

IrCe Cathodes For EBIS.

G.I.Kuznetsov

*Budker Institute of Nuclear Physics,
Novosibirsk 630090, Russia
E-mail: GIKuznetsov@inp.nsk.su*

Abstract. To generate a dense high current electron beam for EBIS working at quasi-permanent regime, high temperature cathodes are used. Though LaB₆ cathode is widely employed, an alloy of refractory metals with lanthanoides seems to have better operating characteristics. The IrCe cathode can produce twice-higher electron current than that of LaB₆-monocrystal at the same temperature, and has two-order lower an evaporation rate at the same time. So, the life-time of IrCe cathode is up to 40,000 hours while generating current density of 15-17 A/cm². In the article one can find more detailed description of the IrCe.

IrCe CATHODES PROPERTIES

Considering that in EBIS a magnetic confined electron beam is employed, to use the high current density cathode seems to be preferable to forming an electron-optical system with high beam compression due to difficulty in generating an electron beam of good quality. The quasi-permanent regime that EBIS operating at, limits using of low temperature cathode in high current mode because of cooling the cathode surface by extracting electrons. At present, cathodes made of poly-crystalline as well as mono-crystalline lanthanum hexaboride (LaB₆) are the most widely in use. In 1969 the article about alloys consist of lanthanum group metal and refractory one appeared [1]. The iridium-based alloy with cerium and lanthanum seemed to be more advantageous. In this paper author presents some results of exploiting the cathodes manufactured from those materials in research installations in Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia.

There are different methods of producing IrCe cathode. One of them is to impregnate an iridium surface with melted salt of lanthanum group. Although this cathode shows good emission ability, its life-time is short due to small depth of active metal penetration and it could be used in rather low power systems. Another method is to manufacture an iridium-based alloy in an arc furnace in an argon atmosphere [1]. IrCe alloy containing 13% of Ce has evaporation rates of its components lower than that for pure iridium. It is $1.6 \cdot 10^{-9}$ g/cm²·sec at 2100K. The work-function for IrCe at 1300K is equal to 2.57 eV [1], at 2100K it becomes 2.63÷2.65 eV and seems to

depend on smelting quality. The IrCe surface has an integral blackness factor $0.35 \div 0.4$, and a spectral one $0.4-0.45$ ($\lambda=6500\text{\AA}$) [2].

In Fig.1 corrections to brightness temperature for IrCe, IrLa, and LaB₆ cathodes are displayed.

