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Title: NICKEL-TITANIUM MATRIX CATHODE

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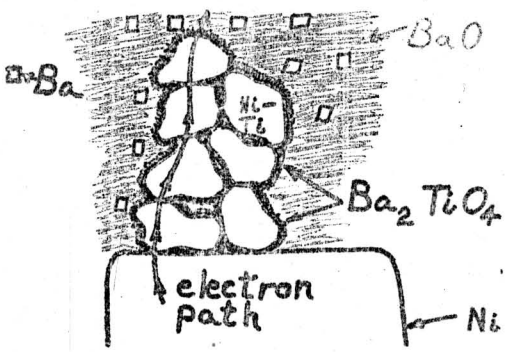
I. Introduction

The following information has been obtained from Dr. V. L. Stout of the Research Laboratory, Schenectady.

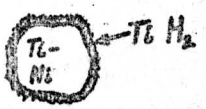
A. Theory

This cathode consists of a porous matrix of a nickel-titanium alloy which is alloyed to a standard nickel cathode base. The purpose of creating this type of cathode is a desire for a large surface area to support and react with the triple carbonate emissive mix. This large surface area will supply more free barium and yet the Ba_2TiO_4 interface formed on the sides of the particles parallel to the electric field will not cause a decrease in the transconductance of the tube.

The porous nature of the metallic matrix furnishes an excellent support for the emissive mix in regards to the emissive coating peeling from the support.



After the metallic paste has been applied to the nickel base, it is shaved, while still slightly moist, to the desired thickness and then heated in vacuum. This heating does not produce a sintering action but rather a surface melting action in which the following is presumed to take place. The TiH_2, which is in the form of much smaller particles than the Ti-Ni alloy, surrounds each particle of Ti-Ni.



As it is heated to within a range of 500°C to 800°C, the TiH2 dissociates and the hydrogen comes off initially in atomic form. This produces an extremely vigorous cleaning action. As the temperature is increased to around 1095°C, a surface melting action

I. Introduction

A. Theory (Cont.)

takes place (see Ti-Ni phase diagram) which binds the particles together and to the nickel base and changes the total end alloy composition to around 56% Ni -- 44% Ti.

B. Materials

The powdered metal of 70% Ni -- 30% Ti composition and the titanium hydride may be obtained from Metal Hydrides, Inc., 12 Congress Street, Beverly, Massachusetts.

C. Processing and Construction

The 70% Ni -- 30% Ti powder is passed through a 230 mesh sieve. This powder is next placed in a 425 mesh sieve and the powder which will not pass through is used. The resultant powder consists of particles in the size range of around 0.001 inch.

The above powder is mixed with Ti H_2 in the proportions of:

75% of (70% Ni -- 30% Ti)
25% of (Ti H_2) by weight

The binding material does not appear to be critical and at present is:

for 3 grams of powder -
1 drop of nitrocellulose
Amyl acetate to form thick paste

The cathode base structure is cleaned as follows:

Nitric acid etch (50% sol.) for 2 minutes
Rinse 3 times in distilled water
Acetone rinse
Methanol rinse

The paste is next thoroughly mixed and applied to the cathode as a layer around 0.015 inch thick. In order not to risk deleterious effects from the ceramic material as it is heated to near 1100°C, a cathode without the ceramic disc attached is used at this point. The cathode is supported on a jig such that the paste, when semi-dry, may be shaved to a uniform thickness of 0.010 inch. This thickness is somewhat arbitrary.

The cathode is next placed in a ceramic bucket which is placed in a Tantalum bucket in which a piece of titanium is placed to absorb gases. This set-up is placed in a vacuum system and exhausted to around 0.1 micron pressure. The cathode is heated to around 850°C, as determined by an optical pyrometer sighted on the ceramic bucket, and held for five minutes in order to release H_2 from the Ti H_2. This temperature is not critical. The

I. Introduction

C. Processing and Construction (Cont.)

cathode is next heated to just under 1110°C (it is important not to exceed this temperature) for around fifteen minutes. This period of time is not critical. The complete system is next allowed to cool for thirty minutes before opening to air.

