A TITANIUM SUBLIMATION CONTROL SYSTEM FOR THE CESR INTERACTION REGION

Yulin Li, Benjamin Manvell, William Lucas and Nariman Mistry
Laboratory of Nuclear Studies, Cornell University, Ithaca, NY 14853 USA

*Abstract**

Titanium sublimation pumps (TiSPs) are used to achieve ultrahigh vacuum in the interaction region (IR) of phase II. This paper describes a Ti sublimation control system developed to provide convenient and efficient control of 28 TiSP cartridges with 84 Ti filaments in the IR. The control system consists of RF filter networks, control cable networks, a PC controlled mobile power supply and multiplexer, and a LabView-based graphic control program. The RF filter network is necessary to block any RF pick-up from the stored beam by the TiSP filaments. The TiSP flashing is done using a constant power scheme.

1. INTRODUCTION

In the upgraded CESR phase II interaction region (IR), massive titanium sublimation pumping (TiSP) is employed to keep average pressure below 2 nano-torr at 300 mA of stored beam[1]. The extreme low residual pressure in the IR is essential to the Phase II operation as the scattered particles from the residual gas not only produce background in the CLEO high energy detector, but could also damage sensitive electronic components in the detector.

Six new vacuum chambers[1] with TiSP plenums are installed symmetrically on both sides of the interaction point (IP). There are a total of 28 TiSP cartridges (Model ST-22, Vacuum Generator Inc.) with a total of 84 Ti filaments (85%Ti/15%Mo alloy, Ø2.0 mm wire) installed on these new vacuum chambers. During the commissioning of Phase II, especially in the early stage of the operation, we anticipated a large synchrotron radiation desorbed gas load which would saturate titanium film deposited on the pumping plenum. A TiSP control system is called for to provide convenient and efficient re-activation of all the TiSP cartridges in the CESR IR.

2. SYSTEM DESCRIPTION

2.1. System Requirements

(1)RF seal and filtering network

The TiSP filaments in the pumping plenum may couple RF power from the bunched beam to the environment. The RF leakage through the TiSP cartridge may produce noise or even cause damage to electronic components. The system must contain and filter out the RF power by at least 60 dB.

(2)Mechanical protection of vacuum feedthroughs of the TiSP cartridges.

(3)Multiplexing and central control

Multiplexing and control cable network of the system should enable control of all the Ti filaments on the 28 TiSP cartridges, which are distributed over 12 meters on each side of the IP, from one or two stations.

(4)Ti Flashing Control

A programmable power supply with PC-based control software to allow an operator to control and monitor the activation (or Ti flashing) process.

2.2. RF Seal and Filtering

Mechanical protection, RF seal and filtering are provided by home-made TiSP boxes mounted on each of 28 TiSP cartridges, as shown in Figure 1. The box is divided into two compartments. The compartment A is made to be RF-tight with silver-brazed seams and wire-mesh gasket sealed joints. The TiSP filaments are connected to the compartment B via capacitance filter power feedthroughs (MTK Electronics, Inc.), which have a cut-off frequency of 10 MHz and a DC voltage drop of less than 10 mV at 50 A DC current. Further filter networks are included in the compartment B for the Ti flashing power line and Ti filament voltage monitoring lines, respectively, to filter out frequencies above 10 kHz.

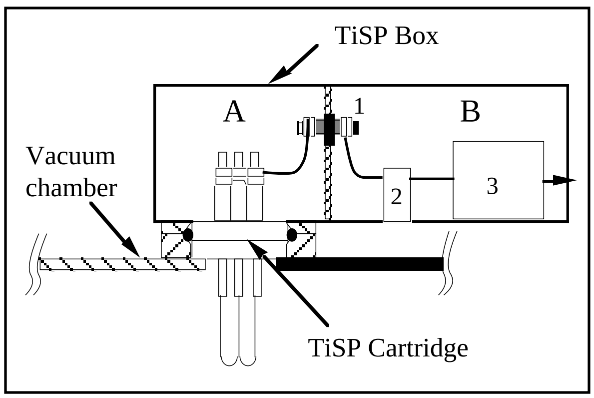

Figure 1. Schematic of CESR interaction region TiSP box. (1)Capacitance feedthroughs; (2)DC contacts (3)LC / RC filter networks

2.3. Multiplexing and cabling

Cable network connect all the TiSP cartridges and Ti filaments to two TiSP flashing terminals, located about 15-m away from the IP on either side of the IP. Selection of TiSP chambers is done by plugging into corresponding power and control terminals, and selection of TiSP cartridges and Ti filaments is accomplished by a set of rotary switches on a multiplexing box.

