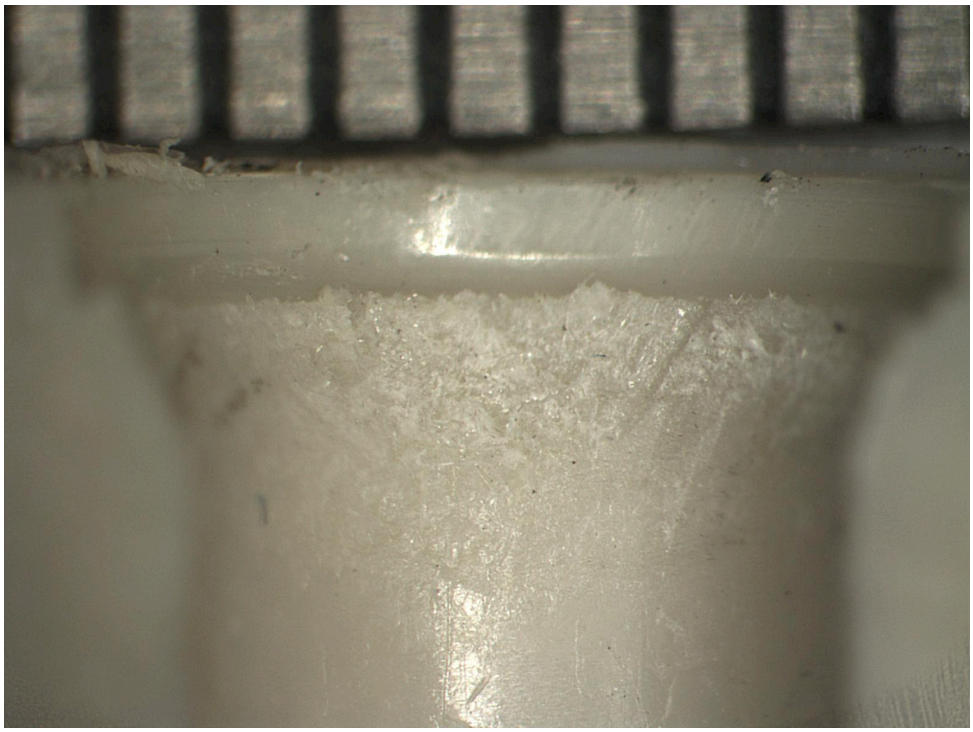

**Figure 2: Sample 1403A11-001A stock part collar**

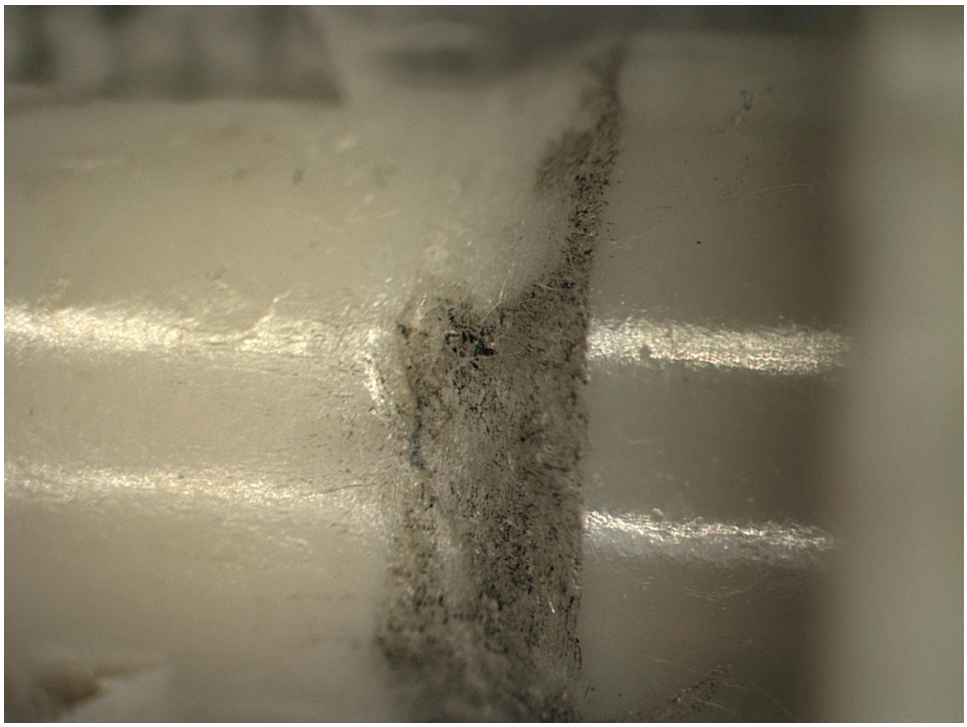

**Figure 3: Sample 1403A11-001B failed post**

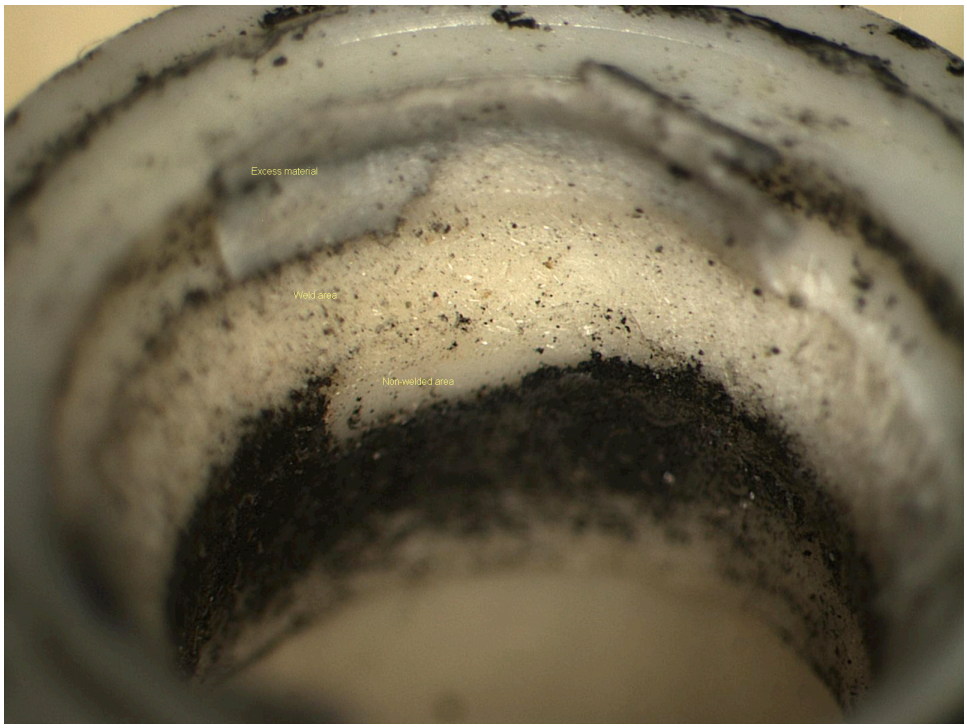


**Figure 4: Sample 1403A11-001B failed collar**

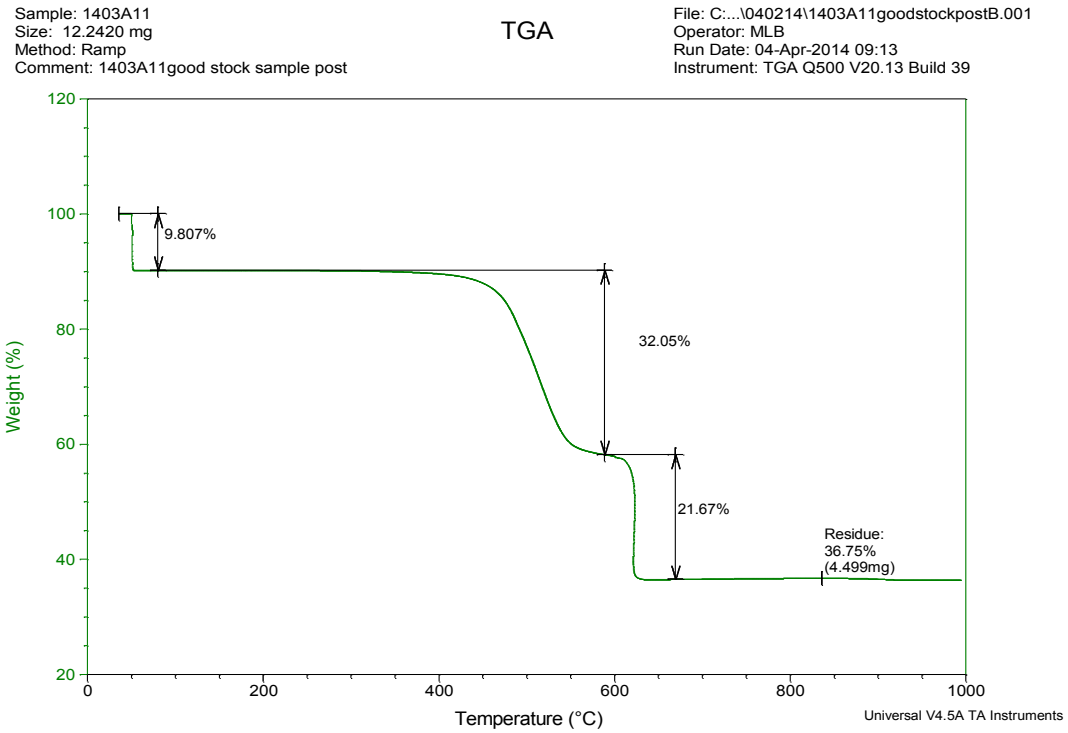


**Figure 5: TGA Thermal graph of good stock part post around weld area**

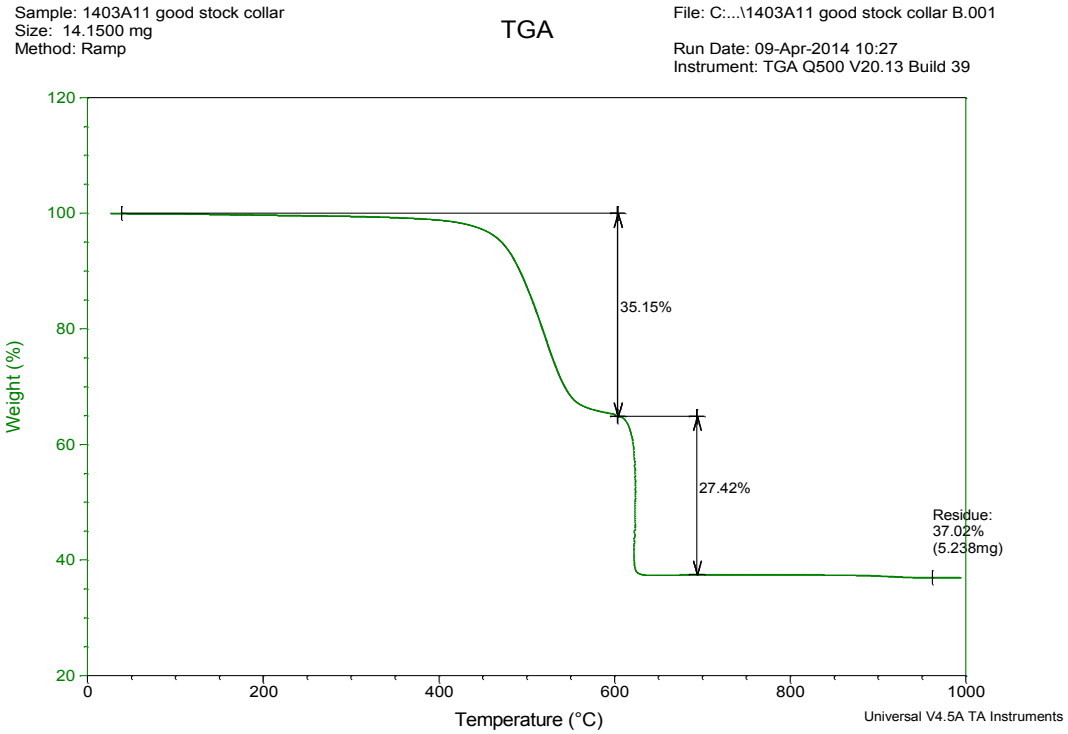


