DEVELOPMENT STATUS OF THE PAL SEALED-OFF PSEUDOSPARK SWITCHES

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Abstract

We developed sealed-off type pseudospark switches for high current applications over 100 kA, with long pulse duration of several ms. We investigated the characteristics of sealed-off pseudospark switches, such as trigger delay times, hold-off voltages, peak currents, and effective charge transfer energy losses, recovery times. Effects of the electrode material and structure, power level of the switch reservoir, and vacuum conditioning of virgin electrodes as a method of electrode pretreatment are considered in this investigation. We also discuss the fabrication process of the high current sealed-off type pesudospark switches at the Pohang Accelerator Laboratory (PAL).

I. INTRODUCTION

Since the introduction of the pseudospark discharge in 1977 by Christiansen and Schultheiβ [1], there have been active studies of the pseudospark discharge in various laboratories. The discharge is located in the left-hand branch of the breakdown characteristics ,similar to the well-known Paschen curve. Typical hold-off voltage of pseudospark switches are below 30 kV for the case of a single stage. These pseudospark switches conduct peak currents of a few 100 kA for several μs, so the effective charge transfers are on the order of 1 C per shot.

When switches conduct high currents for long pulse duration, i.e. high charge transfer, severe electrode erosions occur because of strong arc discharges. Based on the fact that the electrode erosions are related with the arc current density, several schemes have been reported to reduce the current density and thus reduce electrode erosion. Those schemes include multi-channel electrode configurations or arc diffusion using external or self-generated magnetic fields. For extremely high coulomb transferring switch, however, since arc discharges are very strong, the electrode material should have high arc resistance. Tungsten is one of the best candidates as an electrode material for such switches, considering the report that a radial multichannel pseudospark switch with tungsten electrodes conducted 145 C per shot for 6130 shots [2]. It was reported that SiC can be an alternative electrode material of tungsten in a single channel or an axial multichannel pseudospark switches [3][4]. Sintered CuCr was also recommended as an electrode material for a radial type pseudospark switch, because the electrode surfaces were not damaged locally after arc discharges [5].

In this paper, we report test results of a radial type sealed-off pseudospark switch that has electrodes made of SiC or sintered CuCr. The fabrication processes affects the final performance of the switch. The fabrication processes of the sealed-off pseudospark switch are discussed in this paper.

II. SEALDED-OFF RADIAL TYPE PSEUDOSPARK SWITCH

Figure 1 shows a schematic of the sealed-off radial type pseudospark switch. the major portions of the anode and the cathode were made of oxygen free high conductivity copper (OFHC). The cathode disk was made of CrCu (Cr:25%, Cu:75%); while the anode disk was made of either CrCu or SiC. The disks were brazed on the OFHC main bodies. The switch was housed in a ceramic chamber.

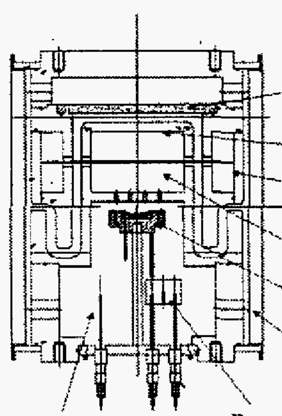

Figure 1. Schematic of the sealed-off radial type pseudospark switch.

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As shown in Figure 1, the anode is extended to prevent coating of the chamber wall. The switch had eight equally spaced 5-mm diameter boreholes on the anode and cathode walls. The switch had a cathode cavity with inner diameter of 40 mm and length of 32 mm. The width and the length of the anode cavity were 12 mm and 32 mm, respectively. Electrode wall thickness of the two switches was 5 mm. The gap distance between electrodes was 5 mm.

Two reservoirs (ST707) were installed to control the internal gas pressure of the switch. A high dielectric trigger unit was installed underneath the hollow cathode cavity. $BaTiO_3$ was used as the high dielectric material and has a dielectric constant of over 1500. Twelve 2-mm diameter holes are drilled at the bottom plate of the cathode cavity to form a cathode baffle. The electrons generated at the trigger unit are extracted to the hollow cathode cavity through the cathode baffle [6].

