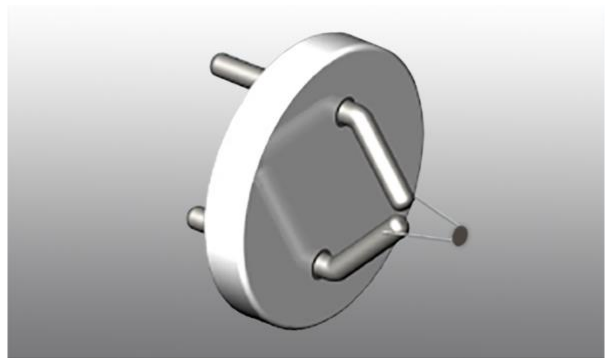
Tantalum Disc Cathode ES-042
User Information



Tantalum Disc Cathode ES-042 on AEI Base.

Introduction

The Kimball Physics ES-042 Tantalum Disc Cathode consists of 0.84 mm (0.033 inch) diameter tantalum disc, that is attached to a 0.076 mm (0.003 inch) tungsten 3% rhenium heater wire.

This refractory metal cathode is quite sturdy and provides stable and uniform electron emission for a wide variety of electron source applications. The tantalum disc is welded to the tungsten hairpin at a single point which results in a unipotential and planar emission surface. The tantalum disc is directly heated by current through the tungsten hairpin. Since no heating current passes through the tantalum disc, the energy spread is kept to a minimum (<0.5 eV). Tantalum has a very low vapor pressure at high temperatures, a high melting point (3188 K) and a work function of 4.1 eV. The ES-042 cathode structure is available mounted on a standard AEI base, on a Kimball Physics CB-104 base and on custom or nonstandard bases.

Handling

Cathodes are fragile and caution must be used in handling. Do not touch the cathode structure itself, only the cathode base.

The Tantalum (Ta) Disc Cathode is shipped vacuum clean. When handling the cathode, the use of clean-room gloves is recommended to keep surfaces free of fingerprints or other contaminants.

Example of Cathode Transport Container.

To remove the cathode assembly from the purple shipping container:

a) Place the purple base on a level surface.
b) Holding onto the lower part (purple) of the shipping container, unscrew the upper cover (plexiglass) and remove it vertically to avoid hitting the cathode.
c) Loosen the Philips screws to release clamp on the cathode.
d) Carefully lift off the cathode assembly.

Example of cathode with AEI base secured in transport container base.

Care should be taken to avoid exposing the cathode to mechanical or thermal shock. Do not allow anything to come in direct contact with the cathode.

The cathode is not harmed by repeated exposure to atmosphere when cold; however, at temperatures above 700K, oxidation of both the tantalum and tungsten takes place in the presence of water vapor, air or oxygen with a resulting decrease in cathode lifetime. At temperatures above 1200 K, tantalum nitrides form in the presence of nitrogen; these compounds degrade the emitting characteristics of the tantalum disc.

To preserve the integrity of the cathode structure, the cathode should be allowed to cool to temperatures below which significant oxidation will occur (<700 K). Cool down times will vary depending upon the source's structure.

Cathode Mounting / Heat Sink

When mounting the ES-042, it is important to have adequate heat sink / temperature control for the cathode pins and base, otherwise the cathode may burn out quickly. In the cathode connection, heat sinking is more important than electrical conductivity. For example, heavy copper leads are recommended, the diameter depending upon the length of the leads. Alternatively, copper mounting structures that hold the base may be employed.

Operating Procedure

The ES-042 Ta Disc Cathode is specifically designed to be a low input power device and should be driven by a voltage source rather than a current source. Due to the relatively small cathode surface area, the predominant avenue for power loss is conduction rather than radiation. A current source will cause an unstable increase in cathode temperature, resistance and voltage which results in premature heater wire burnout. When driven by a voltage source, heater current decreases over time as the cathode temperature and resistance rise, resulting in stable power conditions.