**Figure 6: TGA Thermal graph of good stock part collar around weld area**

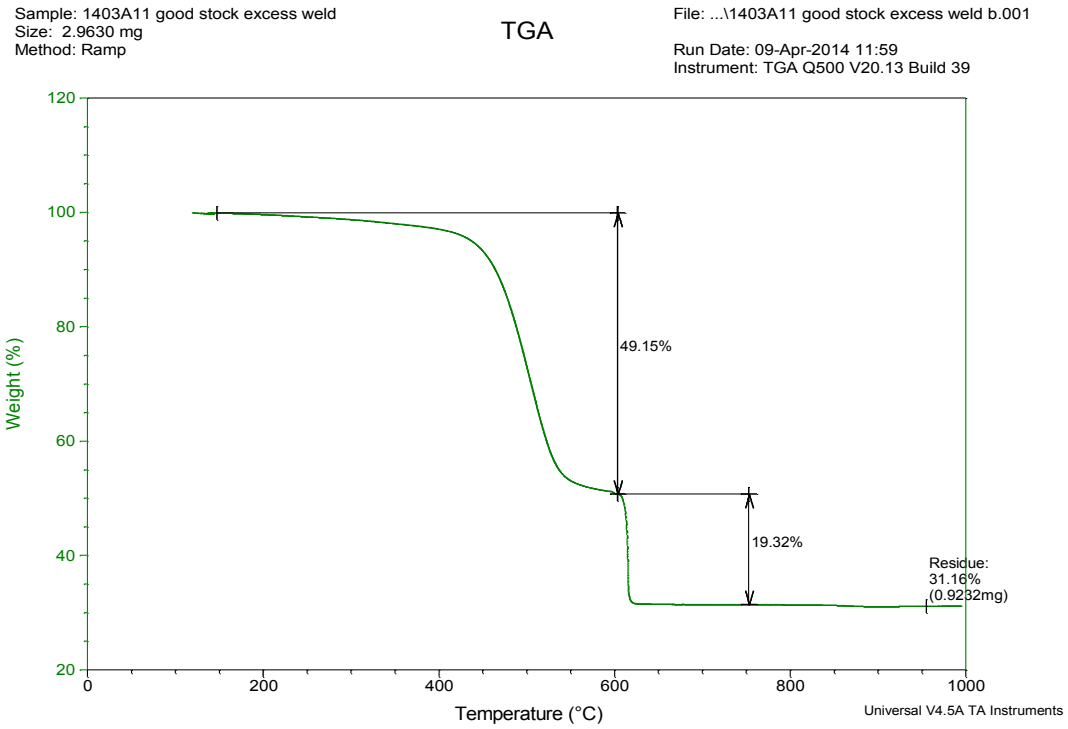


**Figure 7: TGA Thermal graph of good stock part excess around weld area**

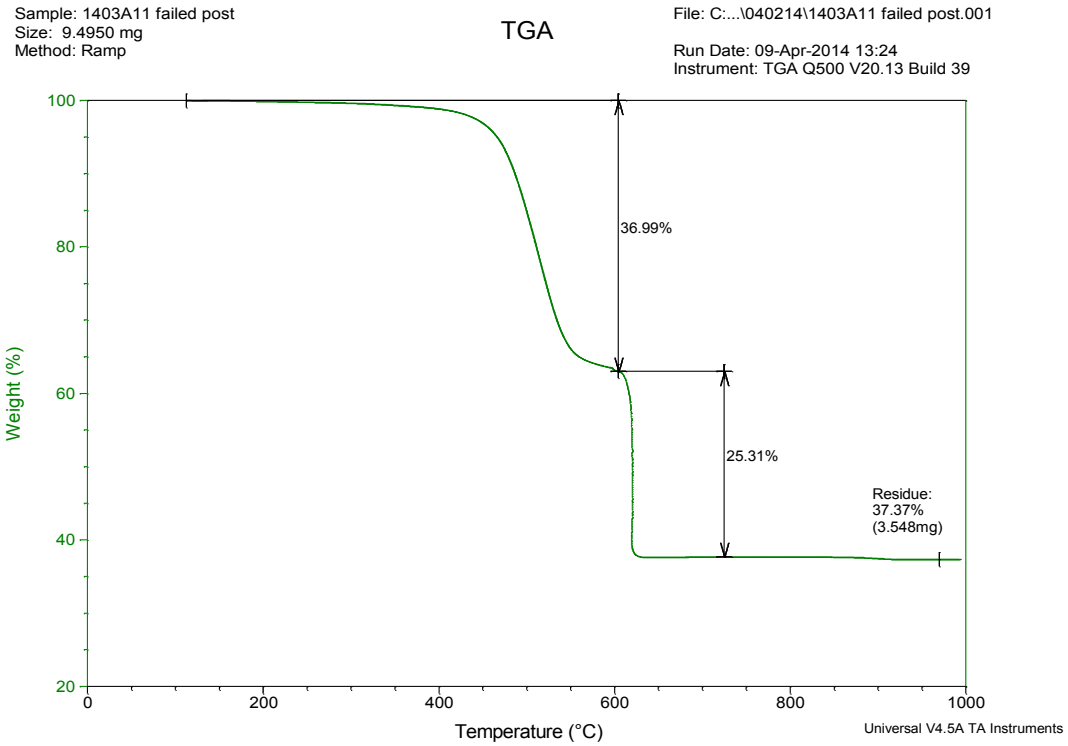


**Figure 8: TGA Thermal graph of failed part post around weld area**

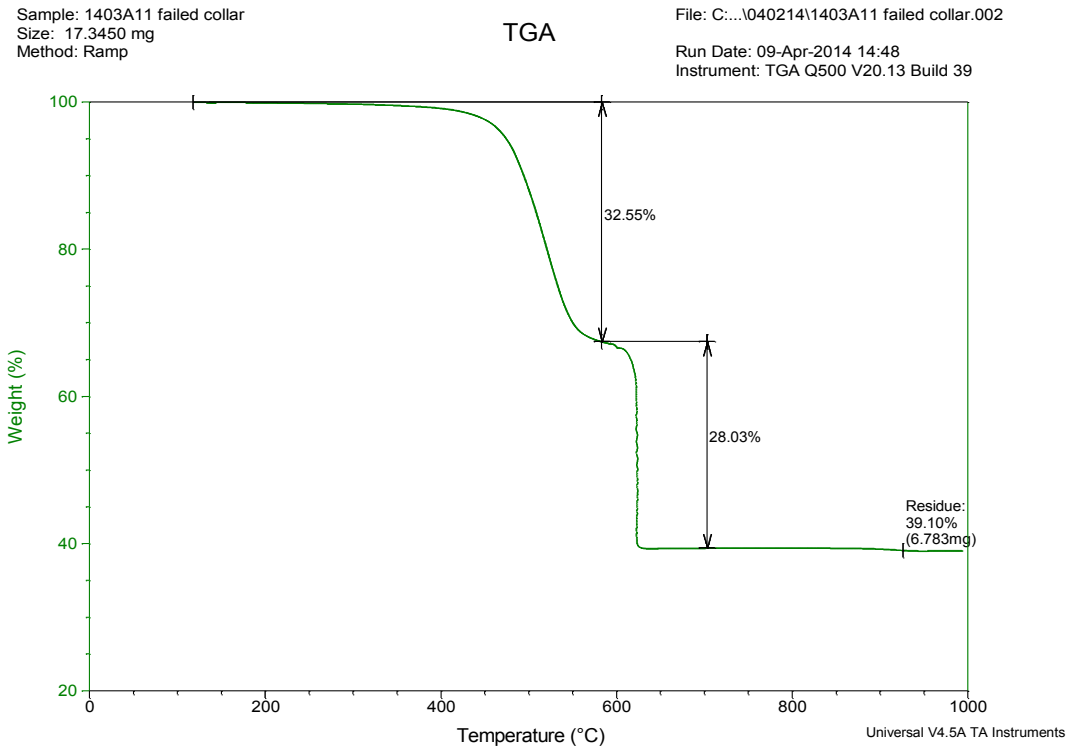


**Figure 9: TGA Thermal graph of failed part collar around weld area**

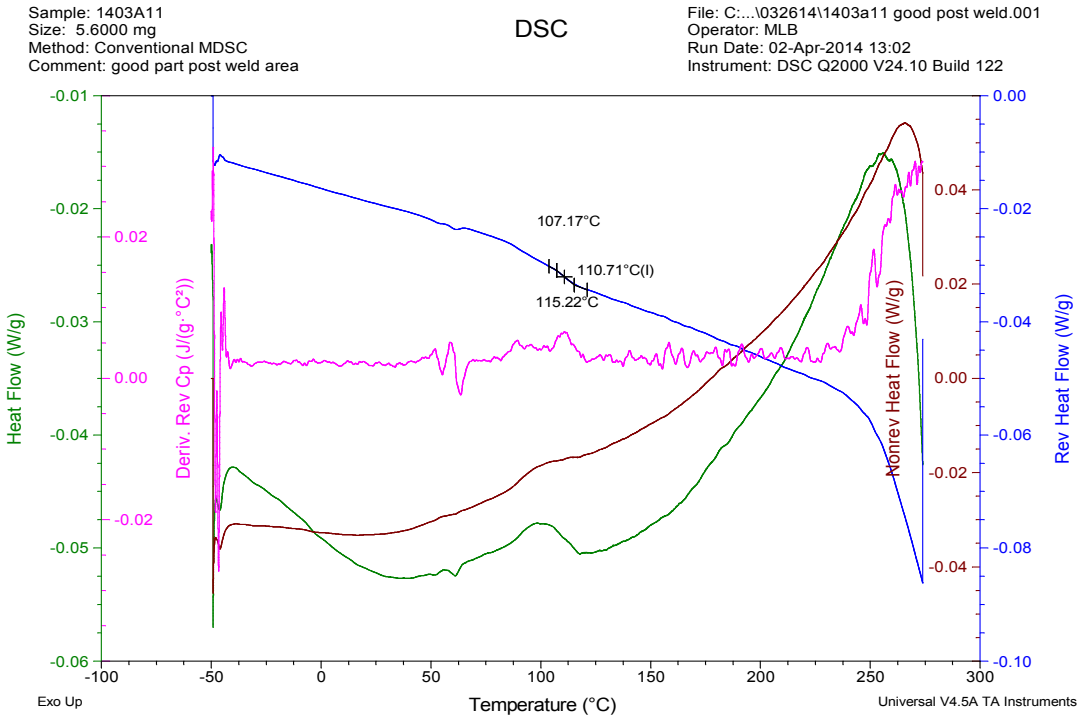


