Characterization of the Uniformity and Stability of Resistive Glass

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Introduction

Resistive Glass Products are geometric glass structures with resistive properties that can be used to create uniform electric fields in order to guide or direct charged particles.

New applications for Mass Spectrometers are constantly emerging; however, many potential applications are very cost sensitive.

Component and assembly costs often times determine the viability of a new instrument design.

Simplifying assembly in these instruments could lead to a significant reduction in manufacturing cost.

Ion Guides and Drift Tubes made from Resistive Glass may be used to facilitate rapid product development and reduced manufacturing cost.

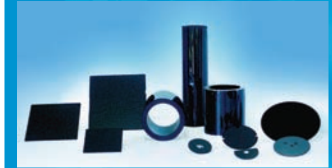
Processing

Resistive glass products are fabricated from reduced lead silicate glasses.

These proprietary lead glasses are produced from high purity raw materials. They are formed into tubes or flat glass and then heat treated to produce a semi-conductive layer on the surface of the glass.

They can be prepared with thin film metallization contact points.

Resistive Glass Formats and Features



Inlet Holes, Rectangular Shapes and Geometric Shapes

Grids and Ion Gates

Electrical Connections: Flying Leads, Metallized Glass or Fritted Mechanical Mounts

Potential Resistive Glass Applications

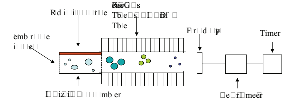
- Ion Mirrors (Reflectron Lens)
- High Voltage Dividers
- Collision Cells for CI and Linear Reaction Cells
- Ion Guides
- Conversion Dynodes
- Drift Tubes for Ion Mobility Spectrometers

Resistive Glass Reflectron Lens vs. **Conventional Reflectron Lens**

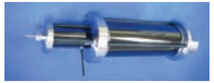
One Piece Design

6 Mounting Posts + 20 Metal Rings + 108 Ceramic Spacers = 134 Total Pieces

Ion Drift Tube for Ion Mobility Spectrometer



Prototype Resistive Glass Ion Mobility Spectrometer



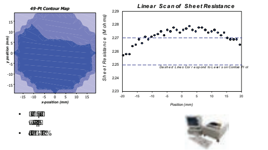
Material Characteristics

[illegible]	MCP-10 Glass	65-12 Glass
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	80	82
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	82x10 [illegible]
[illegible]	[illegible]	[illegible]

Resistance Uniformity

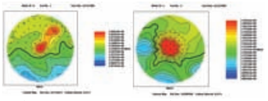
Resistance Uniformity: Flat Plate

Measured with a 4 - Point Probe



Resistance Uniformity: Large Flat Plates

Measured via 4-Point Probe*



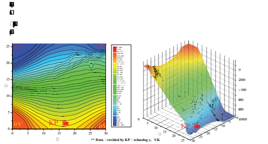
6512 glass
75mm diameter sample
Overall variation in Resistance +/- 1.5%

75mm diameter sample
Overall variation in Resistance +/- 2.5%

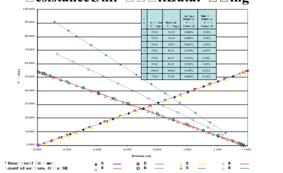
* Data courtesy of Four Dimensions, Inc., Hayward CA

Resistance Uniformity: Flat Plate

Measured with a Kelvin Probe**



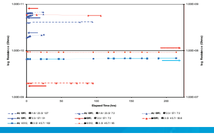
Resistance Uniformity Data: [illegible]



Resistance Characterization

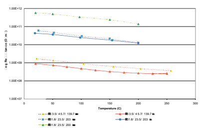
Resistance Stability at Room Temperature

In Air and Vacuum



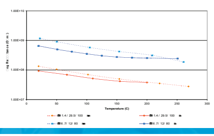
Resistance as a Function of Temperature: MCP-10 Glass

In Air and Vacuum

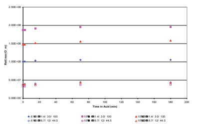


Resistance as a Function of Temperature: 6512 Glass

In Air and Vacuum



Chemical Durability:



