Vacuum Capacitor (VC)

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Abstract

We have been developing and manufacturing Vacuum Capacitors (VCs) since 1992 as the one and only VC supplier in Japan. In making VCs, we adopt the technologies and know-hows related to Vacuum Interrupter (VIs) that we accumulated as we develop and manufacture VIs and Vacuum Circuit-Breakers (VCBs) for more than half a century. Our VCs are used as an embedded product for Radio Frequency (RF) power supply for the plasma generation of thin film manufacturing equipment and control circuit devices for thin film equipment (vacuum process equipment for the deposition and modification of thin films.) Our VCs are contributing to the manufacture of semiconductors, Flat Panel Displays (FPDs) and Solar Panels. Our VCs come in Fixed Vacuum Capacitors (FVCs), Variable Vacuum Capacitors (VVCs), and Auto tuning Vacuum Capacitors (Auto-VCs). The Auto-VCs adopt the module design where motor and control systems necessary for static capacitance control, are put together in a module. Using our own unique technologies, we are able to commercialize two types of VCs; one that features the double bellows realizing a low torque, and the other with the ball screw, which is applicable to high-speed control and long-lasting use. In addition, we realized capacitance tolerance rate of ±1% and a compact design. We provide VCs that meet various needs of our customers.

1 Preface

For more than half a century, we have been developing and manufacturing Vacuum Interrupters (VIs) and Vacuum Circuit-Breakers (VCBs), which applied for railway facilities and high-voltage substations.

By using the knowledge that we accumulated as we developed VIs and VCBs, we started to develop Vacuum Capacitors (VCs) in 1992, and succeeded in manufacturing in 1994. Since, we have continued developing and manufacturing various types of highly reliable VCs as the one and only supplier of VCs in Japan. Major application fields of VCs are manufacturing equipment of semiconductors, Flat Panel Displays (FPDs), and Solar Panels. Our VCs are used as an embedded product for Radio Frequency (RF) power supply for the generating plasma of thin film equipment (vacuum process equipment for the deposition and modification of thin films) and control circuit device for thin film equipment.

They are also used in various areas of broadcasting communication equipment, analytical equipment for mass analysis or X-ray inspection, for research facilities such as accelerators, and for induction heating equipment or CO_2 laser machines. It can be said that our VCs support the RF energy power supply of various industrial equipment. This article introduces the major features of our VCs.

2 Trends of Development

In the recent semiconductor industry, the Central Processing Unit (CPU) and the Micro Processing Unit (MPU) earned better performance and greater capacity of memory. As we mentioned, semiconductor manufacturing equipment is required to fit into nano-level processing, and to perform frequent processing for multilayer structure. The VCs are required to speed up accordingly. Meanwhile, in the field of FPD, the screen image quality of smartphones is improved like the High Dynamic Range (HDR) Organic Light-Emitting Diode (OLED)

panel and the screen sizes of FPD TVs and digital signages are increasing in size. The size of glass has been expanded in proportion (10.5th generation: 2940 × 3370mm). Consequently, accuracy level of the manufacturing equipment has gotten higher and screen areas have been enlarged. Accordingly, the VCs are required to secure higher accuracy, higher withstand voltage, and larger current carrying capability.

To meet these requirements, we recently developed the ball-screw VC with a capability of high-speed control, the Auto tuning Vacuum Capacitors (Auto-VCs), the Fixed Vacuum Capacitors (FVCs) that assures a high accuracy of capacitance tolerance rate of ±1%, and the Vacuum Variable Capacitors (VVCs), which its current capacity is 400Arms.

3 What is a VC?

The VC is a capacitor with the electrode gap in a vacuum. Fig. 1 shows the internal structure of the Meiden VCs. Unlike ceramic capacitors where electric charges are stored by inserting a dielectric substance in the electrode gap, dielectric loss can be eliminated by the effect of a vacuum.

It becomes a small and high withstand voltage capacitor by keeping vacuum insulation. The current capacity of VCs is therefore, more than 100Arms, and the withstand voltage of VCs is a one-tenth than the atmosphere distance by the vacuum insulation, so a large current can be supplied in a compact size. In addition, VCs have the superior temperature stability among capacitors, and the capacitance characteristic is almost not affected by external environmental changes such as temperature, humidity, and dirt.

Further, among the types of VCs, there are VVCs in which the capacitance can be adjusted by bellows that expands and contracts while sealing a vacuum. For example, VVCs can adjust capacitance of more than a figure like 1500pF from 10pF. This is a function that can adjust the impedance continuously, which other capacitors do not have for high voltage applications. VVCs were, therefore, used in the past for the channel adjustment of broadcast equipment. In recent years, it is being used for plasma control – it especially fits for RF technology application which controls high frequency energy of kW class or more. From now on, it is expected to be applied to wireless power transfer for EV/PHV.