A typical V-I characteristic for the ES-042 is shown in the graphs section below in Fig. 1 (cathode driven from low to high voltages; 15 second interval between each point). Although it is recommended that the cathode be heated by a voltage source, cathode temperature and emission are more accurately predicted by source current values; therefore temperature and emission are shown as functions of source current in the figures presented here (see graph figures below).

Even though source current values are often given as operational benchmarks here, it is still assumed that the cathode is being driven by a voltage source.

Small changes in electron emission will occur during the first 20-30 minutes of operation, until thermal equilibrium is achieved. In the graphs below, Fig. 4 illustrates the time course over which an element of the ES-042 cathode structure, the mounting post, heats. As the temperature of the mounting post structure rises, heater current and emission decrease due to increased resistance of the tungsten hairpin heater wire. Furthermore, over the entire

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operating period, physical changes in the cathode such as evaporation and contamination result in a decrease in heating current and emission. Constant electron emission can be achieved by using a feedback control that adjusts the source voltage to maintain a set emission current value. This is the recommended mode of operation for a stable beam current and maximum cathode lifetime. Kimball Physics can supply power supplies with feedback stabilized emission current control.

First Time Turn-On

This procedure applies to the ES-042 cathode that is being turned on for the first time or has been exposed to air for a prolonged period. Turn on cathode power supply and gradually increase heater current to 1.5 to 1.6 A (amps) while monitoring heater current, heater voltage and vacuum pressure.

As the cathode heats up, small increases in vacuum pressure will most likely be noticed, due to out gassing of the cathode and surrounding structure. Maintain vacuum pressure at $1\text{x}10^{-5}$ torr or better. Once the cathode current has reached its optimal range of 1.5 to 1.6 A, and the vacuum pressure has stabilized, an extraction field can be applied and electron emission should be measurable. Electron emission can be varied by increasing or decreasing cathode source voltage. If the cathode heating current exceeds 1.85 A, cathode failure occurs rapidly. See the graph figures 2 and 3

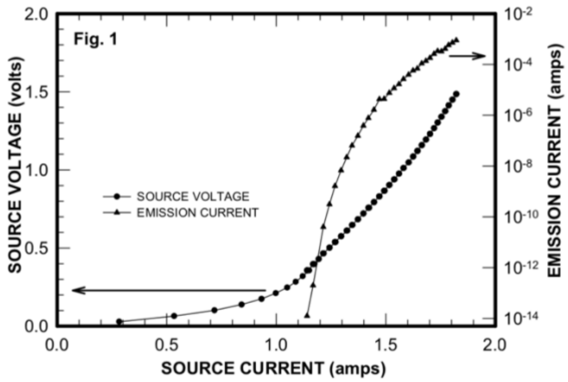
Subsequent Turn-On and Normal Operation

A cathode that remains in vacuum or is exposed to air for a short time may be brought to the desired operating temperature almost instantly.