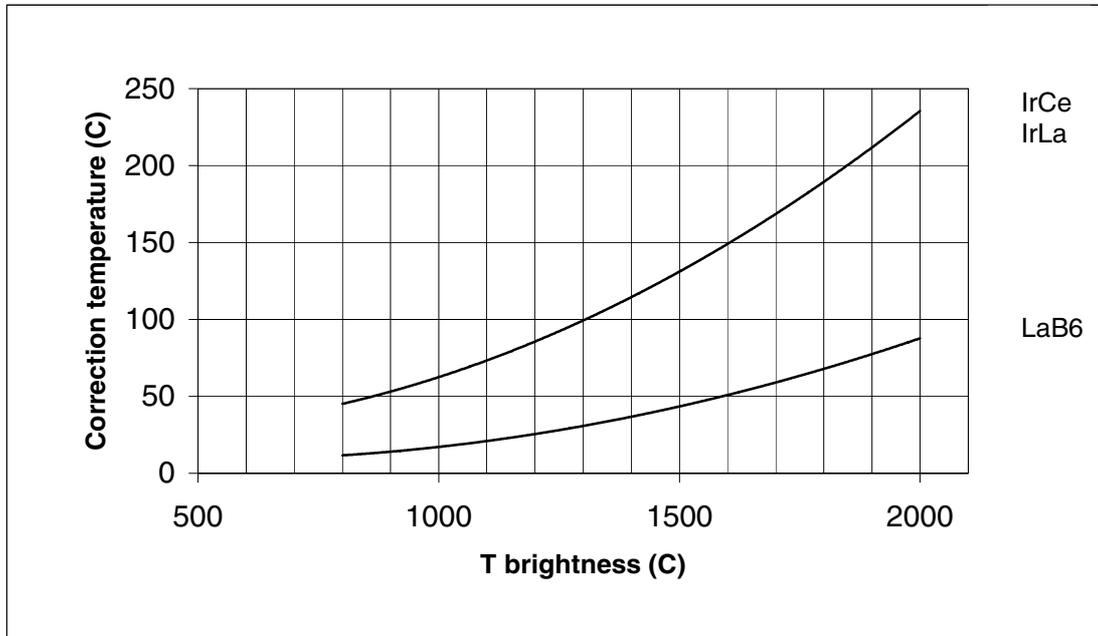


FIGURE 1. Correction temperature.

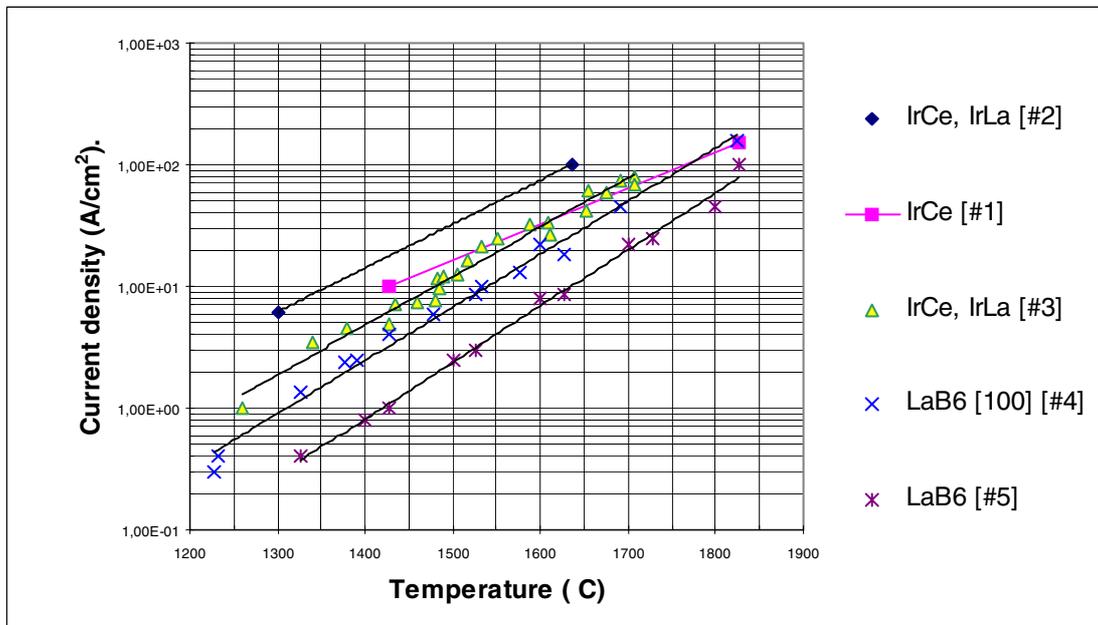


FIGURE 2. Current density of cathodes versus temperature.

In Fig.2 current density dependences of temperature for IrCe and IrLa cathodes, mono- and poly-crystalline LaB₆ are shown.

The line #1 corresponds to data for IrCe cathode presented in first publication [1] .

The line #2 displays data taken from Ashkinasi review [2] on different kinds of emitters.

The results obtained by author during of about 30 years of exploitation in varies institute devices of IrCe cathode produced from several ingots are presented as a curve #3.

The line #4 shows data combined from different papers including those of author's [3] for [100]-face of mono-LaB₆. They are quite similar.

The curve #5 is the results for polycrystalline LaB₆ taken from [4] and obtained by author himself. One can see the divergence for higher temperature. It should be realized that emitting properties of polycrystalline LaB₆ cathodes could varies three times at the same temperature. It is due to difference in quality of initial LaB₆ powder and manufacturing method.