**Figure 10: DSC Thermal graph of good post around weld area**

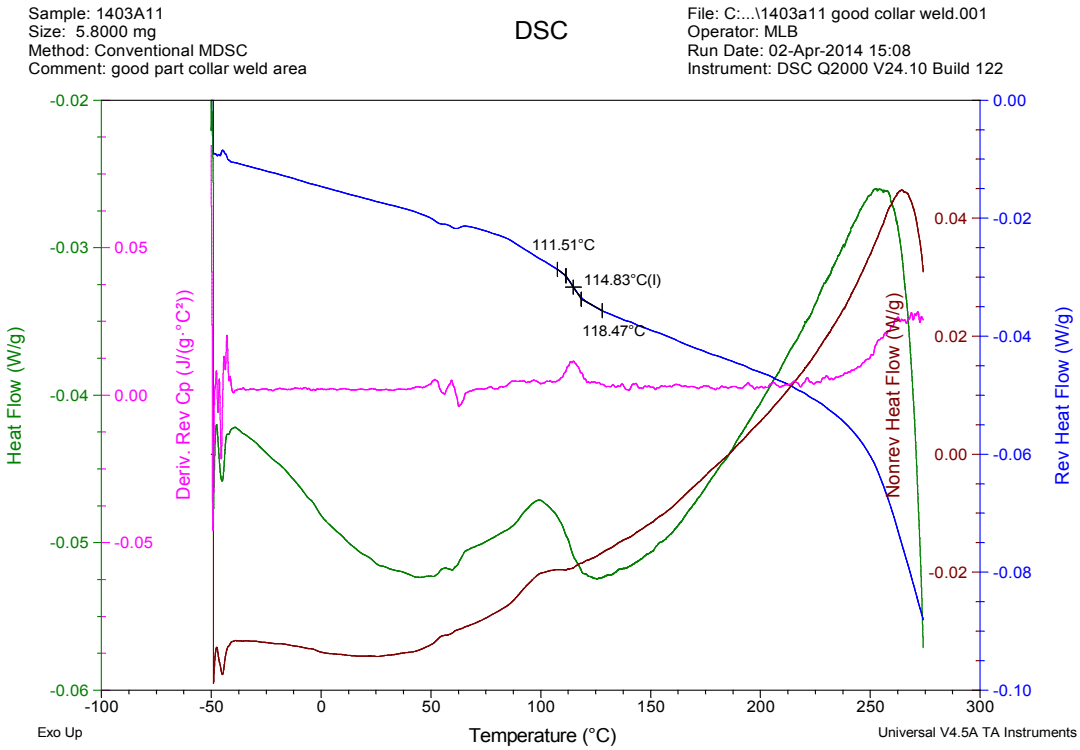


**Figure 11: DSC thermal graph of good collar around weld area**

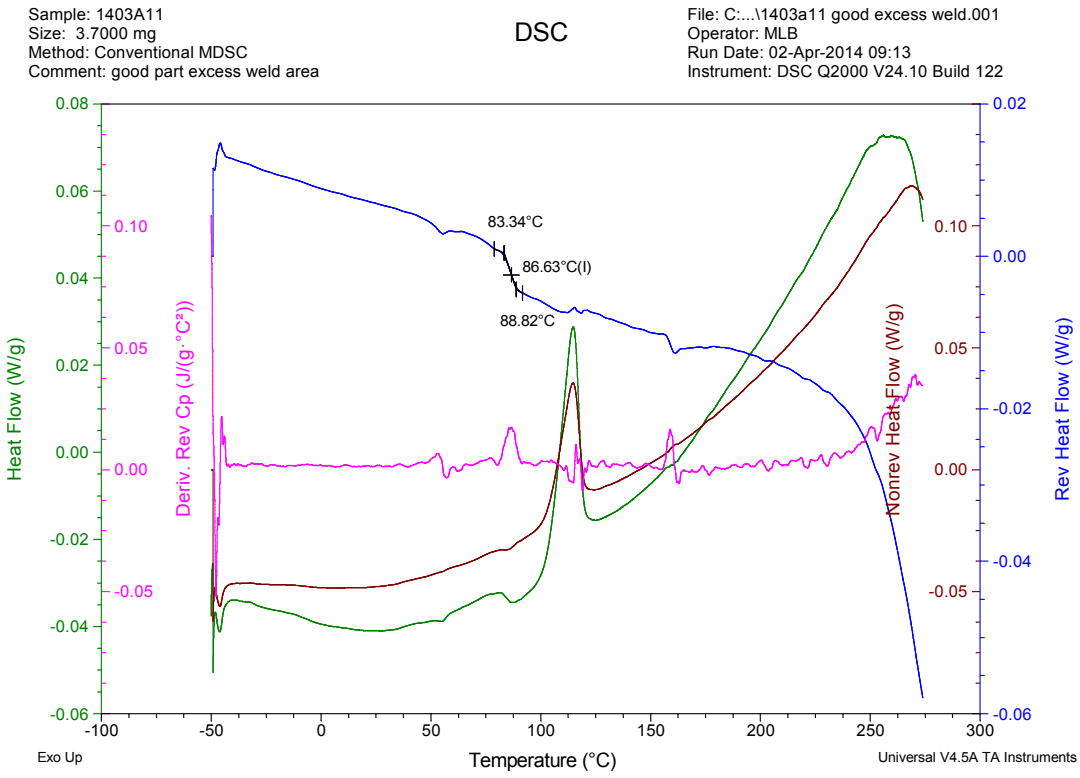


**Figure 12: DSC thermal graph of excess PPS around weld area of good part**

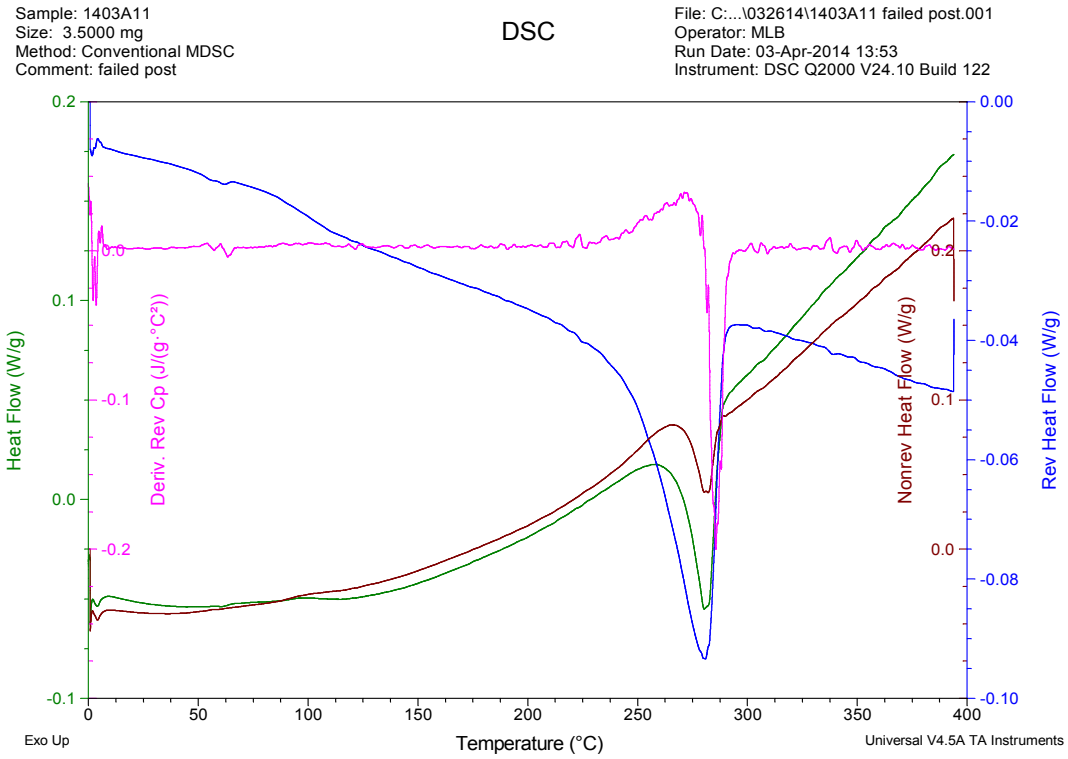


**Figure 13: DSC thermal graph of failed post around weld area**

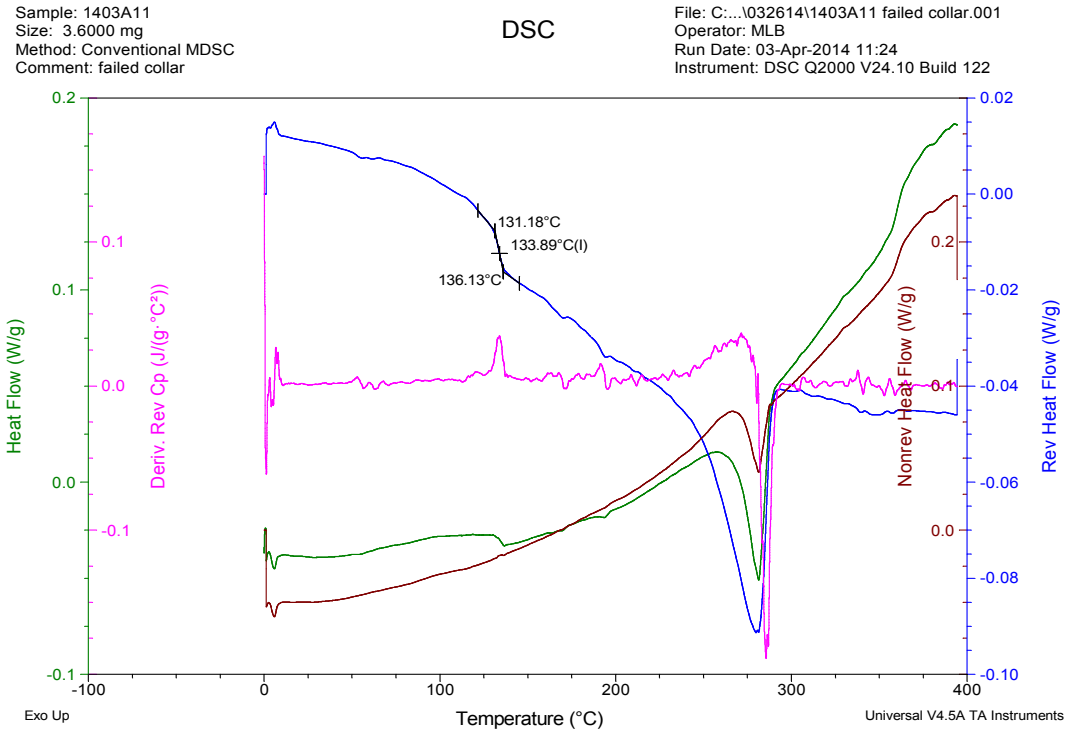