Next the jig is set by means of a depth gauge to allow a thickness of around 0.002 inch of emissive coating. The standard R.C.A. 33-C-131 triple carbonate emissive mix is next dropped on to the porous surface until it builds up to the desired height. It is allowed to dry and then is shaved with a razor blade. It is now ready to mount in a tube.

D. Special Diode and Activation Schedule

A special diode is used by Dr. Stout for testing the cathode. In order to minimize the possibility of poisoning the cathode when the anode is outgassed, the anode is supported on the end of a long arm which pivots about a wire support at right angles to the arm and has a small sheet of soft iron as a counterbalance. The anode is rotated away from the cathode, by means of a magnet acting on the iron counterbalance, while it is being outgassed.

The following activation schedule was used on a cathode which was being processed while I was present:

E_f (Volts)	I_f (Amps.)	Cathode Temp. (°C)	Highest Pressure (μ)	Time (Min.)
5.25	0.52		0.12	5
10.50	0.84	985	4.50	4
9.60	0.80	940	0.018	3
6.30	0.61		0.0008	2

The anode is next rotated back into position, with a spacing of 0.030 inch between it and cathode, and a check on emission current made:

$E_f = 6.3$ V $\quad I_f = 0.62$ amp. $\quad E_b = 5.0$ V
$I_b = 1.5$ ma.

The cathode was considered not sufficiently aged so 9.0 volts were applied to the filament for ten minutes and then another emission check was made at $E_f = 6.3$ volts and $E_b = 5.0$ volts. A current of 3.0 m.a. was obtained and declared satisfactory.

E. Test of Cathode Quality

The test of quality is the determination of the work function of the coating through use of Richardson's equation for temperature-limited emission current. The saturation current for different temperatures is found by pulsing a voltage across the test diode at a rate which is slow enough to compare with d.c. emission - (not true pulse emission). The value of saturation current is read directly from a calibrated oscilloscope.

II. Progress To Date in the Materials and Processes Section.

Several cathodes with the matrix alloyed to the nickel base were brought back from the Research Laboratory for coating and further tests. A jig was given to this section on which to position the cathode for accurate coating thickness and also a small quantity of the Ti-Ni-TiH_2 paste was furnished.

Several attempts were made to coat the cathodes with emissive mix by depositing drops on the surface and then shaving to the desired thickness, as was done at the Research Laboratory, but the coating either peeled when moist or flaked when dry. In order to save time and to prevent possible damage to the matrix structure during the many recleaning processes, the cathodes were sprayed with a wet mixture of the triple carbonates and it was presumed that the mix flowed into the cavities of the matrix. Four 12SP7 tubes using the matrix cathode, were made.

A. Activation and Aging

The activation and aging schedules used for these cathodes were the standard schedules used for planar cathodes.

Activation Before Tip-Off

If	Time	
0.45 amp.	3 min.	During activation the first grid is heated by induction to around 750°C.
0.60 amp.	3 min.	
0.70 amp.	2 min.	
0.85 amp.	2 min.	
0.70 amp.	2 min.	
0.65 amp.	5 min.	

Aging Schedule

Filament power = 10.6 watts E_{g1} = 0	2 minutes	
Filament power = 5.76 watts E_{g1} = +5. volts E_{g2} = +250 volts	40 minutes	

Since it is the power absorbed by the filament which controls the temperature of the cathode (as well as the spacing between filament and cathode) rather than the voltage placed across the legs, the cathodes are assured of more uniform temperature treatment if filament power is the parameter rather than filament voltage in the aging process and in making electrical tests. This is especially important in testing for zero bias emission currents since emission is rather sensitive to cathode temperature variations. Probably in the majority of instances the filament resistances will be identical and, for a given voltage, also the power; however, in many instances it has been noted that there are substantial differences in filament resistances. The values of filament power chosen in this experiment were derived from values of resistance which have proven to be average.