In Fig.3 one can see the dependence of brightness temperature of IrCe cathodes manufactured for BNL TEST STAND in BINP based on 10 mm in diameter standard high temperature heater. The surface temperatures of cathodes are quite similar for poly-crystalline LaB₆, mono-crystalline LaB₆, and IrCe at the same heating power, but extracting current densities correlate as **1:3:6** at T=1400°C and **1:2.5:3.5** at T=1700°C. The problem to have desired current density of more then 50 A/cm² from IrCe cathode is its eutectic with tantalum that used for manufacturing high temperature cathode units at the temperature required.

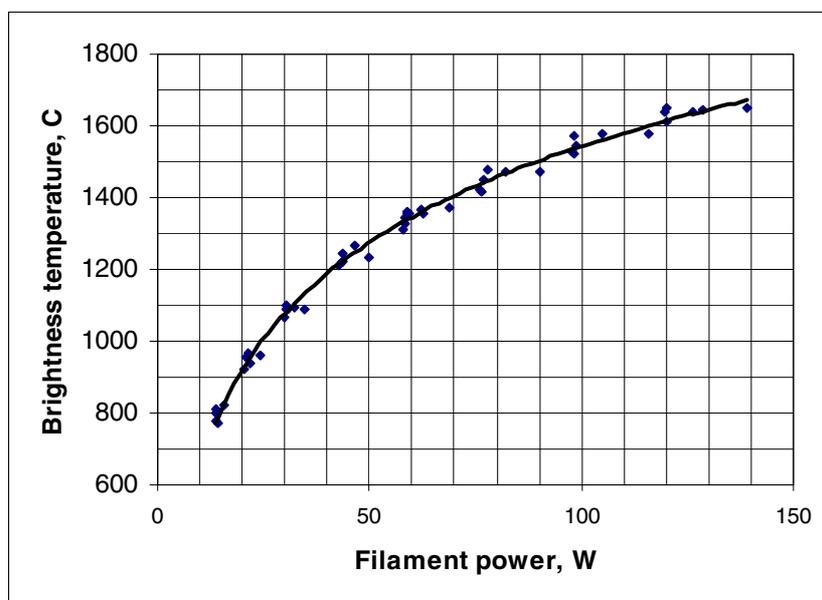


FIGURE 3. Brightness temperature versus heater power for BNL IrCe cathodes.

IrCe CATHODES LIFETIME

A cathode life-time defines often by thickness of layer which one can allow to evaporate or take out by ion bombardment without fatal change in optics of a device. For microtron cathode this layer is only 0.05 mm. For big size cathodes it could be up to 0.5÷1 mm. Let's take as an example IrCe cathode operating in linac injector (55 MeV, $\lambda=70$ cm, pulse duration 30 ns, repetition rate 1-2 Hz) at BINP. It has the diameter 31 mm, to say surface area 7.5 cm², produces current density of 17-20 A/cm² and has life-time of about 40,000 hours [5]. The last one depends on two factors mainly. In one hand, the polished surface of the emitter turns rough, iridium needles and separate crystal faces appeared on the surface screening the latter reducing an electric field near the surface and decreases an extracting current. On the other hand, described upper phenomenon leads to increasing black body factor that requires more heating power to keep up surface temperature and hardening heater load. The non-homogeneous evaporation is due to several factors. They are: multi-component structure of the cathode solid solution of Ce in Ir, chemical compound Ir₅Ce, Ce vapour in pores etc. One can find more details in [6]. The surface of a long worked cathode looks like worn-out wrinkled men face. But after polishing the cathode can output practically original characteristics.

IrCe CATHODES POISONING

In Fig.4-7 current density of IrCe cathode versus pressure of some gases that usual are presented in vacuum tanks are displayed. The experiments were carry out in a preliminarily baked at 200°C metal tank with metal gaskets, pumped by 400 l/sec ionic pump. So at the beginning of each experiment the vacuum was better than $5 \cdot 10^{-9}$ Torr.

