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INVESTIGATION OF Re-X GLASS CERAMIC FOR ACCELERATOR INSULATING COLUMNS*

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Abstract

In an induction linac the accelerating voltage appears along a voltage-graded vacuum insulator column which is a performance limiting and major cost component. Re-X glass ceramic insulators have the long-sought properties of allowing cast-in gradient electrodes, good breakdown characteristics, and compatibility with high vacuum systems. Re-X is a glass ceramic developed by General Electric for use in the manufacture of electrical apparatus, such as vacuum arc interrupters. We have examined vacuum outgassing behavior and voltage breakdown in vacuum and find excellent performance. The housings are in the shape of tubes with type 430 stainless steel terminations. Due to a matched coefficient of thermal expansion between metal and insulator, no vacuum leaks have resulted from any welding operation. The components should be relatively inexpensive to manufacture in large sizes and appear to be a very attractive accelerator column. We are planning to use a standard GE housing in our MBE-4 induction linac.

<u>Re-X</u>

Induction linacs have very severe insulator column requirements due to the nature of their construction and operation. While rf linacs and induction linacs are both induction linacs, the common usage of the term induction linac refers to a transformer type of accelerator where the beam is usually thought of as constituting the secondary winding. In such an accelerator, the primary voltage is either the full voltage applied to the beam across an accelerating gap, or, depending on the core winding geometry, a few times smaller. In the more common rf accelerator utilizing resonant cavities, the drive voltage may be very small compared to the voltage applied to the beam at an accelerating gap. In an induction linac for long pulses, it is a practical necessity to fill the accelerating "cavity" with an induction core which is incompatible with vacuum requirements in the area occupied by the beam, therefore the full accelerating voltage appears across an insulator which separates the core from the beam. The voltage pulses are unipolar, of about 1 µs duration, applied a few times per second. The characteristic voltages of interest are about 1 MV/meter for the average rate of acceleration, which translate to comparable fields across the vacuum insulators.

The two most common solutions for the vacuum insulator problem for induction linacs are shown in Fig. 1(a), where the insulator is either centrally located and is close to the beam, or peripherally located where the beam can not strike it directly, Fig. 1(b). In this latter version, the accelerating field in the region of the beam appears across a vacuum gap formed by metal electrodes which are capable of supporting much higher voltages and fields than possible along the insulator surfaces. The average electric field along a surface and the voltage at one location can be substantially increased by subdividing the insulator in many short sections separated by metal gradient rings, as in the insulator shown in Fig. 1(a).



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Fig. 1(a). Central insulator column as used in Astron Injector



Fig. 1(b). Peripheral insulator as used in ERA, ETA, and ATA.

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There is a conflict between placing the insulator far from the beam and the size and cost limitations of existing insulators. The frequently used ceramic insulators are difficult to obtain in sizes larger than 26" ID, 28" OD, and cost in the range of \$10,000 per meter of structure. Conceptual designs of fusion driver accelerators¹ require of the order of 1-1.5 meters for the beam hole diameter in the central-insulator designs, and the peripheral-insulator design has heretofore not been seriously considered because of the even larger size requirement. For more than a decade we have been considering and occasionally trying to make an insulator with cast-in gradient rings of either of the two designs shown in Fig. 1 for various real and proposed machines. We were actively engaged in pursuing several inorganic material loaded castable plastics without being aware of the existence of the commercially manufactured Re-X material which has many of the sought-after properties, which are listed in the manufacturer's data sheet, Table 1.4 An example of an existing insulator is shown in Fig. 2. The insulator has the desirable properties of low outgassing, high mechanical strength, a cast-in gradient ring, and the possibility of inexpensive joining to other components of a beam line by welding. The current use of the material in vacuum switch gear housings is similar to that required in accelerating columns, but, because there is no apparent requirement to use them at high surface fields the design details do not appear to have been optimized for high-voltage high-field use. For test purposes we have sawed apart and reassembled short sections of the material into a few sections of accelerator column. We have also taken a longer insulator and measured the breakdown voltage as a function of distance by changing the electrode separation. The results of voltage breakdown tests as a function of insulator length are shown in Fig. 3. In the breakdown tests, the samples were conditioned to progressively higher voltages over a period of a few hours. We would intend to use them at one-half of the breakdown voltage or less. The attained values are acceptable for near



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Fig. 2. Re-X Insulator with cast-in gradient ring.

TABLE 1

Physical and Mechanical Properties of Re-X Glass Ceramic

Coefficient of Thermal 8.6x10⁻⁶ in/in°C Expansion 0 - 200°C 9.4 0 - 400°C 10.7 0 - 600°C 12.6 Safe Temperature at 830°C Continuous Heat Crystal Size .5 - 1 μ 25,000 lbs./in. Modulus of Rupture Porosity 0.00% Density 2.37 gm/cc - glass Anneal Pt. (Glass) 456°C Strain Pt. (Glass) 424°C Softening Pt. (Glass) Undefinable Softening Pt. (Ceramic) 850°C (Est.) Hardness DPH 100 g Load 630 Kg/MM **Tensile Strength** Compressive Strength 150x10 PSI Est. Modulus of Elasticity 12.6x10 PSI Est. Impact Strength l cm x l cm x 8 cm .54 Ft. lbs. (20°C) Est. Coefficient of Friction Static .19 Static Est. Dynamic .16 Dynamic Est. Thermal Conductivity .007 cgs units Est. Specific Heat .22 cal/gm/°C .28 Outgassing Schedule for Tubes, Gaps

Weathering Resistance

2.42 gm/cc - ceramic

800°C - 1 Hr. < 10⁻⁶ Torr Better than glass, as good as glazed porcelain.



XBL 844-10444

Fig. 3. Surface breakdown voltage versus distance for Re-X insulator.



Fig. 4. MBE -4 Insulator

term applications such as the MBE 4^2 experiment which is presently under construction, where the insulator to be used is shown in Fig. 4. The main motivation and interest in the material is of course for the HTE [3] and fusion driver machines, where we would be interested in the performance of a full size, cast-in-one-piece section of accelerating column with the gradient electrodes and end flanges resembling the column shown in Fig. 1(a).

The outgassing measurement results are shown in Fig. 5. The outgassing rates are compared to those of unbaked stainless steel and unbaked alumina, and are similar. These values are acceptable for the desired operating pressures of better than 10^{-7} Torr for the near-term requirements and for the longer term 10^{-8} Torr that would be required for a linear induction accelerator fusion driver.

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Fig. 5. Outgassing data for Re-X insulator

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