Resistive Glass Drift Tubes with Air Stable Surface and Multiple Voltage Stages

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Introduction:

Resistive Glass tubes have been used successfully as drift tubes in ion mobility spectrometry, capillary inlet tubes for atmospheric pressure ionization and reflectrons for time of flight mass spectrometry. Resistive Glass provides key benefits for ion mobility drift tubes, such as highly uniform electric fields with minimal radial inhomogeneities, simple one-piece construction and containment for counter-flow gas. The combination of uniform electric field and the turbulence-free counter-flow gas produces resolving powers of over 100. However, for some applications, the resistivity drift of Resistive Glass tubes exposed to oxygen-containing environments can be problematic. A new process has been developed that provides greater stability of resistivity when Resistive Glass tubes are operated in air. Improved stability was also realized for tubes heated in air to 200ºC.

Recent developments have also allowed the creation of monolithic Resistive Glass tubes that have been divided electrically into custom segments. Conductive rings were printed on the inner diameters of Resistive Glass tubes. Connections were then made to these inner features by means of connector pins inserted and bonded through holes in the tube walls. A desired potential could then be applied at these locations to provide the ability to manipulate the electric field inside the Resistive Glass tube.

Background:

Resistance Uniformity
The uniformity of the electric field within a Resistive Glass tube will depend on the uniformity of the resistive wall. Resistance uniformity tests were performed along a 8-inch length structure with good results (Figure 1).

A saturated solution of sodium chloride was slowly poured into the cylinder. The level of the fluid was measured with a ruler and data was taken for every 0.5”. For each measurement, the test voltage was reduced to maintain the test current at 30nA and the voltage and current were recorded and used to calculate the resistance of the cylinder above the fluid.

Height of fluid (in)	Measured Resistance (Gig)	Calculated from best-fit linear equation Resistance (Gig)	Error
0.0	17.571	17.677	0.604%
0.5	16.720	16.786	0.396%
1.0	15.849	15.895	0.294%
1.5	15.010	15.004	-0.038%
2.0	14.124	14.113	-0.076%
2.5	13.248	13.222	-0.193%
3.0	12.385	12.331	-0.439%
3.5	11.509	11.440	-0.607%
4.0	10.599	10.549	-0.477%
4.5	9.723	9.658	-0.675%
5.0	8.827	8.767	-0.690%
5.5	7.923	7.876	-0.595%
6.0	7.002	6.985	-0.245%
6.5	6.093	6.094	0.008%
7.0	5.192	5.203	0.212%
7.5	4.291	4.312	0.481%
8.0	3.389	3.421	0.929%

Figure 1: Linearity Measurement Results for Uniformity.

The results indicate a uniformity of better than 1%.

Results:

Resistivity Stability:
One important performance parameter for resistive devices is the long term resistance stability. Recent advancements in passivation technology have demonstrated only a 4% increase over a three year period when stored in air. The same process demonstrated enhanced stability at elevated temperature (Figure 2).

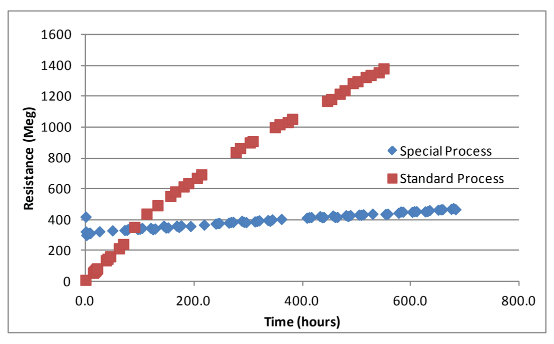

Figure 2: Resistance Stability at Elevated Temperatures.

Segmented Resistive Glass Tubes:
A single stage reflectron lens fabricated with Resistive Glass is somewhat limited in performance. If a multi stage device could be fabricated, higher performance could be achieved.

A new technology has been developed which enables a single Resistive Glass tube to be divided into segments. The locations and dimensions of these segments are variable by design.

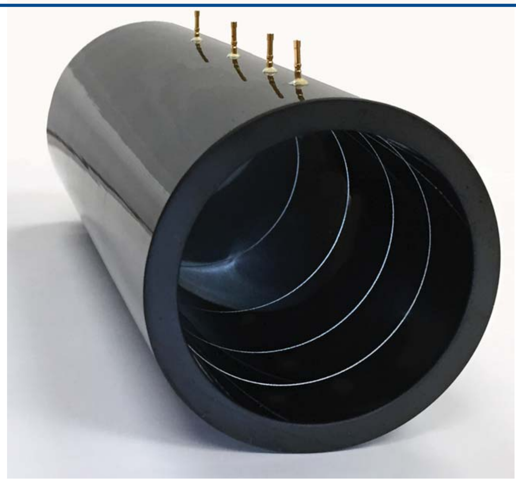

Figure 3: Photograph of a manufactured Segmented Resistive Glass Tube with the circular rings clearly visible.

Results (continued):

A method has been developed which enables small vias to be produced at any desired location. These vias are used to apply potentials from outside the Resistive Glass tube.

A series of metallic inks composed of gold or silver have been developed which are then applied in a printing fashion within the inside diameter of the tube. The location of the metallic printed features can be precisely controlled. These conductive pathways are then electrically connected to the vias. Applying potentials to the locations can then precisely control the resultant electric field.