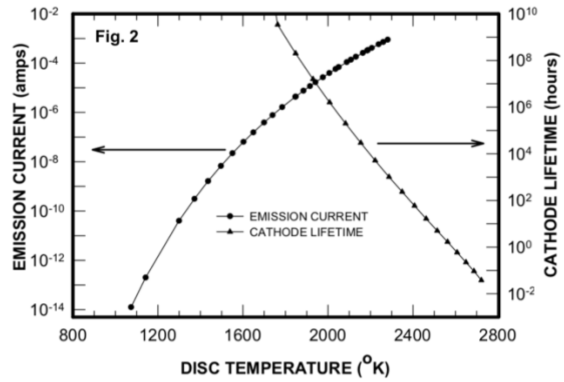
Tantalum Cathode Comparison Table

Parameter	ES-042	ES-044	ES-046
CATHODE MATERIAL	Tantalum	Tantalum	Tantalum
DISC SIZE	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	0.048 in dia. x .004 in thick (1.22 mm dia. x 0.1 mm thick)	0.062 in dia. x .004 in thick (1.57 mm dia. x 0.1 mm thick)
HEATER WIRE SIZE	0.003 in dia. (0.08 mm dia.)	0.004 in dia. (0.1 mm dia.)	0.007 in dia. (0.18 mm dia.)
LEG LENGTH	approx. 0.11 in (2.8 mm)	approx. 0.12 in (2.8 mm)	approx. 0.15 in (3.8 mm)
HEIGHT ABOVE CERAMIC BASE	on CB-104 base: 0.14 in (3.5 mm) on AEI base: 0.256 in (6.5 mm)	on CB-105 base: 0.25 in (6.4 mm) on AEI base: 0.256 in (6.5 mm)	on CB-105 base: 0.27 in (6.9 mm) on AEI base: 0.256 in (6.5 mm)
EMISSION AREA	$5.52\text{x}10^{-3}$ cm^2	$11.7\text{x}10^{-3}$ cm^2	$19.5\text{x}10^{-3}$ cm^2
EMISSION CURRENT	1 mA typical	3 mA typical	5 mA typical
HEATING CURRENT	1.4 A to 1.8 A	2.4 A to 2.8 A	5.7 A to 6.6 A
POWER SUPPLY CAPABILITY	Voltage regulated power supply recommended, 2 V, 2 A	Voltage regulated power supply recommended, 2 V, 3 A	Voltage regulated power supply recommended, 2 V, 7 A
CATHODE BASES	AEI, CB-104	AEI, CB-105	AEI, CB-105
CATHODE LOADING	0.25 A/cm^2 recommended, typical; High loadings result in reduced lifetime		
WORK FUNCTION	4.1 eV		
OPERATING TEMP	2200 K typical		
ENERGY SPREAD	Approx. 0.6 eV		
LIFETIME	Hundreds of hours with medium current		
VACUUM LEVEL	10^{-5} torr or better, recommended		

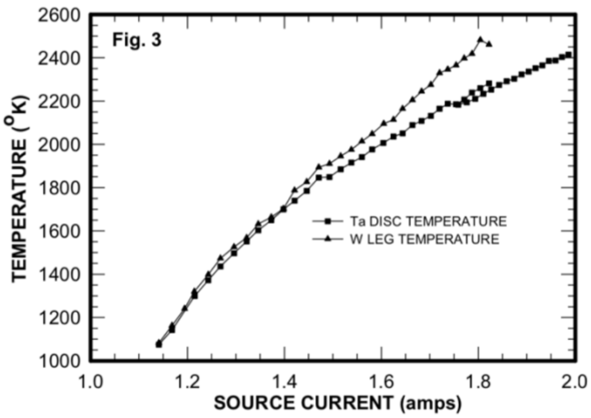
SOURCE VOLTAGE and CALCULATED EMISSION vs SOURCE CURRENT



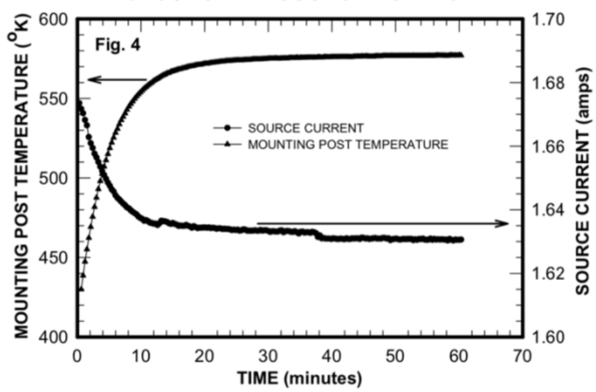
CALCULATED EMISSION and LIFETIME vs DISC TEMPERATURE



