Development of Resistive Glass Multi-Capillary Inlet Tubes for Enhanced Ion Transport

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Abstract:
Resistive glass tubes have been used successfully as reflectrons in TOF mass spectrometers and ion drift tubes in an ion mobility spectrometer. This novel technology enables the exceptional performance of single capillary inlet tubes for ion transmission in atmospheric pressure ionization sources.

Uniform electric fields which guide sample ions are generated within the internal single-channel glass tubes. An improvement in ion transfer efficiency by a factor of 100 compared to quartz inlet tubes has been reported. To further increase ion transmission, multi-capillary inlet tubes of resistive glass have been developed. These tubing have a circular array of six channels for the same outer diameter. Unique extrusion and drawing procedures used to create these multi-channel tubes will be described and illustrated.

Introduction (continued):

Resistive Glass:
- Resistive glass tubes are designed to guide ions by generating a uniform electric field.
- Resistive glass tubes are comprised of a proprietary glass and nickel-chromium layer which is uniformly extruded over the entire circumference, not only as a coating (Figure 1).
- The resistivity is a property that is typically measured in a laboratory setting.
- Resistive glass products are highly uniform.
- A remote probe indicates a consistent resistivity within a ±1% variation of the starting material (Figure 2).
- Kelvin probe indicates that the uniform resistivity makes it a uniform electric field. The resistive glass products are highly uniform within the resistivity of the glass itself (Figure 3).

Methods (continued):
Multi-Capillary Tube Process Development:
- The more intricate multi-capillary process requires drawing of a composite assembly consisting of small, non-conducting hollow tubes surrounding a solid center. This composite assembly becomes an electric field that selectively attracts ions to the inside of the tube. The multi-capillary process can move ions more easily into the mass spectrometer.
- It also prevents collisions with other ions and the tube walls, which are produced in the mass spectrometer. The walls are then redrawn to the final diameter.

Results (continued):
Three of these, the single capillary inlet tubes help prevent collision with other ions and the tube walls which can produce ion loss and provide the ability to preferentially attract positive or negative ions.
- In addition, new glass compositions were developed for high resistivity requirements and long, 12" tubes.
- The resistivity of two multi-capillary tubes with a total length of 120 cm and a 30 cm length was tracked for 5 months. The tubes were stored at ambient temperature and humidity for the duration of the test. The data presented in Figure 14 shows an overall stability of ±0.1% for the lower resistor tube and is measured at 10% for the lower resistor tube with a relative humidity over an uncontrolled environment.
- For manufacturing, Resistive Glass, Inc. Dunn and Ritzau7 showed that resistive glass tubes are highly stable in a vacuum and dry nitrogen with less than 1% increase in resistance over a five-month period.

Conclusions:
A unique multi-bore extraction process was developed to create resistive glass multi-capillary tubes.
- An increase in ion transmission of ~10X has been realized by a leading mass spectrometer manufacturer through the successful implementation of the multi-channel configuration with the unique resistive properties of the inlet tube.
- Uniformity of resistivity was demonstrated which leads to a highly uniform electric field.
- Good stability of resistivity was shown over 5 months in an uncontrolled environment for both low- and high-resistivity tubes.

Manufacturing Capability of Resistive Glass:
- Capillary inlet tubes are available in grades, sizes, and wall thicknesses that meet the specific requirements of the mass spectrometer.
- Custom-made design and fabrication of specific capillary configurations is available.

References:

Figure 1. Cross-section of resistive glass.
Figure 2 (above).
Figure 3 (right).
Figure 4. Examples of products made with Resistive Glass.
Figure 5. Typical single capillary resistive glass tube shown.
Figure 6. Nickel-Chromium metallization areas for applying voltage.
Figure 7. The extrusion of a single capillary inlet tube.
Figure 8. Photo of un-reduced multi-capillary assembly before redraw.
Figure 9. Photo of un-reduced multi-capillary assembly after redraw.
Figure 10.
Figure 11. 1.5" diameter multi-capillary tube.
Figure 12. Resistivity data for single capillary inlet tubes.
Figure 13. Resistivity data for multi-capillary inlet tubes.
Figure 14. Resistivity of multi-capillary tubes tracked over five months shows reasonable stability over time in an uncontrolled environment.

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