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2.4. TiSP flashing controller

A mobile TiSP flashing controller consists of a programmable DC power supply, a multiplexing switching box and a control PC. The computer reads back Ti filament current and voltage, and controls the power delivered to the filament through a multi-functional data acquisition plug-in card (National Instruments, LabPC+). TiSP flashing control software, developed with the graphic programming tool LabView (National Instruments, Inc.), allows an operator to set Ti flashing control parameters and monitor the flashing process in real-time. A *constant-power* Ti flashing mode is adopted in CESR. Measurements carried out by the authors[2] indicated that the constant power Ti flashing mode yields many more flashing cycles before filament failure while providing comparable Ti sublimation rate as compared to a *constant current* Ti flashing mode.

The Ti flashing process includes the following steps:

(1) TiSP cartridge and filament selection. The Ti flashing parameters are preset for all the TiSPs in the CESR IR, and these parameters are listed in Table 1.
(2) Filament test. A 100 mV voltage is applied to the selected filament. The flashing process ceases if the filament current at the testing voltage is less that 1A, as a typical filament resistance is much less than 0.1Ω.
(3) Power Ramp-up. A one-minute power ramp-up follows the filament test. The smooth power-ramp is designed to avoid current surge and thermal shock to the filament.
(4) Ti sublimation for assigned period.
(5) Record average sublimation current and voltage.

Table 1. TiSP Flashing Parameters for Phase II CESR IR

Chamber Name†	Q1	ISP	SB3
Distance from IP (m)	2.2-2.5	6.4-7.6	8.8-12.1
Flashing Power (W)	195	205	205
Flashing Time (min.)	2	2	2

†see ref. [1] for description of the chambers

Each of the six TiSP pumping vacuum chambers is equipped with a cold cathode gauge (CCG). The TiSP chamber pressure is monitored during the power ramp-up and the Ti sublimation, and an "Over-Pressure" (pressure set-point, typically 10^{-5} torr) will terminate the flashing process. The average sublimation current and voltage are recorded for each filament for every flashing, in order to document the filament resistance change. As discussed below, the filament resistance and the resistance change from each flashing cycle is a good measure of filament status and Ti sublimation rate.

3. Ti FILAMENT CHARACTERIZATION

Since the installation of the CESR phase II IR vacuum chambers in late 1995, some of the Ti filaments have been subjected to many flashings due to the large gas load created by the intense synchrotron radiation. It is important to be able to characterize the status of a Ti filament installed in the IR vacuum system. We have conducted extensive measurements of Ti sublimation rate, by measuring the pumping speed and pumping capacity of the Ti film in a test vacuum chamber. These measurements show that one can characterize the status of a Ti filament by its resistance. The details of the measurements are reported in Reference [2], with major results summarized as below.

3.1. Filament lifetime vs. filament resistance

One of the important parameters of a Ti filament is its ultimate lifetime, or total number of flashing cycles before failure of the filament. During the test, Ti filaments are repeatedly flashed at either constant current mode or at constant power mode in a testing setup until the failure of the filaments. In the *constant current* mode, the filaments were flashed at a current of 55 Amps for two minutes for each cycle with 1-minute ramp-up. In the *constant power* mode, the filaments were flashed at 205W for 2 minutes for each cycle with a 1-minute ramp-up. Two filaments were tested under the constant current mode, and four were tested under the constant power mode. The resistance of the filaments were recorded for each flashing, and the typical results are given in Figure 2. Several conclusions may be drawn from the results. First, a Ti filament lasts more than 200 activation cycles for the constant current mode and nearly 800 cycles for the constant power mode. This assures us that there is no need for concern about the lifetime of the Ti filaments used on the TiSP cartridges installed in the CESR IR at normal situation, as we expect to flash less than 100 times over a 5-year operation period. Second, the characteristic resistance curves for the two activation modes are somewhat similar. For comparison, the rates of resistance change are plotted in Figure 3. Initially, the filament resistance increases with number of activation cycles at a

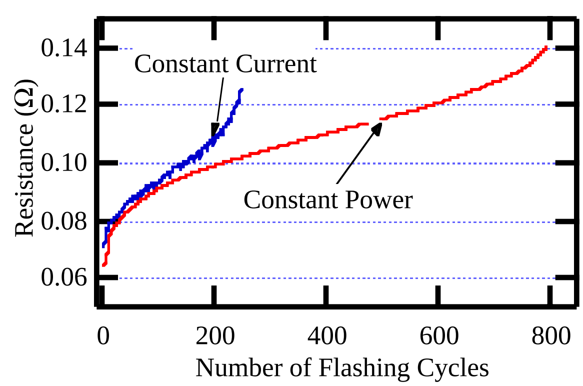

Figure 2. Resistance of Ti filaments during Ti flashing

very large rate for both activation modes, and the rate of resistance change drops rapidly with the activation cycles. After certain activation cycles, the Ti filaments reach a stable condition and the rate of resistance change levels off at a smaller constant rate. Lastly, the rate of resistance changes starts to increase rapidly before a filament opens up. This is the case for both activation modes. In practice, one may use this feature to predict when a Ti filament is about to fail, so that one can switch to another filament before the filament opens up, as an open Ti filament may short the other filament(s) on the same TiSP cartridge.

