Auto Tuning Vacuum Capacitor (Auto-VC)

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Abstract

The Variable Vacuum Capacitor (VVC) is a circuit element (a quantitative attribute characteristic (capacitance) of an electric circuit) essential for the radio-frequency plasma control of semiconductor and Flat Panel Display (FPD) thin-film processing equipment, such as Chemical Vapor Deposition (CVD) equipment and etching equipment. The VVC is steadily extending its application range with the growth of electronic device industries. The Auto tuning Vacuum Capacitor (Auto-VC) is a modular design product based on an innovative idea. It is a package design combining the VVC and the control unit. This product features a required static capacitance that can be easily and precisely set up by using the dedicated controller. Using a simple command, our users (semiconductor manufacturing equipment suppliers) can control the static capacitance via RS-232C (a serial communications interface) or RS-485 (another serial communications interface.) The UW Series of the Meiden standard VVCs, the VP Series for application to large currents, and the VD Series featuring compactness are currently available. All these products can be converted to Auto-VCs by using module options.

1 Preface

The Variable Vacuum Capacitor (VVC) is an electrical component that can adjust the static capacitance. This is done by adjusting the rotating position of the tuning screw. The major usage of this component is for the control of a Radio Frequency (RF) matching network. Nowadays, the VVC is widely used for the High Frequency (HF) plasma matching network for thin-film processing equipment.

In the development of a HF matching network by using a VVC and conventional method, it was necessary to develop a coupling part for the connection between the VVC and the motor. Since this type of coupler requires high assembly precision, the occurrence of a mechanical malfunction was frequently reported due to lack of accuracy. In order to eliminate such difficulties, the Auto tuning Vacuum Capacitor (Auto-VC) has been developed. The Auto-VC is capable of increasing reliability because the VVC, motor, and connecting part went through the module design. This paper introduces the features of the Auto-VC and its product lineups.

2 Features

2.1 Easy Introduction

Conventionally, developing a HF RF matching network using VVC, in addition to the intended main circuit development, peripheral developments such as a motor control system are also required. This means the real development costs added up. The initial introduction of our Auto-VC was easy because all key components necessary for VVC capacitance control such as the motor, insulation coupling, dedicated controller, etc. are all available in the module design. Our customer's development resources can therefore, be focused on the HF RF matching networks.

In addition, our Auto-VCs offer a custom design to meet the customer's individual requirements, such as installation method, etc. In doing so, we have enhanced its product applicability. Fig. 1 shows the configuration of the Auto-VC. The Auto-VC uses the RS-485 (standard specification) as the serial communications interface. By customer request, another interface, RS-232C, is also available as an option.

2.2 High Reliability

A part where a motor and a VVC is connected calls for the performance for complicated and challenging conditions: such as mechanical strength, high withstand voltage, accuracy “concentricity ‘high-precision parts level tolerance’,” and heat resistance. Given above, this connection part tends to give rise many failure cases.

Fig. 2 shows a structure of the Auto-VC. For the VVC driving motor, we adopted a two-phase stepping motor with an optical encoder. With this encoder, we can detect an unexpected occurrence of a motor step-out. By means of a built-in program, it can perform the auto recovery mode operation.

For the connection part between the driving motor and the VVC, we developed a coupler with the withstand voltage of 10kVp. This coupler is based on the design of the Oldham coupler. This coupler realized two factors: absorption of the axial misalignment and a high insulation level. For an external insulation tube, we adopted a special plastic material with high toughness, flame resistance, and high insulation. In order to reduce mechanical stresses to be applied to the VVC, we achieved optimal control on motor acceleration/deceleration.

