Vacuum Capacitor with Higher Current and Larger Capacitance (VP150 Type 5kVp-6000pF)

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Abstract

Reflecting the trend which a Radio Frequency (RF) generator is large and the frequency range is varied, recently there have been increasing demands for a higher current and larger capacitance of a Vacuum Capacitor (VC). In order to achieve the higher current of VC, we have adopted our own technology, "Double bellows," and solved the challenge of the short life span of bellows during high current conditions. With innovations on structure design and material selection, the effect of the VC heat dissipation increased and high current was achieved; thus, we could develop a variable VC, "VP150 Type," which can carry an estimated 400A_{rms} (at 13.56MHz, 1200W by water-cooling). To increase the capacitance of the VC, our in-house manufacturing processes for spiral electrodes were modified into a lengthy size in order to produce a model of VC up to 5kVp-6000pF. We are planning to develop a VC up to 10,000pF in the future.

1 Preface

Since the space between the electrodes of a Vacuum Capacitor (VC) is in the vacuum, the withstand voltage is extremely high. In addition, since this vacuum state does not include any dielectric substance, there is no heat generation due to dielectric loss, therefore, the maximum permissible current of this product is high. We use bellows to make a variable type of VC. However, since the dielectric constant is small, our product series ranges up to a level of 2000pF. These capacitors tend to be used as a built-in module unit, mostly for a 3-100MHz System; however, the sizes of wafers and panels are getting larger and we receive requests from our customers to increase the VC's current capacity. In addition, there is demand for a VC with a frequency range of 1MHz and lower. In order to meet such a frequency range of 1MHz, there is a need for a variable VC with 5000pF or more capacitance.

This paper introduces our program regarding VC with High current and large capacitance.

2 Program to Realize Higher Current Variable VC

The maximum permissible current ratings of Meiden VC are: 170Arms (at 13.56MHz by air-cooled VH110 Type) and 235Arms (at 13.56MHz, 500W by water-cooled VH110 Type). The most important challenge in increasing the VC current is the life span of the bellows. The bellows is a thin-wall part, and when a high current is carried through it, high heat will be generated by the effect of self-heating due to Joule heat. If the bellows is exposed to the atmosphere, oxidation is accelerated and the life span of the bellows will be shortened. To solve this challenge, we adopted our own technology, "Double bellows," a configuration which the VC has the bellows for vacuum sealing and current carrying. Due to this approach, we could remove possible causes of bellows life reduction because of the following reasons: "the bellows for vacuum sealing does not carry currents and oxidation is not accelerated because of freedom from high-heat conditions," and "the bellows for current carrying is kept under the vacuum and no oxidation takes place without being influenced by the atmosphere." Another challenge was heat dissipation around the movable electrode positioned under the vacuum. Efficiency of heat dissipation has been improved by arranging an optimum combination of materials of the capacitance adjustment unit and a combination of shapes of the capacitance adjustment unit. As a result, we developed the variable VC, VP150 Type, which can carry 230Arms (at 13.56MHz by air-cooling) and an estimated

Fig. 1 VP150 Type

This is our largest vacuum capacitor with an external diameter of 150mmϕ and a total length of 265mm. It is estimated to carry 400Arms. The exposed part of middle section of copper has a port for water cooling.

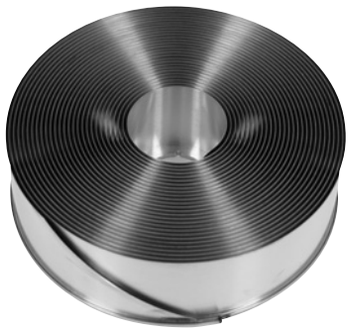

Fig. 2 Spiral Electrode for 5kVp-6000pF

Since the electrode diameter tends to be increased, spiral electrodes are internally manufactured in a lengthy material processing line. (Electrode Gap 0.6mm, wound 30 times)

400Arms (at 13.56MHz 1200W by water-cooling). Fig. 1 shows an external appearance of VP150 Type.

3 Program to Increase VC Capacitance Much Larger

We could increase capacitance of our VC. This was achieved by using the in-house manufactured spiral electrodes with increased diameters. Fig. 2 shows a 5kVp-6000pF spiral electrode. For a 2000pF product, the full spread length of the electrode is about 4 meters. Materials are procured in a form fully stretched (straight). In order to obtain a large diameter, however, the material length needs to be 10 meters or more, and materials in the straight state are difficult to procure. As such, we made a process that is straightening line, in our factory. Presently, we could manufacture up to 5kVp-6000pF. In the future, we will work on the development of a 10,000pF VC.

4 Postscript

By the development of VP150 Type, Meiden VC made it possible to carry an estimated 400Arms. We will continue to promote the development of electrodes to realize products with higher withstand voltages and larger capacitance in our products. Lastly, we would like to express our gratitude to the key suppliers for our VC for their support during our development of the latest products.