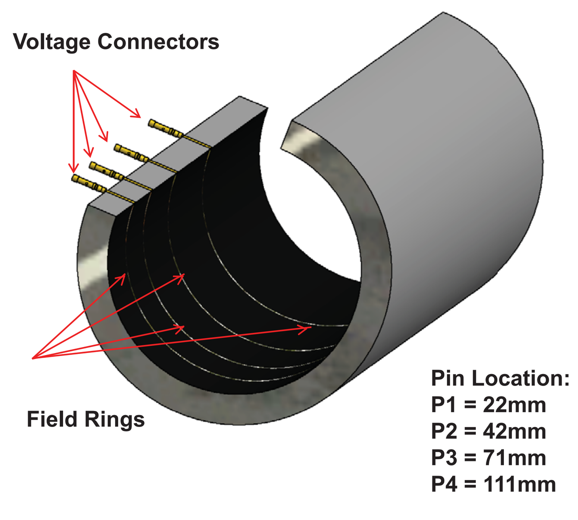

Figure 4: Cutaway diagram of a Segmented Resistive Glass Tube.

Figure 4 illustrates the concept of a Segmented Resistive Glass Tube. The manufactured tube (Figure 3) has an inner diameter of 60mm, a length of 177mm and has pin locations at 22mm, 42mm, 71mm and 111mm.

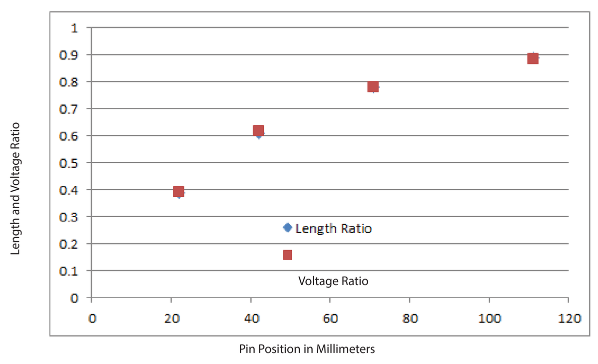

Figure 5: The graph indicates pin position in millimeters, and shows a good correlation between the position of the pins and the measured voltage.

In air, a voltage was applied across the tube and the voltage subsequently measured at each pin location. Note the good correlation between the pin position and the measured voltage (Figure 5).

Another useful embodiment of this technology is to produce collision cells or ion guides. In Figure 6, a cylindrical tube is shown in cross section. A dielectric coating can be applied between the Resistive Glass surface and the silver electrode.

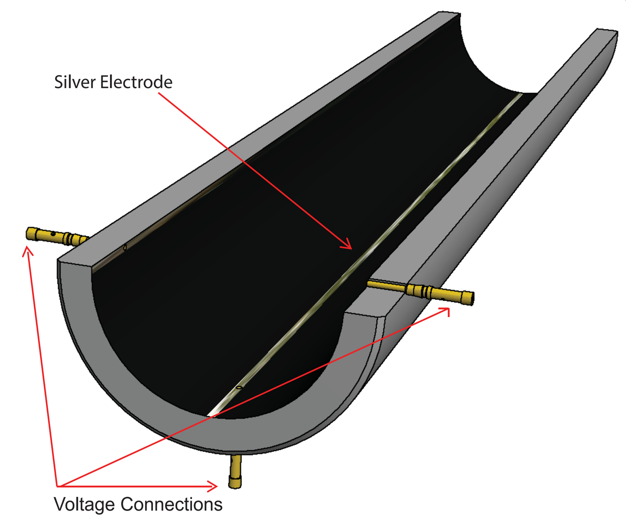

Figure 6: Cross section of a Resistive Glass Tube configured as a collision cell or ion guide.

In operation, an RF signal may be applied to two opposite electrodes while a DC potential applied to the tube drives the ions to the exit lens. Collision gas can be introduced through machined inlets in the tube body.

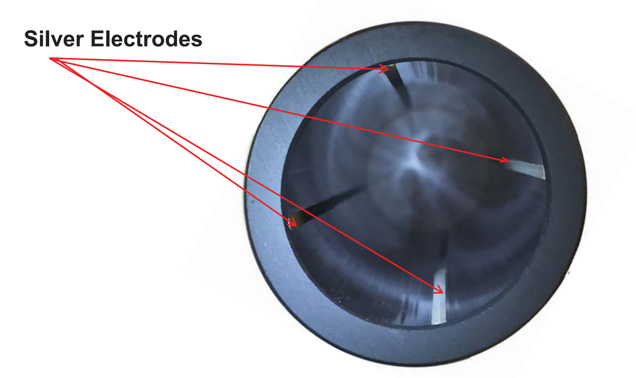

Figure 7: Photograph of a manufactured ion guide with silver electrodes applied.

Figure 7 shows a photograph of silver electrodes applied to the inside diameter of the ion guide. Silver electrodes are electrically isolated from the Resistive Glass surface by a thin dielectric coating.

Conclusions:

- Resistance stability has been improved significantly through the application of a passivation process.
- Resistance uniformity has been demonstrated to be better than 1%.
- A method has been developed which enables segmentation of Resistive Glass structures. This method consists of printing high vacuum compatible metal electrodes on the surface of Resistive Glass structures. In the case of tubular structures these electrodes are accessed by through-wall connectors.
- This new technology enables simple one piece multi-stage reflectrons, ion guides and collision cells to be fabricated at lower cost and provide higher performance compared to the stacked ring approach.