**Figure 14: DSC thermal graph of failed collar around weld area**

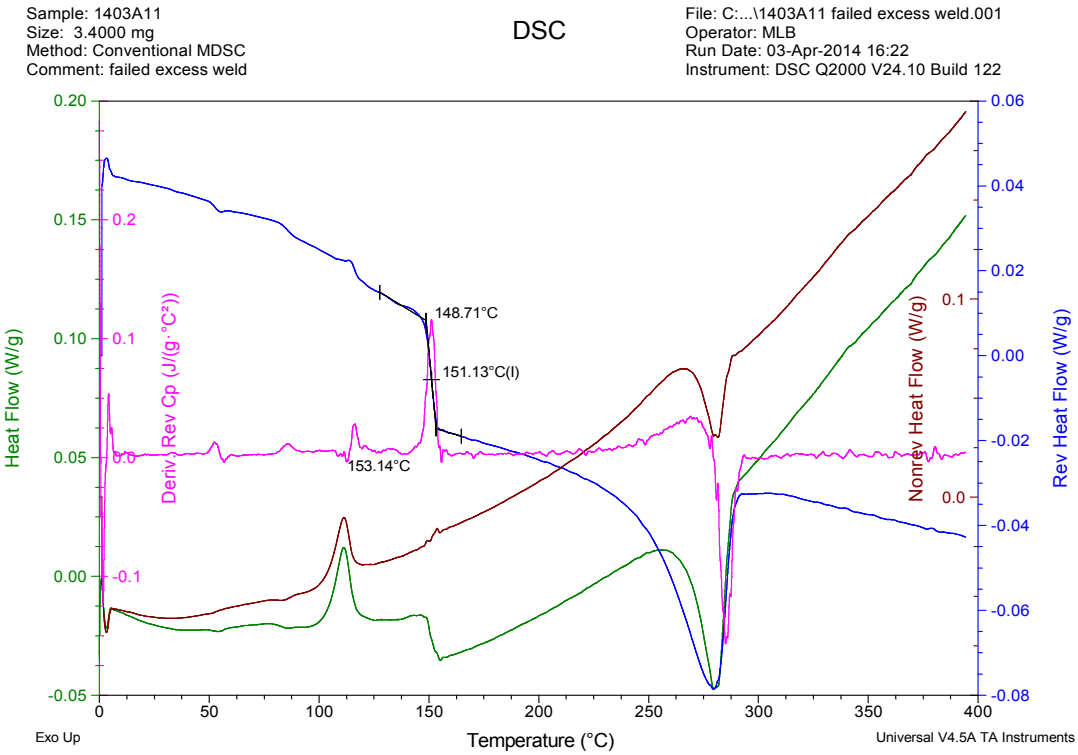


**Figure 15: DSC thermal graph of excess PPS of failed part around weld area**

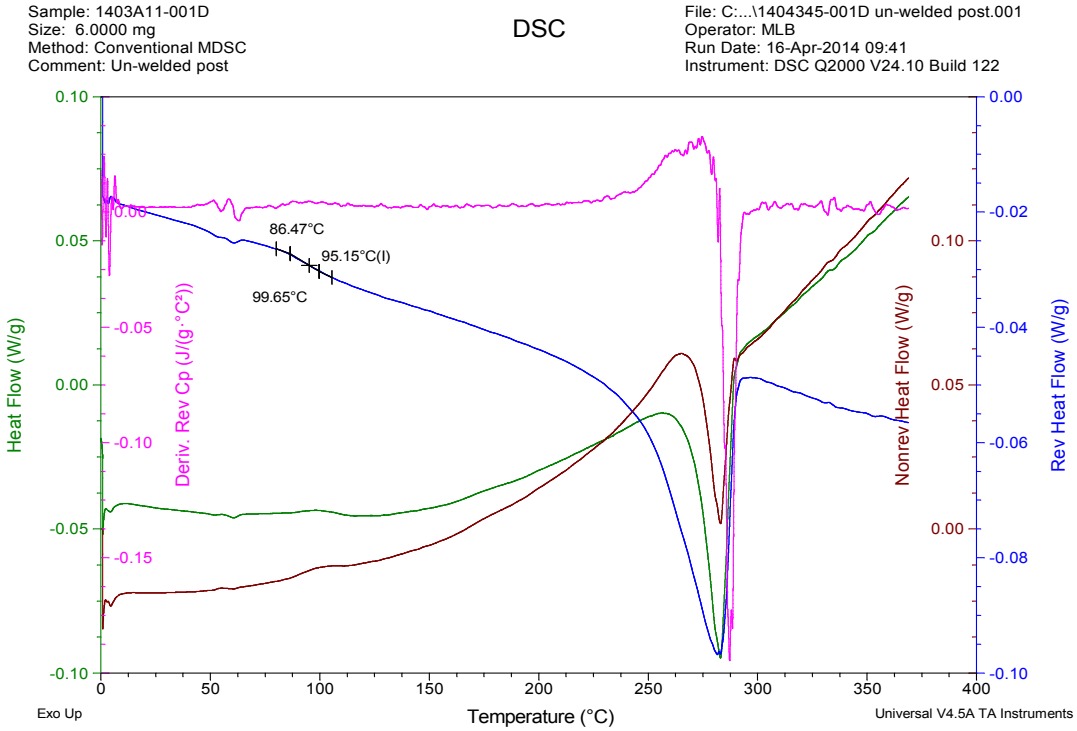


**Figure 16: DSC thermal graph of un-welded post around weld area**

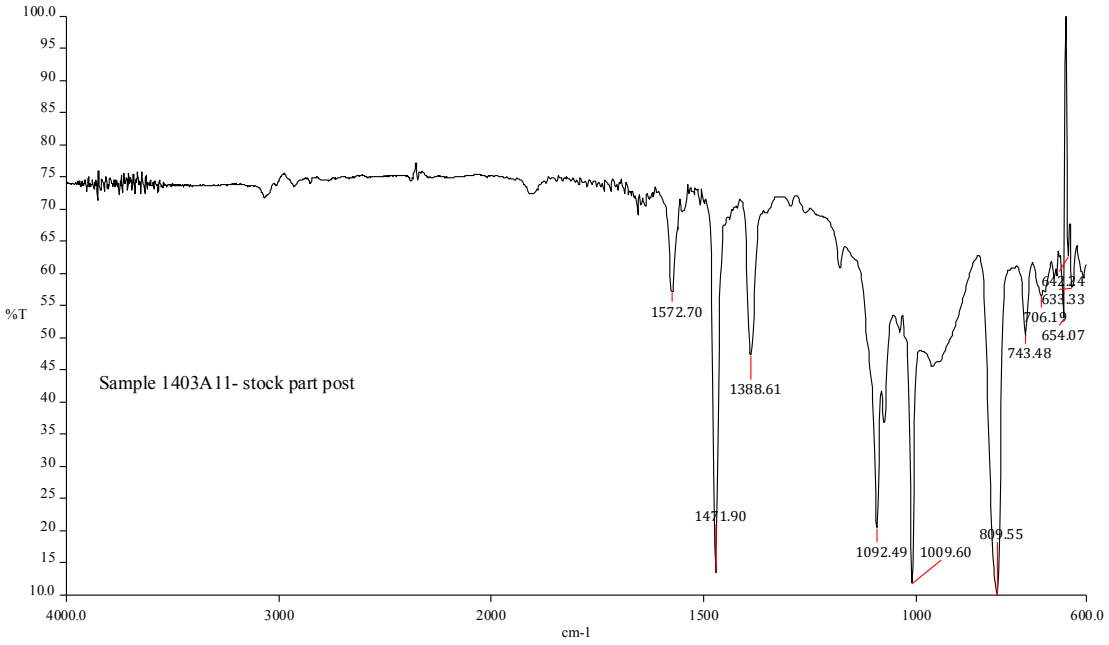


**Figure 17: Sample 1403A11-001A Stock post**

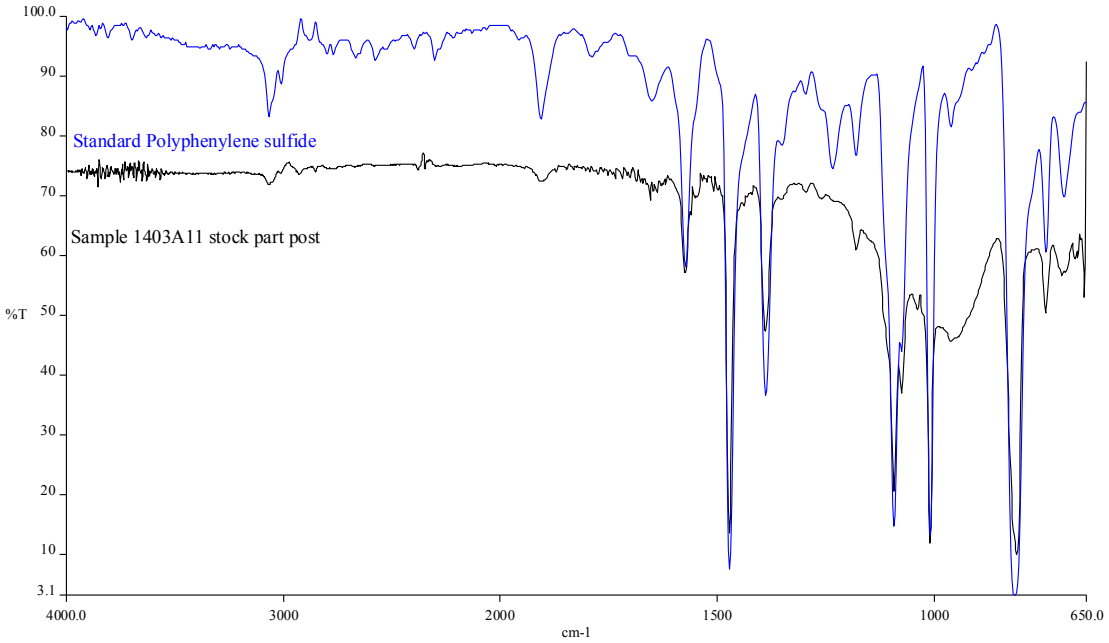