II. Progress To Date in the Materials and Processes Section

B. Initial Tests

DATA BEFORE AGING

Tube #	Filament Resistance R_f (at 6.3V)	Filament Power P_f	$I_f = \sqrt{\frac{3.9}{R_f}}$	Gas Ratio	I_s	Cut-Off
C #1	10 ohms	3.9 watts	.63 amps.	.20		
C #2	10	3.9	.63	.82		
C #3	10	3.9	.63	.029	525 μa	-30 V
C #4	Tube cracked around anode button. Gun to be resealed into new tube.					
* C #5	10	3.9	.63	.038	550 μa	-37 V
* C #6	10	3.9	.63	.052	500 μa	-36 V
* C #7	No readings possible. Tube Scrapped.					

* Control Tube - standard cathode

AGING AND INITIAL TESTS

Tube #	2-Min. Warm-Up P_f'	Aging Period P_f	I_f	I_s	C.O.	50 V I_s	Gas Ratio	Remarks
C #1	10.6 watts	5.76 watts	.63 amp.	550 μa	-30 V	1050 μa	.014	Put on life test with no Eb
C #2	10.4	5.76	.63	620	-30	1160	.014	Waiting for life test
C #3	10.6	5.76	.63	625	-30	1000	.008	Waiting for life test
C #4								Gun not resealed yet
C #5	10.6	5.76	.63	975	-38	1430	.002	*Waiting for life test
C #6	10.6	5.76	.63	950	-38	1375	.004	*Waiting for life test
C #7	10.6	5.76	.63					*Absolutely no emission

* Control tube - standard cathode

II. Progress to Date in Materials and Processes Section

B. Initial Tests (Cont.)

The 50-volt cut-off zero bias emission values were not obtained from the 50-volt emission nomograph, but were obtained by adjusting the second grid voltage until -50 volts on the first grid exactly cut off all emission. Zero bias emission was then read for that value of second grid voltage. This procedure was deemed necessary since the guns made for this experiment had such a low cut-off value that the accuracy of the nomograph in this range was questionable. An order has been written to place two of the matrix cathode tubes and two control tubes on life test, but up to the present time life test positions have not been available.

C. Life Test

Since life results appeared to be unobtainable in the near future, it was decided to make extension cords for the "lollipop" life rack in the Materials and Processes laboratory and place one tube on life test there, applying only filament, first grid and second grid voltages. It was assumed that the lack of the high anode potential and consequent screen bombardment would not seriously affect any results obtained under these conditions. By direct measurement it was found that the total cathode current is increased by between 5 per cent and 10 per cent upon application of anode potential to a tube originally operating with only filament, first and second grid voltages.

The results of this life test to date are as follows:

TUBE C #1 LIFE TEST

Hrs. of Life	P_f (watts)	I_s (μa)	Cut-Off (-volts)	50 Volt I_s (μa)	Gas Ratio	Remarks
0	6.3	625	31	1125	.007	All emission and cut-off values subject to possible maximum error of around 7 per cent.
1					.0055	
2					.0055	
4					.0030	
9					.0030	
10	6.3	675	31	1175	.0030	
32	6.3	610	30	1140	.0020	
51	6.3	615	31	1160	.0020	
78	6.3	610	30	1140	.0020	
100	6.3	600	31	1090	.0020	
173	6.3	590	30	1125	.0020	
196	6.3	600	30	1160	.0018	
221.5	6.3	600	30	1160	.0015	
245	6.3	575	30	1140	.0010	
269	6.3	560	30	1125	.0010	

II. Progress to Date in Materials and Processes Section

C. Life Test (Cont.)

Due to the tube being made with such a low cut-off value, the zero bias emission is very low; however, when corrected to the standard 50-volt emission value, the emission compares favorably to a standard cathode. For the first 269 hours the emission level remained constant, within the range of accuracy of reading the meters in the life rack.