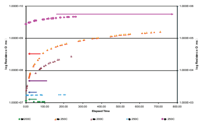
High Voltage Breakdown

OD (mm)	ID (mm)	Sample Length (mm)	Glass Type	Surface Area (mm^3)	Resistance	Break Down Voltage	High Voltage Cable Break Down	Comment
6	1	20	6512	62.8	4.10E+08		18500	Ohmic Heating
6	1	20	6512	62.8	5.12E+08	13000		Ohmic Heating
6	1	30	6512	94.2	3.65E+08		18000	Ohmic Heating
6	1	35	6512	110.0	5.65E+08		17500	Ohmic Heating
2	1	56	6512	175.9	3.52E+08	8000		Ohmic Heating
6	1	20	6512	439.8	3.60E+09		17500	Slight Ohmic Heating
5.4	4	27	MCP10	797.3	9.10E+08	12000		Slight Ohmic Heating
5.4	4	60	MCP10	1771.9	1.63E+09		18500	
16.5	12.6	44.5	6512	4068.2	3.38E+07	10500		Ohmic Heating to current limit
32	23.5	32	MCP10	5579.5	2.33E+09	14500		
63	47	52	MCP10	7678.0	6.20E+10		18000	Slight Ohmic Heating
63.4	47.7	53	MCP10	7942.3	2.00E+09	15000		
63.3	47	25	MCP10	8662.9	6.16E+08	13500		
32	23.5	64	MCP10	11158.9	9.66E+08	12000	18000	
41.9	29.9	50.8	6512	11458.8	6.20E+07		17250	Slight Ohmic Heating
63.3	47.6	100	MCP10	34840.2	4.11E+08		18000	
64.4	47.7	140	MCP10	49304.1	2.30E+08		17500	

Resistance Characterization

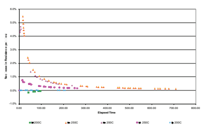
Change in Resistance at Elevated Temperature

In Various Cover Gasses



Change in Resistance at Elevated Temperature

In Various Cover Gasses



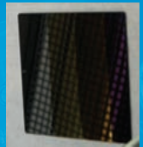
Graded Resistance

A proprietary technique has been developed to produce flat plate samples with distinct regions of varying resistance.

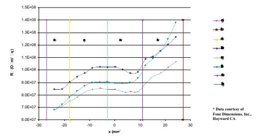
Four point probe data of a 2" x 2" plate prepared with four different resistance regions indicates this technique is viable for producing plates of varying resistance.

This technique should produce tubes and plates with a constantly varying resistance from one end of the sample to the other.

This could be used to create non-linear fields for guiding ions.



Resistance Across Graded Plate



Summary

Resistance Uniformity:

- Flat plate data indicates 1.5 to 2.5% variation in resistance over various size samples.
- Tube data indicates a less than 1% variation in resistance over a 30mm length.
- Kelvin probe data indicates uniform resistance results in uniform electric fields and the glass acts as a good conductor with no surface charging.

Resistance Stability at Room Temperature:

- Tubes are very stable in vacuum.
- There is a slight to moderate increase in resistance in room air (humidity not controlled) that varies depending on the sample configuration and starting resistance.

Resistance Change with Temperature:

- Resistance for both glass types decreases non-linearly with increasing temperature.
- This negative coefficient of resistivity can be estimated as -.85% per degree C for MCP10 glass and -.65% per degree C for the 6512 glass.

Chemical Durability:

- Resistive glass can be cleaned with water, methanol, IPA, acetone, bristle brushes, and steel wool soap pads without affecting the resistance.
- Light to moderate abrasions with sandpaper can be tolerated however, significant scuffing of the surface begins to breakdown the resistive surface, increasing the overall resistivity of the piece.
- Resistive tubes soaked in solutions of 0.6 N HCl, 10% HNO_3, and 10% H_2O_2 showed an increase in resistance between 5% and 10% after 3 hours.

Breakdown Voltage:

- In many cases, particularly for larger samples, the breakdown voltage could not be determined because it occured above the point where our high voltage cables failed.
- Many of the smaller samples began to exhibit ohmic heating prior to breakdown.

Resistance Stability at Elevated Temperature:

- Tubes are extremely stable in vacuum and nitrogen.
- In room air nearly 100% increase is seen in 200 hours.
- The resistance in room air increases more quickly at higher temperatures.
- In dry air the increase is less (40% in 200 hours) but still significant.

Graded Resistance Sample:

- Four point probe data indicates plates can be produced with regions of different resistance.
- Further characterization, including Kelvin probe analysis, is ongoing.

Conclusions

Resistive glass materials have been developed which have been demonstrated to produce uniform resistive surfaces.

These materials produce uniform electric fields when voltages are applied which can be used to direct charged particles.

These materials can be produced in various sizes and shapes and are well suited for use in high vacuum and systems.

Work continues on developing glass samples with controlled variable resistance.

The use of resistive glass structures can greatly simplify the construction of ion reflectors, drift tubes and ion guides.

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