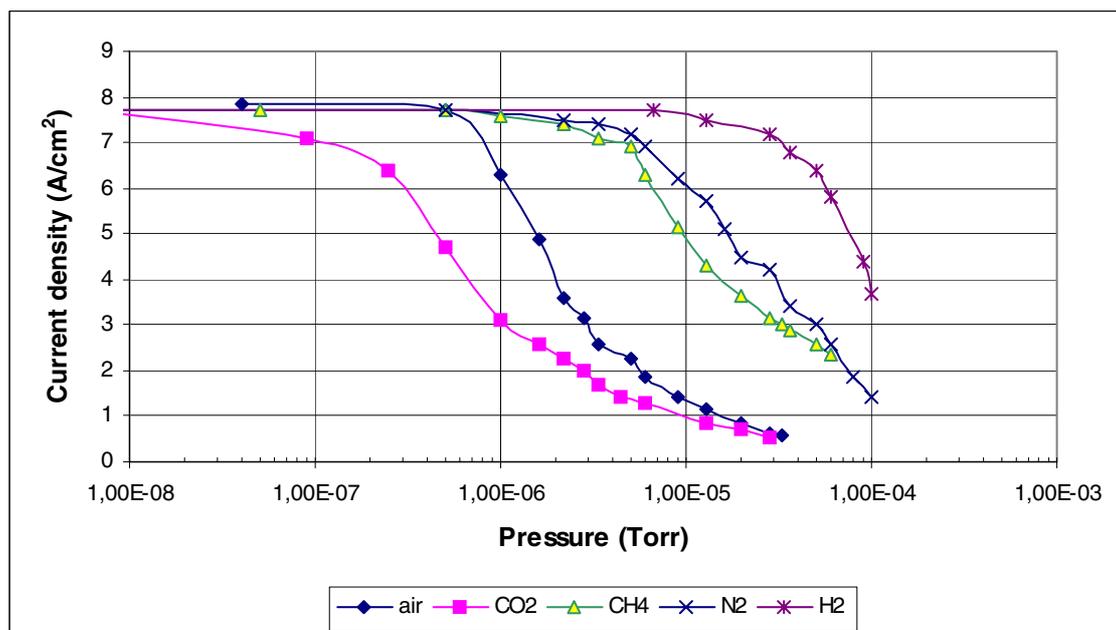


FIGURE 4. Poisoning of IrCe cathode at current density 8A/cm².

