CsI as a High-Gain Secondary Emission Material*

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Since Alvarez and Cone suggested transmission-type electron multipliers for use in high-speed counting systems,¹ most of the work on these devices has made use of KCl for the high gain material in bulk density^{2,3,4,5} as well as low density^{6,7} form. During a study of low density dynodes for use in direct relativistic particle detection systems,^{8,9,10} we have observed some interesting high-gain properties of CsI. It is the purpose of this letter to report some preliminary data on CsI (both bulk density and low density) as a high-gain secondary emitting material.

Dynodes were prepared by evaporation in a diffusion-pumped vacuum system from Mo "dimple" boats onto 1000 Å self-supporting Al₂O₃ substrates with a 500 Å thick overlayer of Al. Bulk density dynodes were deposited at a pressure of $\sim 1 \times 10^{-6}$ Torr. Low density dynodes were evaporated in a 4 Torr atmosphere of argon onto room temperature substrates spaced 2 inches from the boat.

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Two different forms of low density dynodes have been studied. An 8% of the bulk density ($\sim 10\mu$ thick) film was prepared by evaporating 50 mg of CsI in ~ 10 sec, and 2% of the bulk density ($\sim 30\mu$ thick) when 20 mg of CsI was evaporated in ~ 100 sec. All gain, δ , measurements have been carried out in transmission in the vacuum system used for evaporation (at a pressure $\approx 2 \times 10^{-7}$ Torr), immediately after preparation of the dynode.

The data obtained thus far on CsI are summarized in Table I, along with results on KCl for comparison. Maximum gain (for ~ 8 keV primaries) is given as well as the gain for 500-MeV primaries. Bulk density CsI has greater gain than bulk density KCl at both energies, and low density CsI is superior to low density KCl for multi-MeV primaries. In the diffusion-pumped vacuum system, low density dynodes deteriorate with time even without an incident electron beam, as indicated in column 5 of Table I, while gain decreases under electron bombardment as shown in column 6 of Table I. In all cases CsI is superior to KCl, and the results for bulk density CsI measured in the diffusion-pumped vacuum system are seen to be comparable to the best results for KCl which were obtained in clean vacuum systems⁵ (shown in column 7 of Table I). The results presented in the last column of Table I indicate whether or not δ is affected by exposure to a 72° F, 35% relative humidity room atmosphere, and the period of time over which the exposure was carried out. The interesting properties of the CsI dynodes with 8% of the bulk density--high gain, long life, and no change in δ upon exposure to the atmosphere--make them of interest in

multiplier structures which must be opened to air periodically.

The above data, although preliminary, indicate that CsI has high-gain properties of great interest in electron multipliers. Sternglass has suggested the use of CsI,¹¹ but as far as we know, no data have been published on the high-gain properties of this material. Both forms of low density CsI achieve the high gain via field-enhanced secondary emission (as with low density KCl⁷) and show breakdown at high internal fields. Bulk density CsI and KCl dynodes do not exhibit this breakdown phenomenon, and the gain shows no dependence on collector potential above $\sim 10V$, in contrast to the field enhanced emission in the low density forms. It is interesting to note that all three forms of CsI dynodes, as well as bulk and low density KCl dynodes, exhibit a blue fluorescence at high bombarding currents. Blue fluorescence under electron bombardment has also been reported for $[Al]-Al_2O_3-Cs_2O$,¹² bulk MgO ,¹³ and MgO smokes,¹⁴ but an explanation of why so many materials fluoresce with the same color has apparently not been suggested.

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TABLE I

Comparison of the high-gain properties of KCl and CsI transmission-type
as measured in a diffusion-pumped vacuum system.

Material	Density (% of bulk)	Gain, δ			Transmitted charge (C/cm ²) for 10% decrease in δ	
		500 MeV primaries ^a	Maximum δ in DPS ^b		DPS	IPSG ^d
			Initial	δ_L^c		
KCl	100	~ 0.8	8	8	3.5×10^{-4}	8×10^{-2}
KCl	2 - 3	5.7	50 - 60	10 - 15	3.0×10^{-5}	$> 2^g$
CsI	100	1.4	12	12	1.5×10^{-2}	-
CsI	8	-	~ 40	~ 25	$> 5.0 \times 10^{-2}$	-
CsI	2	8	50 - 60	~ 35	4.0×10^{-2}	-

a. Measured in an ion-pumped vacuum system.

b. Diffusion-pumped vacuum system.

c. Charge independent limiting gain in the diffusion-pumped vacuum system.

d. Ion-pumped vacuum system.

e. Relative humidity ~ 35%; room temperature ~ 72° F. Exposure time given in parenthesis.

f. Ref. 5.

g. Ref. 7.