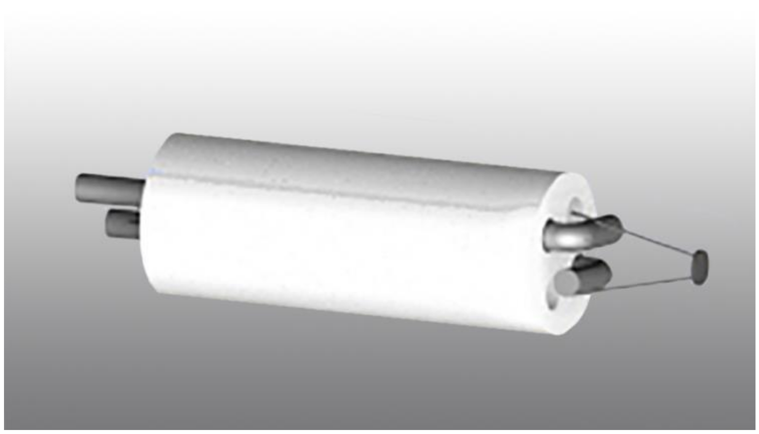
DISC and LEG TEMPERATURES vs SOURCE CURRENT



SOURCE CURRENT and MOUNTING POST TEMPERATURE vs TIME for CONSTANT SOURCE VOLTAGE



Graphs of the Tantalum Disc (ES-042) Cathode Performance
Data is for Guidance Only.



ES-042 Tantalum Disc Cathode mounted on Kimball Physics CB-104 base.

Normal operation is achieved with a source voltage between 0.5 volts and 1.45 volts or a source current between 1.2 amps and 1.8 amps. If more emission current is desired, higher source voltages may be applied but a concomitant decrease in cathode lifetime should be expected (Graph Figs. 2 and 3).

Turn Off.

Heater current may be turned off slowly or instantly. Prior to venting, as mentioned above, the cathode and surrounding structure should be allowed to cool to less than 700 K. Cool down times will vary from several minutes to over an hour, depending on how quickly heat can be conducted out of the structure.

Lifetime Considerations

Some power is lost from the tantalum disc due to radiation; therefore, in order to obtain the desired disc temperature, the tungsten hairpin heater must reach an even higher temperature. This is illustrated in Graph Fig. 3. The temperature of the tantalum disc determines its electron emission density; this relationship can be described by the Richardson-Dushman equation. The expected emission for the ES-042 is shown in Graph Figs. 1 and 2. Actual emission currents will vary depending on the applied DC voltage and the geometry of the source structure. The higher tungsten hairpin leg temperatures make the decrease in leg diameter due to evaporation the determining factor in cathode lifetime (Graph Fig. 2), assuming lifetime is not foreshortened due to other factors such as contamination, poor vacuum or damage. As the tungsten legs evaporate, the resistance of the tungsten wire increases; thus small changes in a cathode's V-I characteristic over its lifetime can be expected. The longest possible lifetime is achieved by running the cathode at the lowest possible temperature.

Service for Repair / Breakage

If a problem arises during initial installation, please contact Kimball. Cathodes may be returned to Kimball Physics for evaluation and possible repair with a return authorization number. In case of breakage, handle the cathode assembly with tweezers, being careful to touch only the base of the cathode If broken off prior to usage, place the cathode in a capsule or in tissue or secure with double-sided adhesive, and return to Kimball Physics along with the cathode base in the original shipping tube.

References

For more information on cathodes operations, you may download additional detailed technical bulletins (not listed below) from our website Resources Page.

Cathodes- Emitters (Overview)

Tantalum (Ta) Cathodes / Emitters- Description and Specifications

Ta Disc Cathode (ES-042) - Cathodes / Emitters: User Information

Ta Disc Cathode (ES-044) - Cathodes / Emitters: User Information

Ta Disc Cathode (ES-046) - Cathodes / Emitters: User Information

Notes:

1. Charts /graphs show typical performance, data is for guidance only
2. It is not necessarily possible to achieve all maximum specifications simultaneously.
3. Specifications Subject to Change Without Notice.
4. DE Altobelli, DT Taylor 2/09/2023

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