Machined components of the switch were chemically cleaned before spot welding and brazing. COBA rings were brazed on the metallized ends of the ceramic chamber to weld with the stainless top and bottom of the switch. The SiC anode disk was brazed on to the main OFHC copper anode body using a molybdenum ring to overcome the large differences in the thermal expansion coefficients between OFHC cooper and SiC. The trigger units and reservoirs were welded to stainless steel feed-through adapter, and then the adapter was brazed with the main OFHC copper cathode body. The main electrode bodies were brazed to disk shaped stainless steel switch covers. The electrode assemblies were then welded to the COBA rings of the ceramic chamber.

After assembly, the switch was leak tested to confirm vacuum tightness. Then, it went through a bake process in which the switch temperature was increased to 150 °C at a rate of 1 °C/min and then baked at 150 °C for 24 hours. Internal pressure of the switch was kept at a low pressure of 10^{-6} Torr during the baking. After baking, the switch was slowly cooled down at a rate of 1 °C/min. The reservoirs of the switch were then activated at 450 °C for 1 hour without pumping. The switch was then pumped out at room temperature for 5 minutes. We checked whether or not the internal pressure was below 10^{-6} Torr, and then pinched off the switch. We could confirm the inner vacuum of the switch by using the vacuum sensor installed inside of the switch. Figure 2 shows a picture of the fabricated radial type multi-channel pseudospark switch.

The fabricated switches were treated with an electrode conditioning process similar to the process for vacuum switches to remove micro protrusions from the electrode surfaces. When the pseudospark switch is not filled with gas, implying no reservoir power, it has the same internal conditions as a vacuum switch. However, the electrode gap of the pseudospark switch is smaller than the gap of vacuum switch. The maximum hold-off voltage of the switch was about 36 kV, which was used as the conditioning voltage for the switch. The hold-off voltage of the switch in cold conditions was lower than 36 kV. Therefore, we always turned on the reservoir to obtain the conditioning voltage. The conditioning process was continued for more than 2 hours.

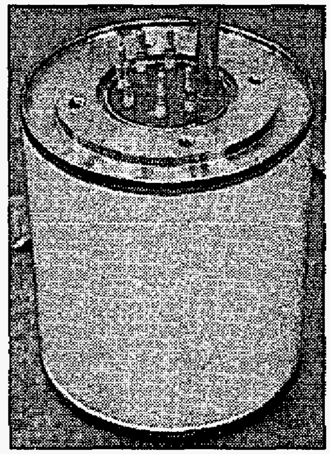

Figure 2. A fabricated sealed-off radial type multi-channel pseudospark switch.

III. TEST RESULTS

Figure 3 shows that the switching delay time, which was measured from the time of the trigger command signal is sent to the turn on time of the pseudospark switch. The delay times of the pesudospark switch were dependant on the applied reservoir power, which controls internal pressure of the switch. To stabilize the internal pressure, we set the reservoir power at 5 W and waited for 30 minutes before testing the switch delay time. The trigger generator produces pulses of 5 kV peak voltage and 400 A peak current. The trigger delay time was about 4 µs.

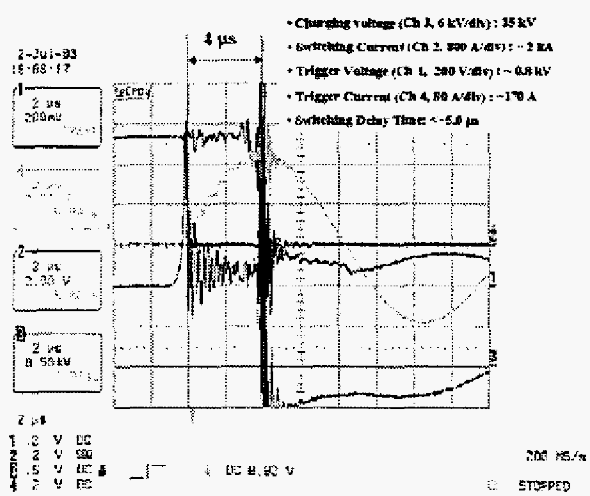

Figure 3. Typical waveforms from the experiment of a trigger delay time test setup.

