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Life Test and Degradation Modes of Continuously Operated NEA GaP Cold-Cathode

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1. Introduction

Negative electron affinity(NEA) devices are very important as electron emitters of light-sensing systems. NEA cold-cathode electron emitters have been demonstrated using GaAs[1),] Si[2),] GaAsP[3)] and GaP[4,5)]. The significant unsolved problems of the cold -cathode for practical applications are instability and short operating life[6)]. GaP has been used commercially for several years as a secondary-electron dynode[7)]. Recently, NEA GaP-GaAlP cold-cathodes have been obtained by improving the material technology[5)]. Reports of the research concerning the operating life of GaP cold-cathode have apparently not been published to date. Only a few paper reported on the degradation of GaAs cold-cathode[6)]. Little is known about the mechanism of degradation in these cold-cathodes.

In this paper, we present the short term degradation of the cold-cathode, which is an irreversible and a reversible decay, and reports the first continuous operation of GaP-GaAlP cold-cathode for period of time in excess of 2000 hours.

2. Experimental Procedure

A schematic drawing of the cold-cathode fabricated in this study is shown in Fig. 1. N-GaAlP and p-GaP were successively grown on n-GaP substrate by liquid phase epitaxy. Then Zn was diffused selectively into the desired part of p-GaP layer for electron emission. Ohmic contacts were made by standard technique. The crystals were diced and mounted in a glass tube which was pumped by ion-pump system operating in $10^{-10} \sim 10^{-11}$ Torr range. The glass tube using this experiment is shown in Fig.2. The surface of p-GaP layer was thermally cleaned. In order to study the effects of the heat-treatment on the cold-cathodes, the temperature of the surface was increased from 540 to 670 °C by irradiation of infrared light. Activation of the surface after heat cleaning proceeds by alternate depositions of Cs and O_2. Cs source used was cesium chromate channels, and O_2 gas was introduced into the vacuum system through Ag tube.

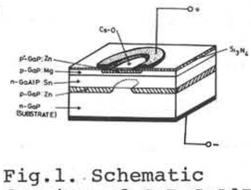

Fig.1. Schematic drawing of GaP-GaAlP cold-cathode.

3. Results and Discussions

The normalized emission currents of the cold-cathodes[diode current(I_d)=10 mA], and photocathodes(at 4450 Å) are shown in Fig.3,as a function of the surface temperature for the thermal cleaning. Maximum emission currents of the cold and photocathodes are observed at 605 and 640 °C,respectively. It is considered

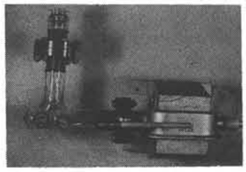

Fig.2.photograph of experimental vacuum glass tube.

that the optimum temperature of the thermal cleaning for GaP surface is about 640°C from resluts of maximum photoemission. In the region above the cleaning temperature of these maximum emission, the emission currents drastically decreased. It seems that the thermally cleaned surface is damaged by thermal etching. Figure 4 shows the typical cold-emission current as a function of diode bias current(I_d) for several thermal cleaning temperatures. At the cleaning temperature of 610°C, cold emission current is maximum at bias current 10 mA. However, at low bias current($I_d <$ 5 mA), cold-emission current decreased. It seems that leakage current of the cold-cathode increases. A photograph of secondary emission image of SEM in the thermal cleaning surface at 580°C is shown in Fig.5. A large number of etch pits patterns are observed. But in samples heat-treated in hydrogen atomsphere gas at 590°C, the etch pits patterns can not be observed. It is found that an irreversible degradation of GaP cold-cathode occurs by thermal cleaning below the optimum temperature. Figure 6 shows the variation in normalized emission current versus continuous operating time for a typical GaP cold-cathode. In region(1) and (3), bias current was constant and surface of the cold-cathode was activated by Cs and O_2, when cold emission decreased. In region(2), bias current was adjusted so as to keep the constant cold emission current, and at time indicated by arrow, the surface was activated by Cs and O_2. It is found that continuous operation over 2000 hours of GaP cold-cathode can be achieved by controlling Cs and O_2 pressure during operation of the cold-cathode, and by controlling bias current.

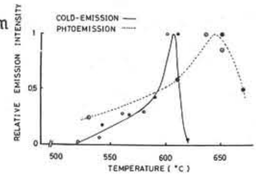

Fig.3.Emission currents versus of the surface temperature.

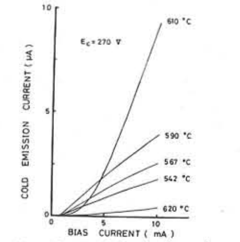

Fig.4.Cold emission currents versus of diode bias current.

4. Summary

During the thermal cleaning of the surface, an irreversible degradation of the cold-cathode occurs below the optimum temperature for surface cleaning. The reversible degradation can be reduced by controlling Cs and O_2 pressure.

Sealed off one-inch vidicon camera tubes were built using the 50 μmΦ cold-cathode and the resolution of 500 TV lines was obtained from the televised RETMA test chart. These results indicate that GaP is a promising material for cold-cathode.

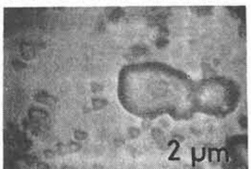

Fig.5.Photograph of the thermal cleaning surface at 580°C in vacuum (by SEM).

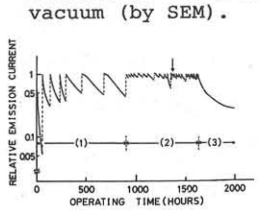

Fig.6.Emission current versus continuous operating time of GaP cold-cathode.

References

1)B.F.Williams et al., Appl. Phys. Letters 14(1969)214.
2)E.S.Kohn, Appl. Phys. Letters 18(1971)272.
3)K.R.Faulkner et al., Appl. Phys. Letters 23(1973)298.
4)E.Stupp et al., J. Appl. Phys. 48(1977)4741.
5)T.Sukegawa et al., *International Conference on Solid Films and Surfaces Tokyo, Japan (1978) July.*
6)H.Kressel et al., J. Luminescence 7(1973)146.
7)H.R.Krall et al., IEEE Trans. on Nuc.Sci., 17(1970)71.