STUDY AND CHARACTERIZATION OF DISPENSER CATHODE OF 10 MEV LINAC

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Abstract

A dispenser cathode of pressed and sintered Ba-Ni powder is used as electron source in electron linac having 10 MeV beam energy and 10 kW beam power at RRCAT. This linac is planned for development of agricultural radiation processing facility. In this e-linac a triode type electron gun is used. This paper describes the cathode behavioural model during operation with addition of sparkle on materials characterization of diminished-emission cathode surface.

INTRODUCTION

When it comes to operation of any particle accelerator, behaviour of particle source matters. The development and characterization of particle sources have benefic impacts on today's research. The particles sources viz. cathodes are important not only for particle accelerators but also for cathode ray tubes and microwave tubes such as klystron where electrons are emitted from cathodes for their operation.

Now a days, different electron cathodes are used worldwide [1]. Two main mechanisms which are mostly applied globally for cathodes: thermionic and secondary emission. Emission of electron resulting, from the heating of a surface is referred to as thermionic emission whereas; electron emission by electron bombardment is referred to as secondary emission. In the majority of systems only thermionic cathodes are used. In some microwave systems both types of cathodes are practiced whereas in few systems such as cross-field devices only secondary emission cathodes are employed [2]. Other types of cathodes include field emission type, which use high electric fields to take out the electrons from the material. The thermionic cathodes come in various families. Those with the lowest temperatures are cathodes containing a thick film layer of mostly barium oxide on nickel [3].

For higher average emission current density, dispenser cathodes are employed which have two varieties: impregnated and reservoir. Both in general employ a transition metal matrix such as tungsten or nickel. Impregnated cathodes have barium compound in the pores of the metal matrix whereas in reservoir, a small container is made behind the matrix and is filled with barium as emissive material [4].

At Raja Ramanna Centre for Advanced Technology (RRCAT), Indore electron linear accelerator (e-linac) based agricultural radiation processing facility is under development. In this e-linac of 10 MeV rated beam energy and 10 kW rated beam power, a dispenser cathode provides electrons to triode type gun having rating -55 kV and 270 A. Table 1 details the specification of dispenser cathode used in this e-linac.

Table 1: Cathode details

Cathode parameter	Value
Cathode material	Pressed and sintered Ba-Ni
Geometry	Cylindrical palette
Diameter	8 mm
Emission current density	3 A/cm^2
Mode of heating	Indirectly heated
Cathode operating temperature	Approximately 1000°C
Nominal filament voltage	6.3 V
Nominal filament current	3 A
Filament voltage in cathode activation mode	7 V
Filament current in cathode activation mode	3.15 A

An electron gun developed at Bhabha Atomic Research Centre (BARC), Mumbai also shows beam signals with machine. This gun uses lanthanum hexaboride as electron source. The present paper explores the understanding and behaviour of dispenser type cathode.

CATHODE BEHAVIOURAL MODEL DURING OPERTION

The thermionic emission model of dispenser cathode of 10 MeV linac can be best explained by Richardson-Dushman equation considering that work function changes linearly with temperature:

$$J=A_0T^2\ e^{-e(\O+\alpha T)/kT}$$

where J is emission current density, Ø is work function at absolute zero, T is temperature, k is 1.38 x 10^{-23} J/K, A_0 is 1.2 x 10^6 A/m^{2}deg^2, α is temperature coefficient of change in work function [5]. This cathode operates close to 1000°C during which barium (melting point: 720°C) in molten state gets evaporated. It is advantageous to use barium as emissive material since it does not contaminate critical surface inside linac accelerating structure owing to its low vapour pressure at 1000°C which is nearly 10 torr.

The mechanism by which barium migrates to cathode surface is similar to Knudsen flow where mean free path length of moving atom is shorter than characteristic length of system. The barium has work function 1.8 eV whereas nickel has work function 5 eV. However the combined action of barium on nickel can result reduction in work function of surface owing to minimum energy available for emission in the presence of nickel. Here barium atom interacts with surface and lowers the work function of surface. This property of nickel type surface is similar to catalyst required by any chemical reaction and is still a subject of extensive research among researchers [6-8].