To test the long pulse switching characteristics of the switches, a 300 kJ capacitor bank was used. Figure 4 shows a schematic diagram of the long pulse test circuit. The capacitor bank consists of six 206 μF, 22 kV capacitors. An inductor, which can be varied from 20 to 160 μH, and a load resistor, which can be varied from 0 to 0.2 Ω, were connected in series between the capacitor bank and the switch. A crowbar diode stack is connected in series with the capacitor to prevent an excessive reversal of voltage on the capacitor and to provide a free-wheel path for the inductive load current. Since, however, we connected a small crowbar resistor unit of 0.1 Ω to protect the diode stack, the closing circuit passing the crowbar path is an over damped RL circuit, which makes a long pulse without ringing. Currents and voltages were measured with a current transformer with a 0.001 V/A sensitivity, 50 Ω impedance and a voltage probe with a 1000:1 sensitivity.

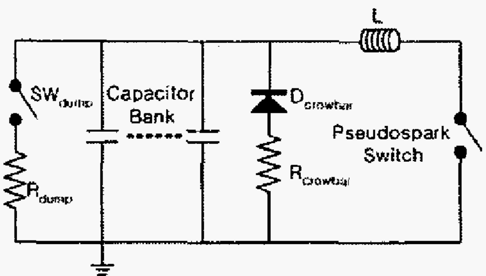

Figure 4. Test circuit of the switch for extremely high coulomb transfer.

Figure 5 shows typical waveforms of current and voltage for the long pulse test of the pseudospark switch. The charging voltage was 19 kV. An inductance of 40 μH, without the load resistance, was used during the test. The switched peak current was 105 kA with total 1.5 ms pulse width. Bank energy and charge transfer were about 223 kJ and 78 C.

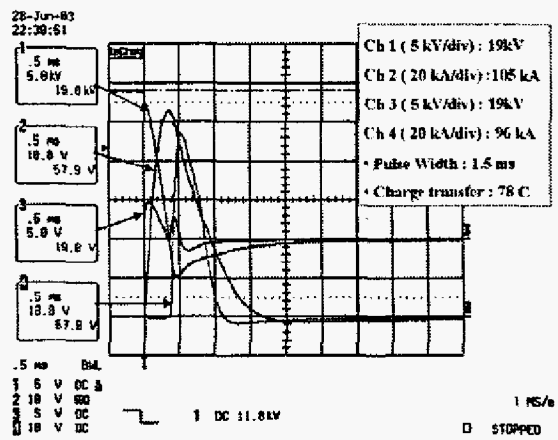

Figure 5. Typical waveforms for extremely high coulomb transfer experiments using the test facility of a 300 μF capacitor. Ch1: Capacitor voltage, Ch2: Switch current, Ch3: Switch voltage, Ch4: Diode current.

We tested two types of sealed-off type pseudospark switches. One uses SiC + CuCr, and the other uses CuCr + CuCr disks, as mentioned before. Both cases show the same voltage current and triggering characteristics. However, during the process of brazing of the SiC disk with the OHFC copper electrode body using a molybdenum ring, several cracks and its chips were observed on the SiC disk edge. Therefore, it is necessary to improve the technology for brazing the SiC disks with the OFHC copper anode body.

IV. SUMMARY

We developed a sealed-off type radial multi-channel pseudospark switch for extremely high coulomb transfer. The pseudospark switch transferred 78 Cin 1.5 ms. Even though SiC is a good material for high-coulomb transfer, there are several problems in actually applying it to a sealed-off type pseudospark switch, such as brazing and hydrogen consuming. We are currently studing technological method to resolve these problems or alternative methods, using self-generated magnetic field diffusing arc discharges.

V. REFERENCES

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