III. Remarks

Due to the method of coating this group of cathodes by spraying instead of by dropping the mix on the surface, all life results should be held as not completely conclusive until it is definitely proven that the emissive mix did penetrate the matrix completely and that the cathode is acting as a dispensing type and not a planar type.

IV. Future Plans

More of these cathodes will be made completely in the Materials and Processes laboratory and mounted in tubes for further tests. More vigorous activation and aging schedules will be applied to attempt to increase the emission. Life tests will be performed in which maximum available continuous d.c. emission and maximum available pulse emission without emission slumping will be determined. Emission failure due to ion bombardment will be induced and recovery time determined. Emissive mix will be applied and then scraped away down to the matrix surface to determine the life which can be obtained due only to the emissive coating inside the matrix.

V. Conclusions

All circumstances considered, it is felt that no definite conclusions about this type of cathode should be drawn at this stage of the investigation.

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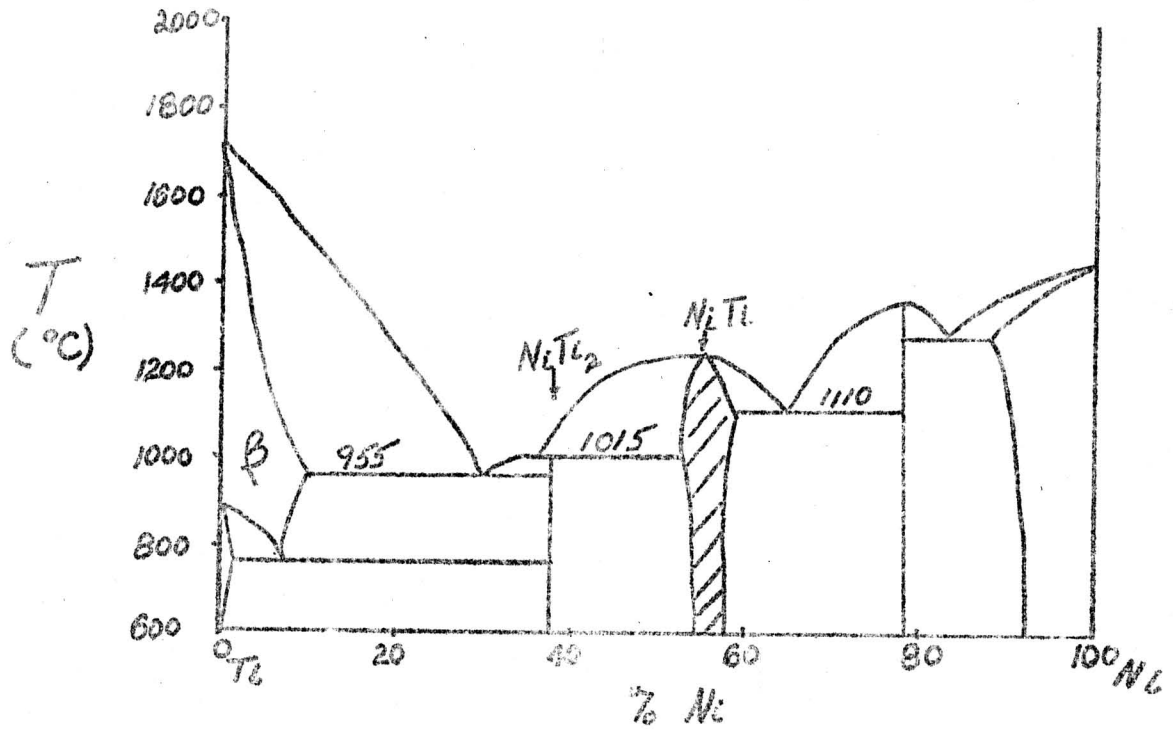

Ni - Ti Phase Diagram