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Maintenance of high vacuum level in a compact and lightweight sealed hard-tube magnetically insulated line oscillator system

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ABSTRACT

Magnetically insulated line oscillator (MILO) is compact and lightweight high power microwave tube. To maintain the MILO below 10^{-2} Pa, we used built-in non evaporable-getter (NEG). In comparison with other pumping technology, the NEG pump operates without power is lightweight and compact. To estimate the vacuum life in static state, we carried out experimental analysis to investigate the outgassing characteristics of the main materials of the MILO in static state. Considering the expected pumping characteristics of NEG pumps in combination with the experimental data, the conclusion is that at room temperature two NEG pumps will maintain high vacuum level in the MILO more than 250 days. Moreover, the pulse desorption characteristics of MILO under high voltage pulse operation (peak voltage 440 kV, pulse width 80 ns) were also measured. At room temperature, the evaluation shows that one NEG pump can maintain the MILO tube in high vacuum level for nearly 8 pulses.

1. Introduction

The future compact, lightweight, portable High Power Microwave (HPM) tubes require the ability to maintain long life high-vacuum without bulky external pumping system [1–3]. It is well known that the vacuum level in the high power microwave tubes is one of the most important factors which would affect the microwave output. Presently the laboratory HPM sources are composed of some high outgassing materials [4,5], such as velvet, high polymer panel and plexi-glass. The velvet is one of the best materials for fabricating field emission cathodes due to its ability to generate plasma across large areas [6]. This material has a low turn-on electric field, namely, a small time delay in the onset of electron emission [7]. However, the velvet easily adsorbs gases which are released into high vacuum environment. The high polymer panel and plexi-glass outgassing rates are usually very high as they cannot be degassed at high temperature. These factors limit the high vacuum life of HPM tubes which usually have to maintain high vacuum level. Multiple changes including the choice of materials and sealing process are required to achieve long vacuum life [8,9]. Some HPM devices have used the above technology, such as the hard-tubed MILO of AFRL and NRL [8], and the hard-tubed RKA of LANL [10]. However, the high vacuum life estimation in static state and under high-voltage operation has been rarely investigated.

The paper focuses on a compact sealed hard-tubed MILO which uses the above hard-tube technology. In order to estimate the vacuum life in MILO, it is essential to investigate its outgassing characteristics in static state and its pulse desorption characteristics in high-voltage operation. The estimations of the life time of MILO in high vacuum conditions are the purpose of this work.

2. Experimental

2.1. The hard-tubed MILO configuration

The hard-tubed MILO has been developed by eliminating all plastic components (such as the grading ring stack in the water–vacuum interface and the vacuum–air interface) and replacing them with a brazed ceramic insulator stack. Furthermore, all o-rings are being replaced with knife-edge oxygen free copper gasket. Therefore, the MILO tube could be baked out at a relative high temperature in order to further reduce the residual gases.

The schematic drawing of the hard-tubed MILO is shown in Fig. 1. The main components of the tube are insulator, cathode, slow wave structure, mode convertor, antenna and dielectric window. Table 1 shows the main materials areas.

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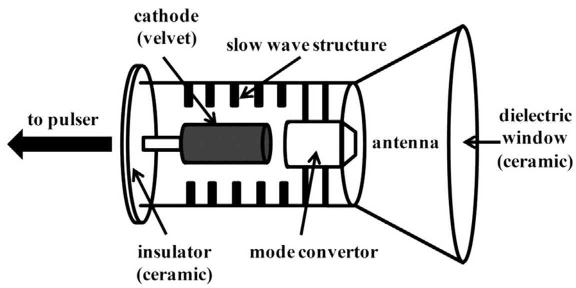

Fig. 1. Brief structure of MILO system.

Table 1
The main material areas of MILO system.

	AISI 304 L stainless steel	Velvet (with conductive glue)	Ceramic
MILO material (m^2)	1.4	3.06×10^{-2}	2.5×10^{-1}

2.2. Experiment for outgassing rate measurement

After the assembling of the MILO tube, an external pumping system is used to evacuate it. In order to release the gases adsorbed on the materials surfaces, we use a heater band which provide an appropriate temperature. As we had baked the velvet at a temperature of 250 °C for 10 h, and the velvet was ablated, however, the velvet ablated phenomenon was not seen at a temperature of 200 °C for 10 h. When the pressure in the tube reaches its ultimate vacuum level, the pump valve would be shut off, and two NEG pumps (SAES Getters CapaciTorr D 400-2 NEG Pump) mounted in the antenna would be activated. As the adsorption capacities and speed for different gases are not the same, and the process is relevant with the adsorption history, therefore, the outgassing rates measurements for all the main materials are required.