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MATERIALS CHARCATERIZATION

The dispenser cathode was analyzed using scanning electron microscope (SEM) at different scale ranges viz. 10 and 20 µm. The micrographs showed grains of different brightness (see Fig. 1). The bright patches correspond to barium whereas dark surfaces stand for nickel, which are confirmed in chemical analysis (see Fig. 2). The parts of the cathode surface, which are covered by barium, operate in space-charge-limited condition and areas which are not covered by barium operate in temperature-limited-condition

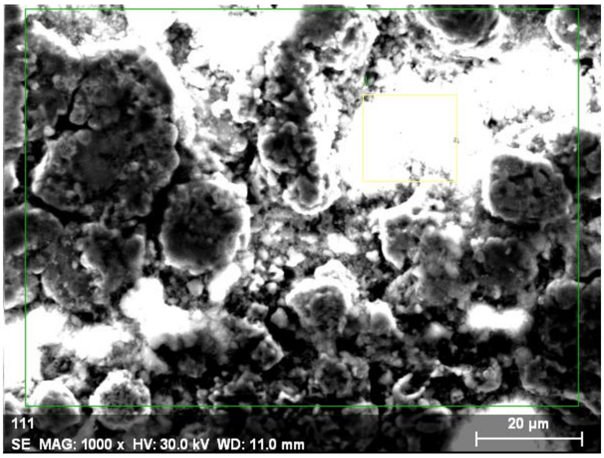

Figure 1: SEM of cathode surface at 20 µm scale range

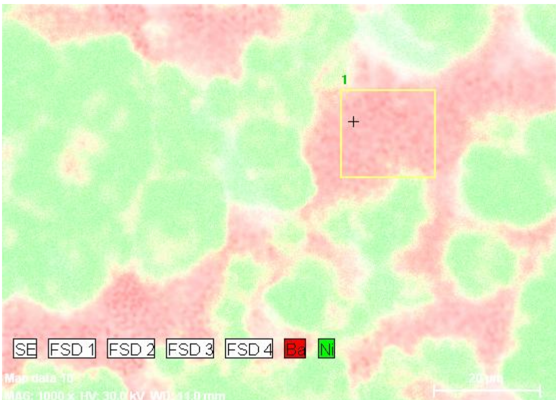

Figure 2: Chemical analytical image of SEM micrograph of Fig. 1 showing Ba and Ni over the cathode surface

The patches of barium lie in the matrix of nickel. For the case of fresh cathode, barium atoms reside inside the matrix. During the activation process, the cathode is heated up to nearly 1000°C by applying AC voltage close to 7 V. In this procedure, voltage is enhanced gradually in order to have slow rise in the temperature of filament which is located near the cathode surface. When temperature close to 1000°C is reached, barium atom is realised from the interior of the nickel base matrix where barium gets freed and comes over the surface for emission. Here barium atom interacts with surface and lowers the work function of surface.

When barium has limited availability or is virtually unavailable for emission then emission current starts decaying. The SEM micrographs in Fig. 1 and 3 showed that cathode surface has limited barium available for emission. Such cathode has reduced electron emission current density.

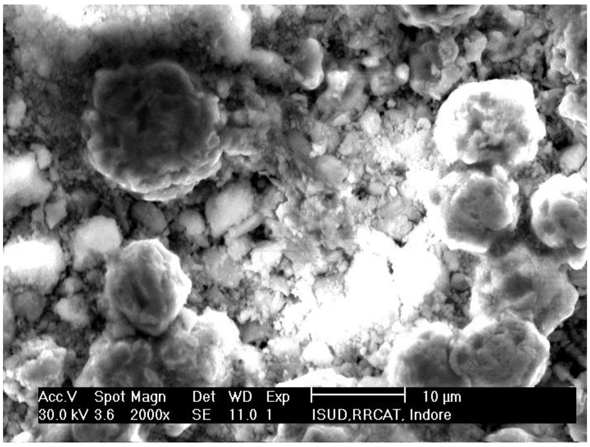

Figure 3: SEM of cathode surface at 10 µm scale range

CONCLUSION

The SEM of surface of used dispenser cathode at 10 and 20 µm scale ranges showed very little availability of emissive material viz. barium over the surface. Hence emission vanishes from dispenser cathode when there is no migration of barium over the cathode surface.

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