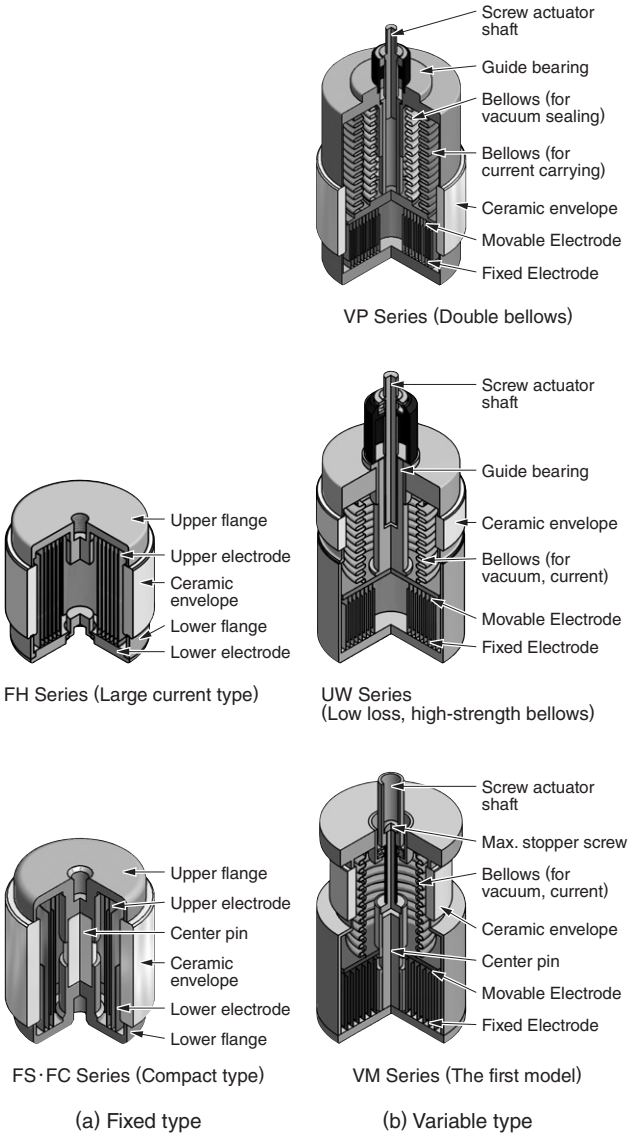

Fig. 1 Internal Structure of Meiden VCs

There are FVCs of a fixed type and VVCs of variable type in VCs. The VVCs have bellows that expand and contract while sealing a vacuum for current carrying.

In the field where the VC is used, any one of the following items is indispensable:

(1) Power supply frequency is Radio frequency form several 100kHz to several 100MHz
(2) Electric power is more than kW class
(3) High withstand voltage is kV class
(4) Temperature characteristic is less than 100ppm/℃
(5) Dispersion in capacitance is less than ±5%

4 Our VC Products

In manufacturing VCs, we adopt the vacuum sealing brazing method inside the vacuum furnace and does not have an exhaust pipe. This method can perform brazing, vacuum exhaust and baking at

the same time; therefore, it is superior in mass-production.

In addition, by drawing on the experience we gained through the development of longer-life vacuum products, such as VIs and VCBs for more than half a century, we could realize more than 20 years of the vacuum vessel life of the VCs.

Our VCs come in FVCs (the fixed type), the VVCs (the variable type), and the Auto-VCs (the motorized variable type). The Auto-VCs adopt the module design where the motor and control systems necessary for static capacitance control are put together in a module.

Our FVCs have mainly two series. There is the FS series which realizes the compact design by the center pin and the other is the FH series that features permissible current of 100Arms or more and a high withstand voltage of 30k$V_{0\text{-}p}$ or more. The FH series realized a high accuracy level by the unique electrode manufacturing technology and dispersion in capacitance is less than ±1% (usually ±5 to 10%.)

Our VVCs are consisted of three series. The first one is the VM series, which is our first released model of our all VCs series. We adopted high strength stainless steel copper-plated bellows that offers both vacuum sealing and current carrying. Other adoption is a center pin that realized keeping the insulation distance between the electrodes and a sliding in vacuum. The product life of the VM series has dramatically improved compared to the initial development stage. The second one is the UW series which achieved a compact design by using our proprietary electrode manufacturing technology. The last one is the VP series which has a double bellows structure where the bellows are divided into one for vacuum sealing and the other for current carrying. This structure design enable to realize low torque and high current capacity.

Furthermore, our VCs support ball screws and DLC coated screws that meet the demand for high-speed control and long life. **Fig. 2** shows the external appearance of the ball screw VC.

For the Auto-VC, we measure the capacitance at the time when we ship our product from factory. By calibrating the capacitance setting command, we realized the capacitance setting accuracy level of ±0.5% or less (These of typical VVCs are ±5%.) In addition, when customers adopt VVCs, they will face issues such as shape of connection between

(a) VH65-B type (b) UW65-B type (c) C82HE-B type

Fig. 2 Ball Screw Type

The VVCs with ball screw are shown. They are designed to meet the requirements of high speed control and long-life operation.

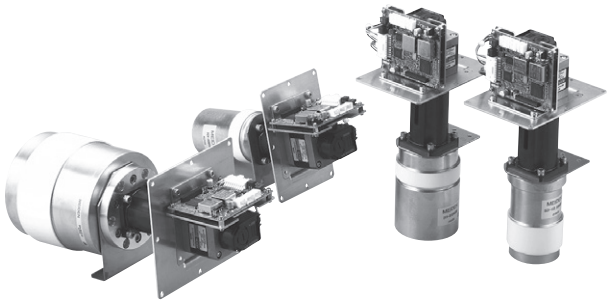

Fig. 3 Auto-VCs

Auto-VCs are shown. Auto-VCs are the product which modularized VVCs, a motor, and a controller. This product can control highly precise capacitance with less than ±0.5%.

VVCs and motor, and motor control. By preparing the suitable shape and motor control, the development period of the customer's system has been shortened. **Fig. 3** shows the external appearance of Auto-VCs.

5 Postscript

Our VCs may not be widely known, but they cover the important part, essential to the production of the semiconductor and FPD manufacturing. Without VCs, smartphones and FPD TVs cannot be mass-produced.

We are going to continue to fulfill our customers' needs and we will work for the VCs' greater performance and convenience. We hope our development of VC products will give the best experiences to our customers.