Photocathodes in Photoinjectors

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Photocathode material

In the known types of photocathodes, metallic photocathodes and semiconductor photocathodes are the most popular used in the photoinjectors. Semiconductor cathodes have higher quantum efficient (QE) but shorter life time than metallic cathodes. Especially the NEA photocathodes (for example, GaAs) has the QE more than 10%, but almost all of the semiconductor photocathodes are extremely sensitive to the contamination, and the working condition for them is ultra high vacuum better than 10^{-6} Pa.

The relevant properties for a Photocathode are: spectral response, operational lifetime, temporal response, saturation level, damage threshold, voltage hold-off, the transverse energy spread of the emitted electron beam and the dark current, average current density.

Metallic photocathodes are the most robust cathodes among known photocathode materials. Most of them have long lifetime and the convenience of air transportable. But the main disadvantage for metal is that Quantum Efficiency is too low because of their high reflectivity and the shallow escape depth, even with special treatment.

Table : Properties of some metallic photocathodes

Fam.	Ele.	Nr.	Work function (eV)	Threshold (nm)	Specials	Lab.
IIA	Mg	12	3.66	339	used in normal-conducting RF gun	BNL
IIA	Ca	20	2.9	427	-	-
IIA	Ba	56	2.5	496	-	-
IB	Cu	29	4.3	288	used in normal-conducting RF gun	BNL, SLAC
IIIB	Y	39	2.9	427	-	-
VB	Nb	41	4.0	310	Nb cavity itself, direct and simple, and no contamination, robust cathode	BNL
Lanthano	Sm	62	2.7	459	-	-
modified	Mg	-	-	-	Mg planted with Cs+ ion	PKU

Among these nonmetallic materials, semiconductor cathodes have higher quantum efficient (QE), but shorter life time than metallic cathodes. Thermionic cathodes are investigated as cathode for RF injector using heating temperature below the usual operating temperature for thermionic emission. Ferroelectric photocathodes and ceramic superconducting cathodes are not very wellknown in the photoelectric performance.

Table: Properties of semiconductor photocathodes

	Material	E a+Eg (eV)	Threshold (nm)
Alkali-halide	CsI	6.4	209
	CsI-Ge	5.0	248
Alkali-antimonide	Cs_3Sb	2.0	620
	K_3Sb	2.3	539
	Na_2KSb	2.0	620
	K_2CsSb	.	.
Alkali-telluride	Cs 2Te	3.5	354
	CsKTe		
	Rb_2Te	4.1	302
	RbCsTe	.	.
	K_2Te	.	.
NegativeElectron Affinity	GaAs (Cs)	.	.
	(111) Diamond	.	<210

Thermionic cathodes are investigated as cathode for RF injector using heating temperature below the usual operating temperature for thermionic emission. Ferroelectric photocathodes and ceramic superconducting cathodes are not very wellknown in the photoelectric performance. From ion-implanted photocathodes not enough information is available to describe them well.

For ferroelectric photocathode a quantum efficiency of QE~6 x 10^{-4} at 355nm wave length was found. The other performance is unknown. Ceramic superconducting cathode were investigsted in but their photoelectric performance is still unknown. Ion-implanted photocathodes were produced by implanting Cs ions to 30 nm of metal, which is about the mean-free path of visible light in metal. Implantations into Ag, Au, W, and Mg were carried out. The quantum efficiency can increase by one order of magnitude. The lifetime carried out. The quantum efficiency can increase by one order of magnitude. The lifetime is longer than that of semiconductor photocathodes. Another significant result is that photoelectrons can be generated with ion-implanted photocathodes by green laser light.

Table: Properties of thermo-photocathodes

Material	QE	Advantages	Disadvantages
Trioxide cathode	0.1%@355nm	Air transportable Can be rejuvenated by heating to700 ^{o}C, the work function of Scandate dispenser is on the order of 2 eV	Long response time. Need slight heating to keep the QE from degrading too quickly
B-type thermionic dispenser	$3.5x10^{-4}$@266nm		Need slight heating to keep the QE from degrading too quickly,
LaB6	0.1%@355nm		