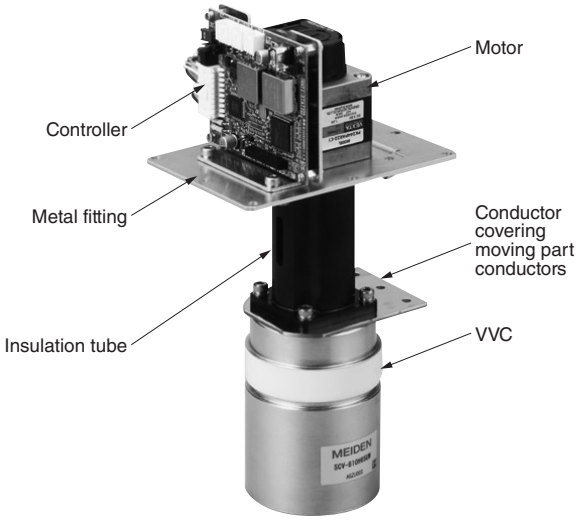

Fig. 1 Configuration of Auto-VC

Metal fittings and a conductor covering moving parts can be customized.

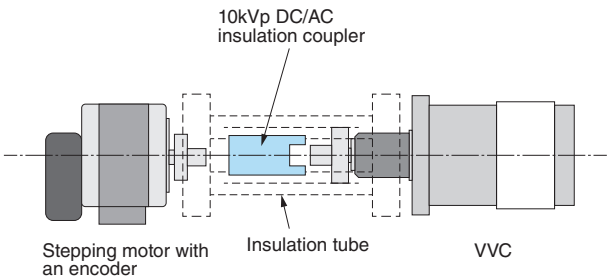

Fig. 2 Structure of Auto-VC

The structure is simple, but various elements are assembled.

2.3 High Accuracy (Static Capacitance)

Fig. 3 shows an example of the mechanical capacitance setting accuracy of the VVC. Regarding the static capacitance of the VVC, each device has an error of ±5% or less due to its mechanical accuracy.

Fig. 4 shows capacitance setting accuracy of the VVC by the Auto-VC (same sample unit used in Fig. 3.) In the case of the Auto-VC, a mechanical

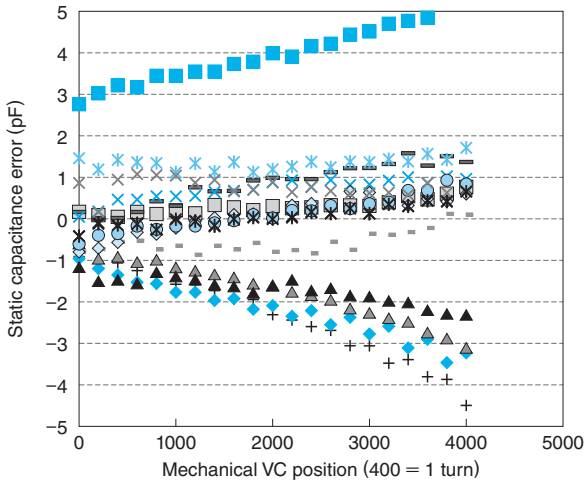

Fig. 3 Mechanical Capacitance Setting Accuracy of VVC

The graph shows an example of measured data: static capacitance error and the screw turning position of VVC (Part No. SCV-125H65UW)

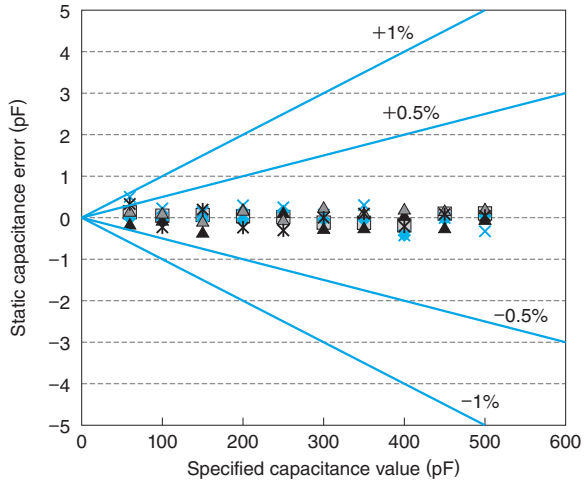

Fig. 4 Capacitance Setting Accuracy of VVC by Auto-VC

The graph shows an example of measured data on a static capacitance error when the capacitance is automatically set up by the Auto-VC (using the same sample unit.)