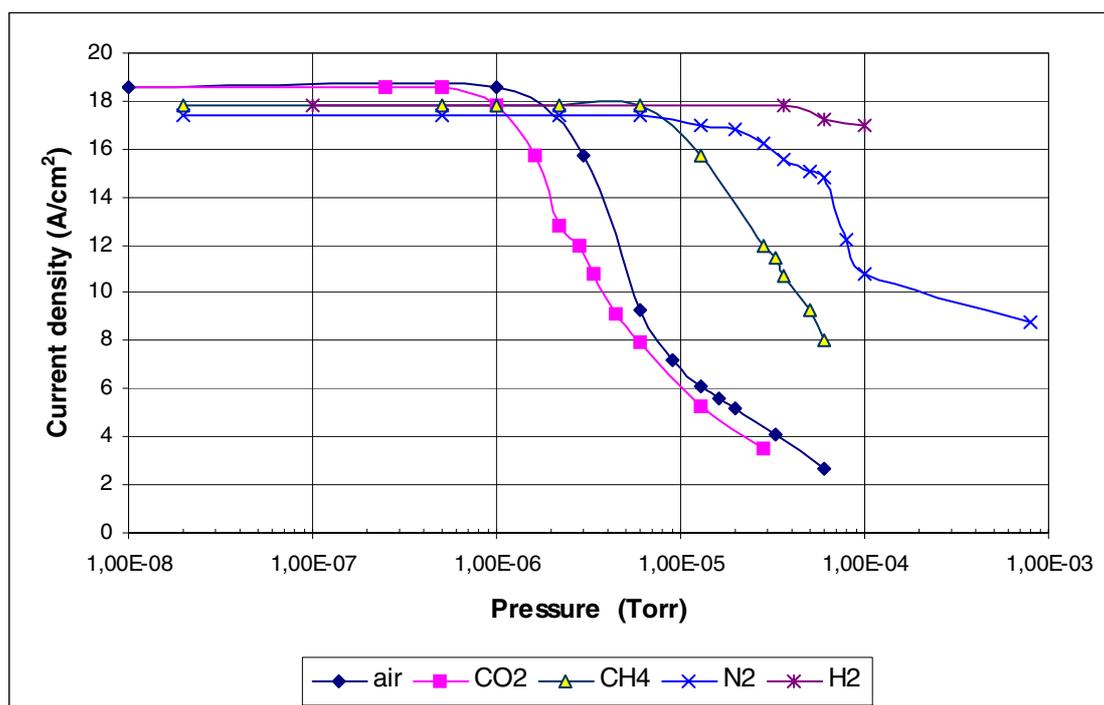


FIGURE 5. Poisoning of IrCe cathode at current density $18\text{A}/\text{cm}^2$.

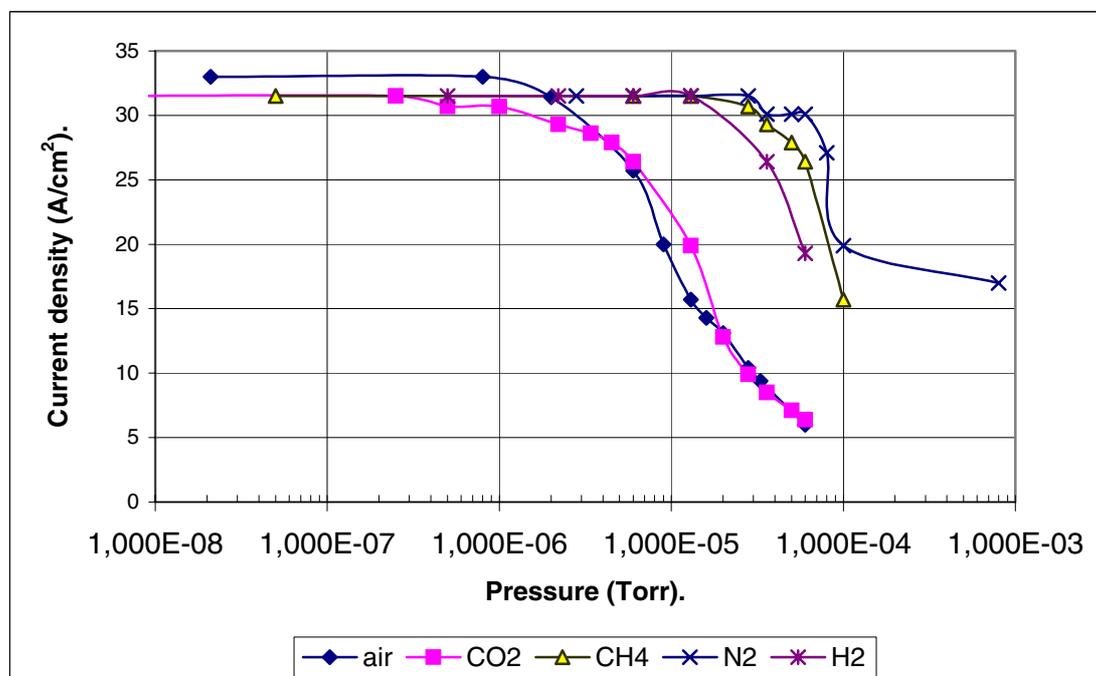


FIGURE 6. Poisoning of IrCe cathode at current density $33\text{A}/\text{cm}^2$.