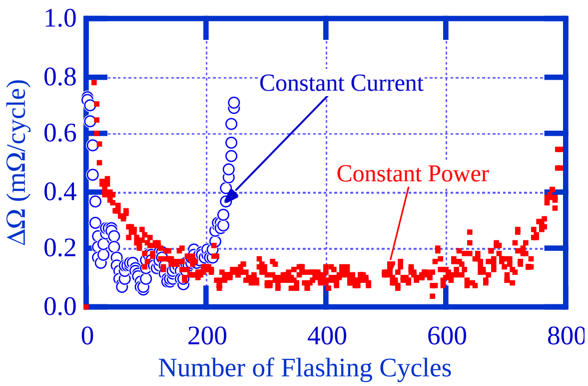

Figure 3. Resistance change rate of Ti filaments, as derived from the results shown in Figure 2.

3.2. Sublimation rate vs. filament resistance

Another important parameter of a Ti filament is the Ti sublimation rate at a given flashing power. As direct measurement of the absolute sublimation rate is rather difficult, we choose to measure relative sublimation rate by measuring pumping capacity of the sublimated Ti film, since, in practice, we are interested in how the Ti sublimation rate, hence the pumping capacity, changes with the filament condition. In Figure 4, the measured relative Ti sublimation rate is plotted as a function of the filament resistance. We found that the sublimation rate of a Ti filament can be characterized very well by its resistance. For the filament (85%Ti/15%Mo, Ø2.0 mm dia., 12 cm long) used in the CESR IR and tested here, the sublimation rate first increases with the filament resistance, simply due to the increased power dissipation on the filament as the filament diameter decreases. After reaching a maximum sublimation rate at the filament resistance of ~70 mΩ, the rate decreases relative rapidly as the Ti filament resistance increases beyond 70 mΩ. The sublimation rate levels off as the Ti filament resistance gets further higher. It is reported[3,4] that a metallurgical transition occurs in the Ti/Mo alloy due to the relative composition change in the alloy. This metallurgical transition results in a "micro-crystalline" surfaces with higher emissivity and therefore lower Ti filament temperature at a given sublimation power. The decrease in the Ti sublimation rate, with Ti filament resistance between 70 to 85 mΩ, may be due to this metallurgical transition of the Ti filament. The Ti sublimation rate levels off at a rate which is 5 to 6 times smaller than at its peak value with its resistance higher than 90 mΩ. Also shown in Figure 4 is the Ti filament resistance change rate as a function of filament resistance. It is expected that the resistance change rate scales with the sublimation rate, as the resistance change rate reflects the loss of Ti from sublimation.

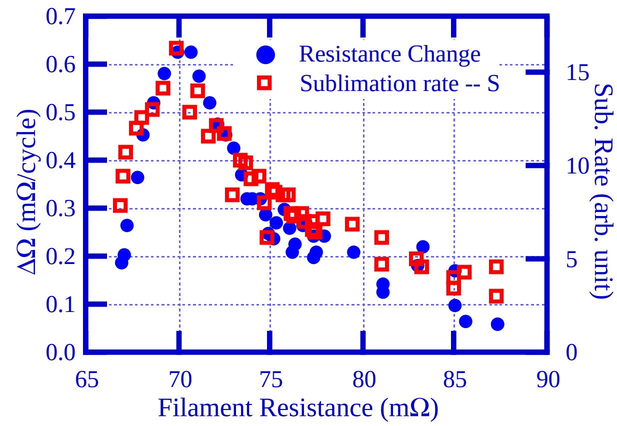

Figure 4. Resistance change rate and relative sublimation rate as a function of Ti filament resistance.

4. CONCLUSION REMARKS

A Ti sublimation control system is developed for the CESR phase II IR. This system successfully meets the requirement of the CESR phase II operation. The laboratory tests showed that one can keep track of a Ti filament status and its sublimation rate by documenting its resistance and resistance change rate.

Acknowledgment

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REFERENCE

1. N.B. Mistry, R. Kersevan and Y. Li, "Massive Titanium Sublimation Pumping in the CESR Interaction Region", these Proceedings
2. Y. Li, LNS Notes, CBN-97-9, 1997, Laboratory of Nuclear Studies, Cornell University, Ithaca, NY 14853 USA.
3. R.W. Lawson and J.W. Woodward, *Vacuum*, **17**, 205 (1967)
4. K.M.Welch, Capture Pumping Technology, p185-223 Pergamon Press, 1991.