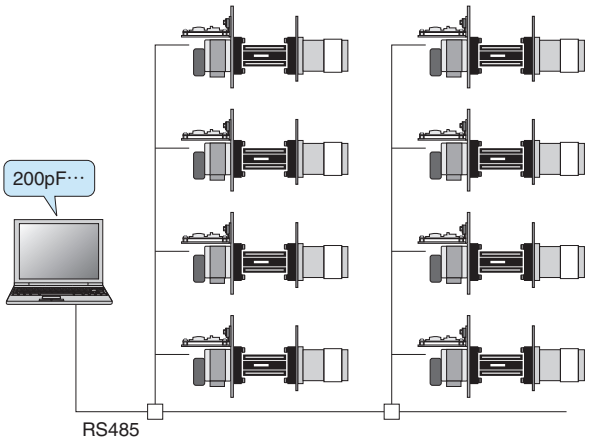

Fig. 5 Auto-VC Network Connection

The network connecting Auto-VCs is shown (Max. 16 units).

Table 1 Product Lineups of Auto-VC Series

Specifications of the Auto-VC Series are shown.

VVC series	Compact	Standard	Large-current
	VD45/55	UW55/65	VP65～VP130
No. of motor steps	3600 steps	4000 steps	5400 steps
Motor	2-phase motor (with an encoder)		
Motor speed	240min^{-1}		
Motor resolutions	400 steps/turn		
Interface	RS-485/RS-232C		
Controller	Exclusively designed controller		
Communication rate	9600bps		
Controller power supply	DC24V (1A)		
Static capacitance setup accuracy	±0.5% or less (Typical)		

error is offset by individually calibrating the VVC capacitance. According to the graph, it is understood that Auto-VC achieved a capacitance accuracy of ±0.5% by this compensation method.

2.4 Ease of Operation (Easy Setting of Capacitance)

A dedicated controller was developed to remotely control the VVC capacitance. For the control communications interface, we adopt the RS-485 which is strong against noise.

By giving a preset command from the host PC to the linked Auto-VC by serial communications, the setting of the VVC capacitance and data retrieval of the process value can be controlled.

Fig. 5 shows an example of the Auto-VC network connection. Up to 16 Auto-VCs can be networked. When performing large-area plasma excitation, control of the surface of the plasma can be realized by connecting and controlling the distributed VVCs in a network.

3 Product Lineups

Table 1 shows product lineups of our Auto-VC Series: for standard VVC series – the UW Series, for large current application – the VP Series, and for compact model – the VD Series. All our VVC series could be turned to an Auto-VC configuration by applying other module units previously discussed in **2.1**.

As a feature of our VVC products, the driving torque value of each series VVCs is almost the same. Due to this reason, when the customer wants to make an Auto-VC unit out of above VVC series, the same motor and driving part can be applied.

4 Our Current Development Program

We are currently developing the EtherCAT-compliant Auto-VC. The EtherCAT (Ethernet for Control Automation Technology) is an Ethernet-based real-time fieldbus system. The application of the EtherCAT is rapidly spreading in the semiconductor manufacturing field. For our Auto-VC, in order to realize more flexible plasma control, we expect the EtherCAT will be a new type platform based on the CANopen protocol and on the Ethernet specifically optimized for industrial automation control.

5 Postscript

We have developed an Auto-VC as a new functional device of our VC offerings. Going forward, we will work on more user-friendly products by improving the current offering of our Auto-VCs.

In addition, we would like to express my gratitude to those who have greatly contributed to the development of this product.

We would like to express our appreciation for the people relating to this development project for kind support and cooperation.