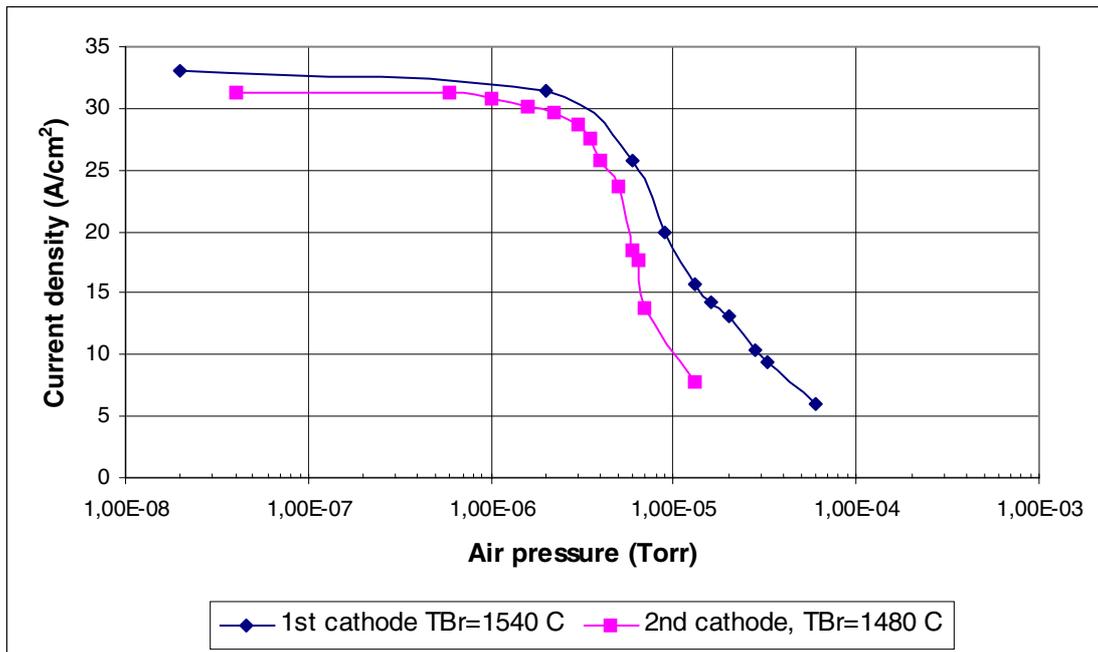


FIGURE 7. Air poisoning for two cathodes of IrCe of different quality at current density 30 A/cm².

For test, a pulse high voltage of 2mksec duration was used. The cathode of 0.7 cm² of area in experimental diode system operated always at temperature limited regime. In the author's experiment the current density reduces by order at $3 \cdot 10^{-5}$ Torr of O₂ at 1675K compare to 2 times shown in [1].

In Fig.7 two IrCe cathodes are displayed. They differ in quality but have similar behaviors and the one of better quality shows more sensitivity to poisoning by oxygen and oxygen-contained compounds.

CONCLUSION

So, IrCe cathode allows one have a high current density, posses a low evaporation rate, and shows a good resistance to poisoning. All this allow us to consider IrCe alloy as the most promising cathode for EBIS devices.

ACKNOWLEDGMENTS

The author wishes to thank Ermakov A.V. from Ekaterinburg, Russia, for IrCe ingot production, and my colleague Batazova M.A. for her help in preparation of this article and fruitful collaboration.

REFERENCES

1. Rozhkov S.E., Kultashev O.K., Gugin A.A., "Technical Characteristics of Thermoemitters from Iridium-based Alloys with Lanthanum, Cerium and Praseodmium," *Generatoryie, Modulatornye I Rentgenovskye Pribory*, **2**, Moscow, 1969, pp. 81-83 (in Russian).
2. Ashkinazi L.A., Loginov L.V., "Thermoelectronic and Secondary Emission Cathodes," Moscow: Informelectro, (in Russian).
3. Kuznetsov G.I., "A Gun for Microtron," in *Instruments and Experimental Techniques*, v.40, **3**, 1997, pp. 424-426.
4. Von Ardenne M., "Tabellen zur Agewandten Physik," 1Band, Berlin: 1962, p.83 (in German).
5. Kuznetsov G.I., "Cathodes for Electron Guns," in *Physica Scripta*, v.T71, 1997, pp. 39-45.
6. Kultashev O.K., Kuranova E.D., Makarov A.P., "Ageing Mechanism of Metal-melting Cathodes," in *Izvestiya Akademii Nauk SSSR*, Physical Series, v.52, **8**, 1988, pp.1619-1922(in Russian).