**Figure 18: Sample 1403A11-001A Stock post and library match of polyphenylene sulfide**

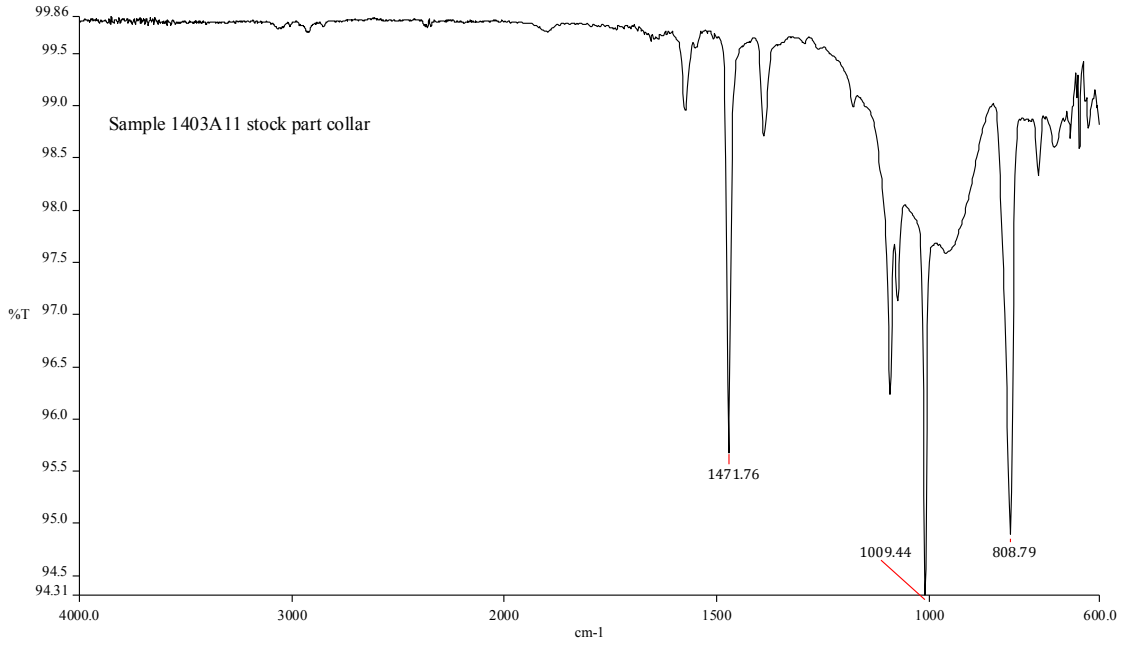


**Figure 19: Sample 1403A11-001A Stock collar**

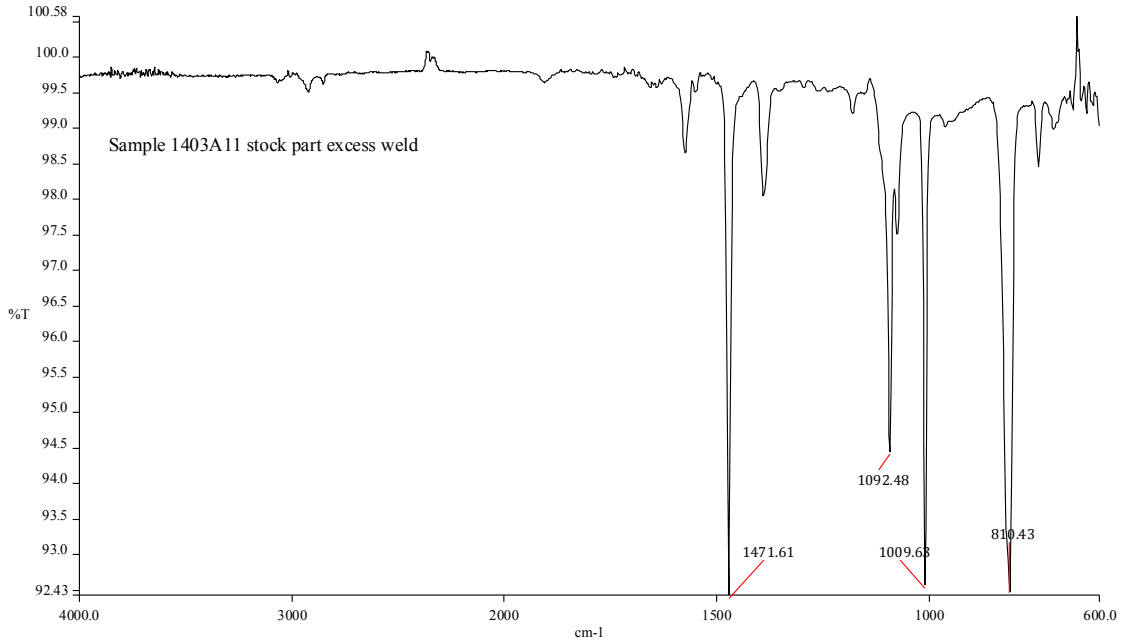


**Figure 20: Sample 1403A11-001A Stock part excess material around weld**

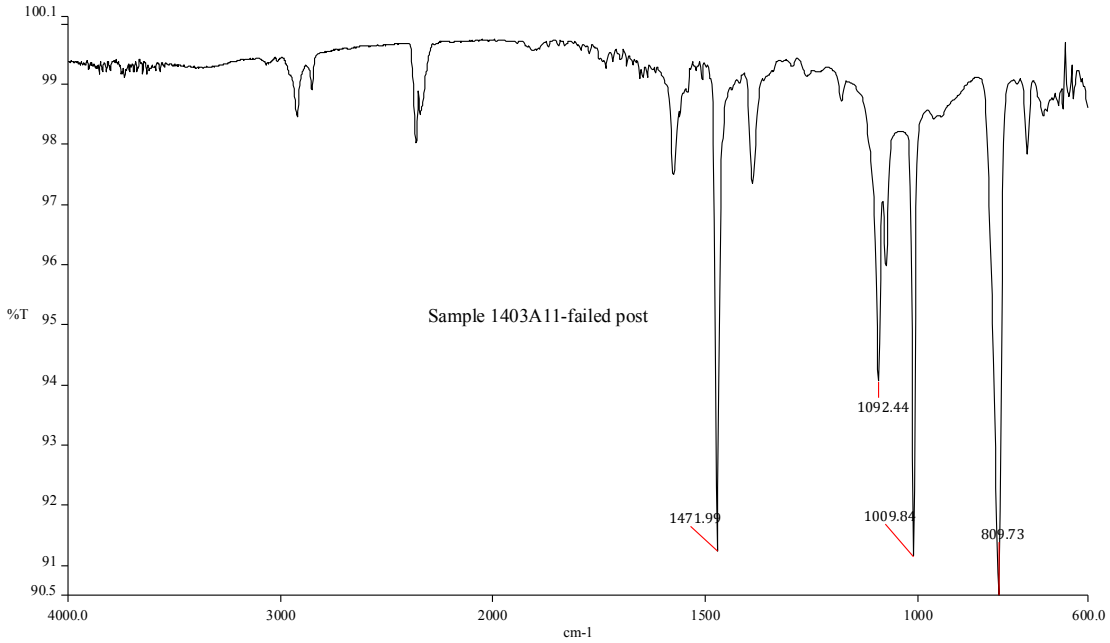


**Figure 21: Sample 1403A11-001B failed post material around weld**

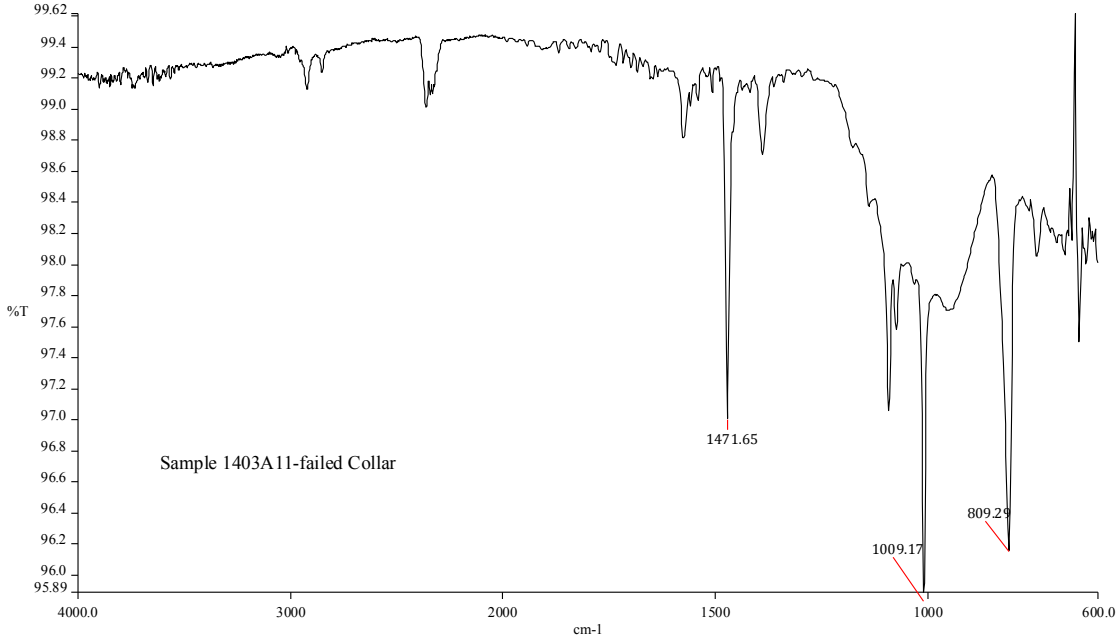


