Residual gas analysis of instrumentation wire for a synchrotron radiation beamline

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Abstract

A residual gas analysis was performed on different styles of polymer coated instrumentation wire. A variety of wires were selected to be analyzed based on cable construction, color coding, pricing and availability for small quantities. Each length of wire was measured to have equal surface area before testing. A vacuum pump down and residual gas analysis of each sample was performed for a period of 48 h. The pump down rate and outgassing characteristics of each wire were compared to determine the best choice of instrumentation wire to use in a beamline vacuum environment.

1. Introduction

Vacuum compatible wiring is mandatory to prevent contamination of beamline optical components. Instrumentation wire that is color coded and stranded can assist in troubleshooting and prevent breakage. Many wiring options are available from manufacturers of which six were chosen for this particular experiment. The products tested were 22–24 gauge, color coded, stranded, and available in small quantities for reasonable cost. Table 1 summarizes the wires chosen for testing.

Preliminary vacuum test data showed great differences in the pump down rate and outgassing characteristics between each wire sample [1]. This data was followed up with an extended pump down schedule and a residual gas analysis. The residual gas analysis helped address the questions of quality and quantity of trapped gases in the polymer coatings on the wires.

2. Test procedure

Each wire was verified to have equal surface area before testing. Gold plated crimps were attached to the ends of each wire leaving a small amount of conductor exposed to minimize trapped gases. Alcohol was applied to each sample with a clean cloth and gloves before testing. Each wire was separately tested by attaching it to the inside pins of a 9-pin electrical feedthrough flange. The flange was attached to a 4-way cross-shaped chamber containing a cold cathode gauge. A

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second 4-way cross was attached containing a 70 l/sec turbo pump and a Stanford Research Systems RGA200 residual gas analyzer. The turbo pump output was connected to an oil free scroll pump. The vacuum pressure was monitored by connecting the analog output of the cold cathode gauge controller to a 16-bit analog to digital converter.

Each sample of instrumentation wire was analyzed for a period of 48 h by setting the RGA200 to a continuous scan mode. The partial pressure measurements on 1 amu through 200 amu were continuously logged for the entire 48 h period. Each scan took approximately 3.40 min to complete. All the partial pressure data along with the time and date of each scan was saved to a separate file for each sample.

3. Experimental results

The cold cathode gauge output was used to monitor the vacuum pressure as well as to determine when to start the RGA200 filament. A pump down comparison for each wire sample using the cold cathode gauge output is shown in Fig. 1. The data shown in Fig. 1 has an approximate lower limit of $1 \times 10^{-8}$ Torr which is the advertised lower limit of the cold cathode gauge [1].

A pump down and residual gas analysis of the empty vessel was performed before and after all the wires were tested. Analysis of the empty vessel showed consistently better results than any of the samples tested. The RGA200 filament scan was started for each sample at approximately $10^{-4}$ Torr. All partial pressure data has an approximate upper limit of $10^{-4}$ Torr due to the operational limit of the analyzer filament [2].

Interpretation of the mass spectra data collected for each wire sample involved comparing each data file with the spectral library provided in the RGA200 software. All masses with partial pressures greater than or equal to $1 \times 10^{-9}$ Torr were highlighted within each data file and compared to the library. The partial pressures of masses still present in each wire sample after 48 h of pumping are shown in Fig. 2. For comparison purposes a square sheet of Kapton film with the same surface area as the wire samples is also shown. Preliminary vacuum test data showed great differences in the pump down rate and outgassing characteristics between Kapton film and Kapton coated wire [1]. The Kapton film was held inside the vacuum

<table>
<thead>
<tr>
<th>Product</th>
<th>AWG/strand</th>
<th>Color</th>
<th>Rel. cost</th>
</tr>
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<tbody>
<tr>
<td>KAP2 Kapton</td>
<td>22/1</td>
<td>1</td>
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</tr>
<tr>
<td>Colored Kapton</td>
<td>24/19</td>
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<td>2.00</td>
</tr>
<tr>
<td>Irradiated PVC</td>
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<td>10</td>
<td>1.40</td>
</tr>
<tr>
<td>Spec55 Space Wire</td>
<td>22/19</td>
<td>10</td>
<td>1.25</td>
</tr>
<tr>
<td>Teflon coated</td>
<td>22/7</td>
<td>10</td>
<td>0.80</td>
</tr>
<tr>
<td>PVC Hook-Up</td>
<td>22/7</td>
<td>10</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Fig. 1. Results of 48 h pump down on each wire sample.

Fig. 2. Partial pressure analysis of masses present in each sample after 48 h of pumping.
chamber with a copper clip. Both the film and clip were wiped with alcohol before the analysis.

Inspection of the mass spectral data within the first 8h of pumping showed the elimination of several of the same masses from each sample within minutes of starting the turbo pump. The Irradiated PVC and Hook-Up wire samples showed the presence of hydrocarbon masses 55 and 57 amu for the first 2h of pumping only. Fig. 3 shows a sequential plot of ethyl alcohol mass 31 amu after 8h of pumping for each sample tested.

4. Conclusions

Fig. 1 shows great differences in the pump down rate and outgassing characteristics between the different instrumentation wires tested. This data is in agreement with preliminary vacuum test data [1]. A relative interpretation of the data is suggested since the gauge was not verified to be calibrated before testing [3,4].

The residual gas analyzer data in Fig. 2 summarizes the outgassing characteristics of the individual wires after 48h of pumping. The four dominant masses present in varying quantities in each wire are hydrogen (2 amu), water (18 amu), air (28 amu), and carbon dioxide (44 amu). The Kapton sheet was tested for comparison purposes and proves that Kapton coated wire traps these masses and prevents a quick pump down rate. Fig. 2 shows that Teflon coated wire exhibits better vacuum characteristics than the other samples tested. Although the data supports the use of this material in a vacuum environment, caution should be exercised when using this material in a high radiation environment. Personal experience and conversations with laboratory staff members confirms that Teflon deteriorates with exposure to radiation.

The sample of Spec55 Space Wire shows better vacuum characteristics than any of the remaining samples. This product is advertised as a radiation resistant low outgassing wire used for outer space applications. Fig. 3 shows that the ethyl alcohol (31 amu) used to clean the samples before testing did not saturate the residual gas analysis. The data shows that the alcohol was eliminated from the Spec55 Space Wire much faster than from all other samples. This report strongly supports the use of Spec55 Space Wire as a vacuum compatible instrumentation wire on a synchrotron radiation beamline.

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References