The outgassing rate measurements of main materials are carried out according to the static method. The outgassing rate measuring system is shown in Fig. 2. The outgassing measurements have been carried out in an AISI 304L vacuum chamber of 2.0×10^{-2} m^3 volume, and the surface area of the chamber is 5.2×10^{-1} m^2. The primary pumping system consists of dry pump (Varian Agilent SH-110 Dry Pump) and turbo molecular pump (TMP) (Varian Agilent TV 301 Navigator Turbo Molecular Pump). The total pumping speed is about 2.5×10^{-1} m^3/s at pressure values below 10^{-2} Pa.

The static method uses a closed chamber to measure the materials outgassing rates after baking out to 200 °C for 10 h. Firstly, the outgassing rate of the background environment is measured. Secondly, in the same experimental condition, the outgassing rates of the chamber with experimental samples are measured. Lastly, the samples outgassing rates can be obtained using the outgassing rates of chamber with samples minus the one of the background. Table 2 shows the outgassing experimental sample areas.

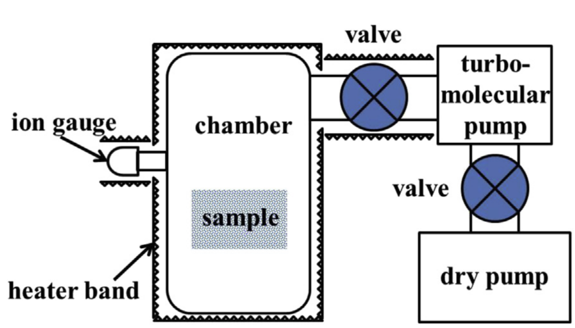

Fig. 2. Material outgassing rate measuring system.

Table 2
The areas of outgassing experimental samples.

	AISI 304 L stainless steel	Velvet (with conductive glue)	Ceramic
Sample (m^2)	5.15×10^{-1}	6.5×10^{-2}	1.15×10^{-1}

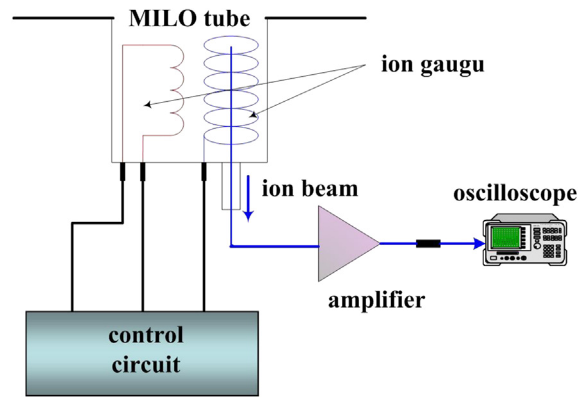

Fig. 3. Online ionization gauge.

2.3. Experiment for outgassing characteristic of hard-tubed MILO under high voltage pulse

High-voltage test is carried out at an HV pulser to study the ability of NEG pump to maintain the MILO tube in high vacuum level under the working conditions. The pulser could provide a ~600 kV, ~100 ns pulse for the MILO tube operation when the load is matched with the pulser. At the time the pulser provide a high voltage pulse to drive the cathode in the MILO emit electrons, a large quantity of gases would release into the MILO tube. To obtain the outgassing quantity of released gases, we use an online ionization gauge [11] (Fig. 3) which is modified from an ordinary vacuum gauge. The instantaneous change of pressure in the MILO tube can be monitored by the online ionization gauge.

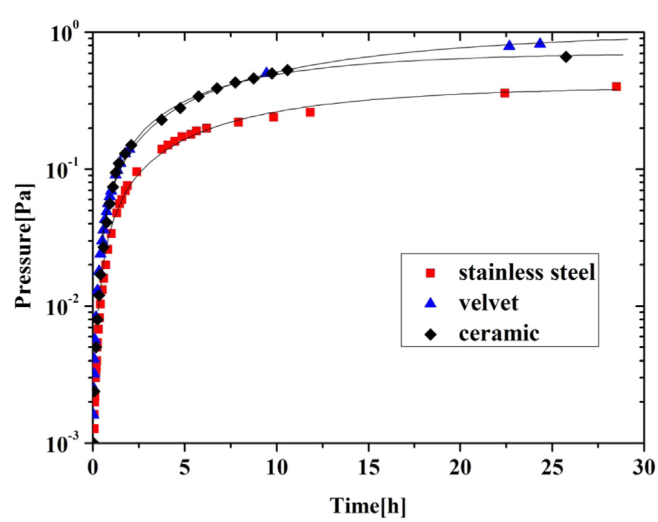

Fig. 4. Pressure rising data and fitting lines.