**Figure 22: Sample 1403A11-001B failed collar material around weld**

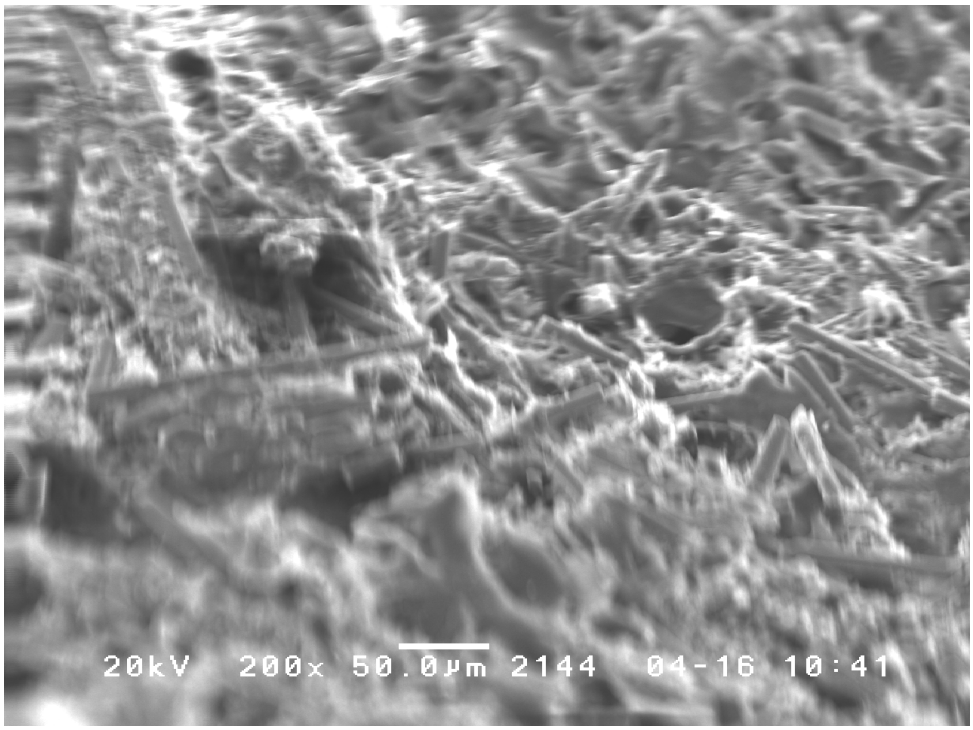


**Figure 23: SEM image of Sample 1403A11-001A (good stock part)**

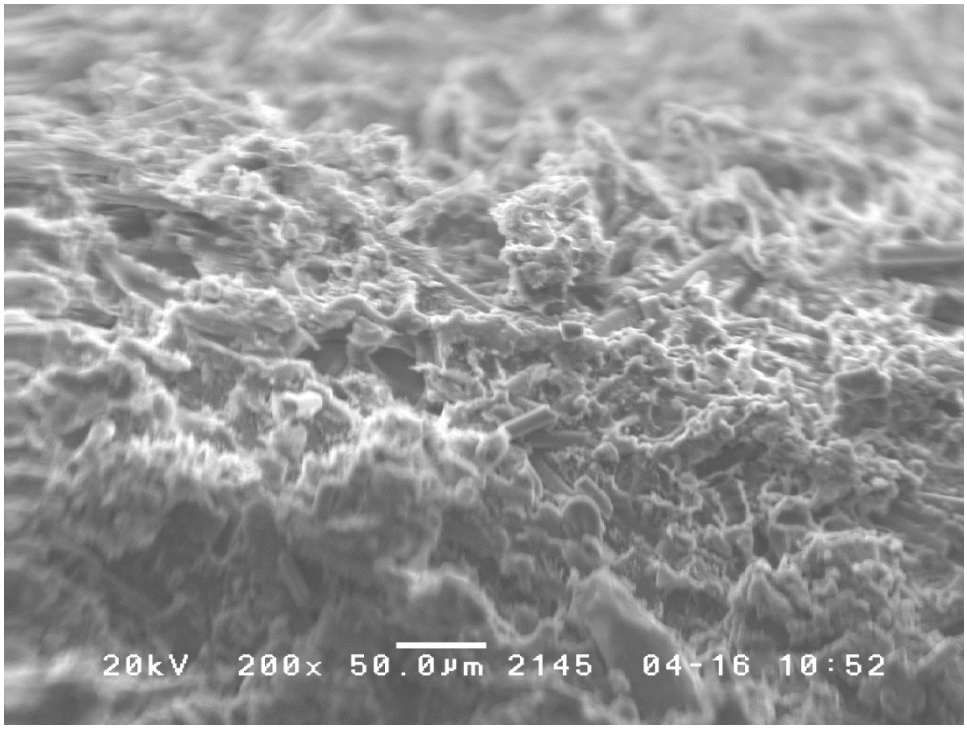


**Figure 24: SEM image of Sample 1403A11-001B (Failed part)**

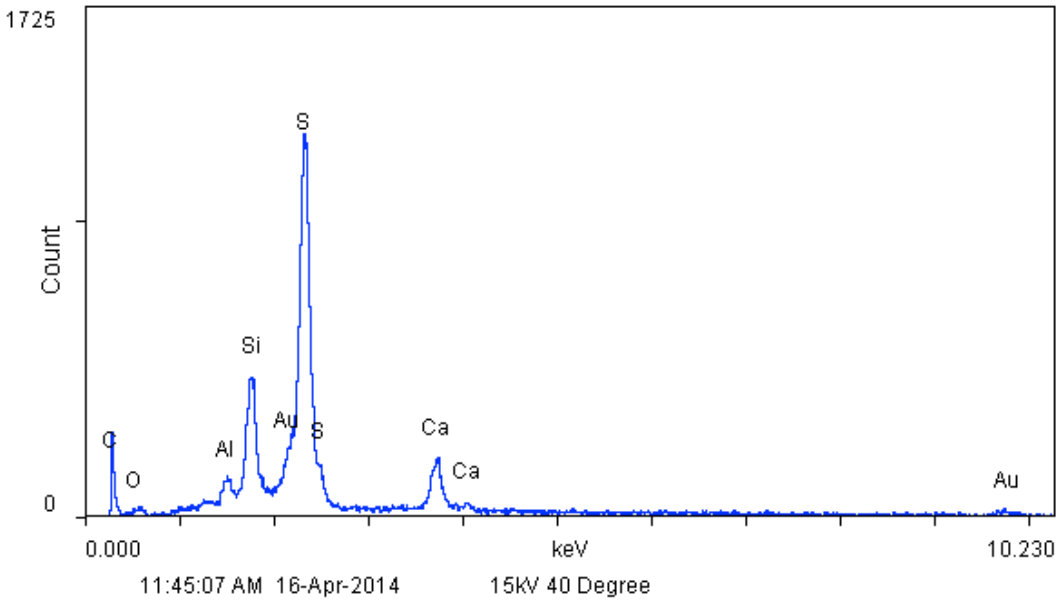


**Figure 15 – EDS of Sample 1403A11-001A (Good Weld)**

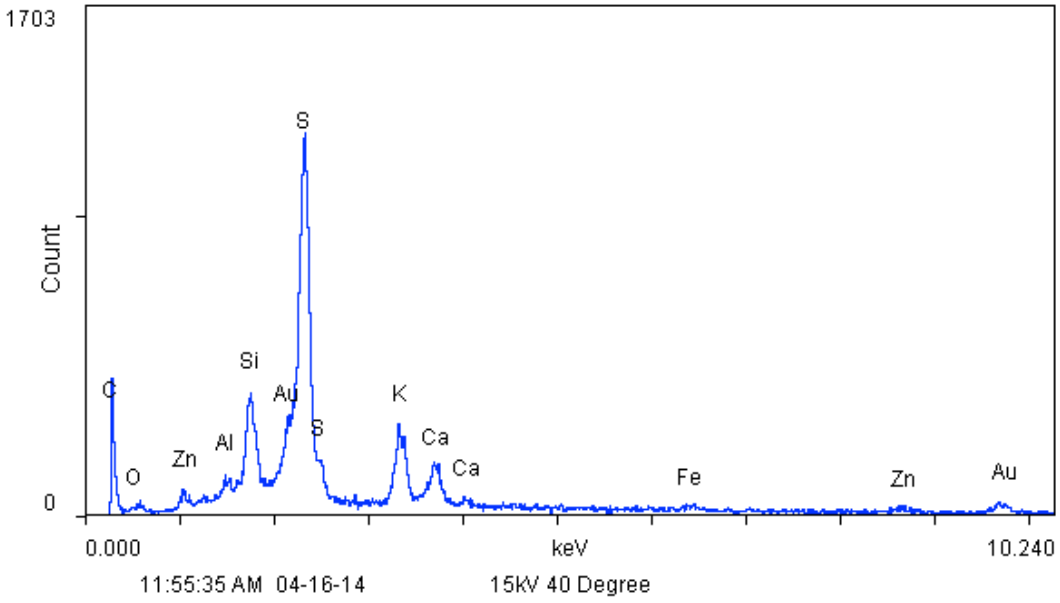


**Figure 26 – EDS of Sample 1403A11-001B (Bad Weld)**

**Conclusion:**

The polyphenylene sulfide (PSS) in the weld area of the failed part was found to have an increased glass transition temperature and a potassium contamination not found to be presents in the stock welded part. This increased glass transition temperature will cause the polymer to become more brittle and allow for fractures more easily than the stock part typically known as brittle failures. The presence of the potassium indicates a possible chemical attack. Although we cannot determine the source or nature of the potassium if it was present in alkali form and at elevated temperatures it would attack the PSS and weaken it over time. It is known that PSS has limited suitability in the presence of alkali chemicals which can lead to brittle failures as seen with this part.

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