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Line Emission from Semiconductive CdS Single Crystals

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Abstract. When a pulse voltage of sufficient width is applied to a semiconductive CdS bar, a large increase in the electric current occurs with an intense light emission. The dominant part of this emission spectrum consists of Cd(I) atomic lines.

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Light emission from the semiconductive CdS associated with the current oscillation phenomena under a voltage pulse exceeding the threshold value ($V_{\text{th}1}$) is reported [1–4]. When this voltage exceeds another critical value ($V_{\text{th}2}$), the oscillatory behavior of the current vanishes, and the large and abrupt increase in the current occurs after the delay time τ. Simultaneously with this current increase the emission of very intense light with the line spectrum is observed. This paper describes the characteristics of such intense line emission.

1. Experiment

The samples ($10 \times 1 \times 1\,\text{mm}^3$ in size) were cut perpendicular to the C-axis from an undoped semiconducting CdS single crystal (resistivity $\varrho = 15\,\Omega\cdot\text{cm}$, carrier density $n = 2.6 \times 10^{15}\,\text{cm}^{-3}$, Hall mobility $\mu = 190\,\text{cm}^2/\text{V}\cdot\text{s}$). After mechanical polishing with SiC powder (#4000 mesh), the CdS was chemically etched in concentrated HCl for 5 s. Then the bar shaped CdS was coated with epoxy resin except the exposed (0001) surface. Metal indium was evaporated onto both end portions of the exposed surface as ohmic electrodes. To avoid the thermal damage of the sample, a single pulse voltage of 20 µs width was applied to the CdS sample. The time variations of the electric current and the intensity of emitted light were measured by using the transient memory, synchroscope and recorder system. The emission spectrum was observed with the grating spectrograph. These measurements were performed at room temperature.

2. Result and Discussion

Typical current (I)-voltage (V) characteristics and the relation between intensity (B) of emitted light and applied voltage (V) are shown in Figs. 1 and 2, respectively. The synchroscope traces of the time variations of the electric current and the intensity of emitted light are also shown as inset in Fig. 1. The threshold voltage $V_{\text{th}1}$ for the moving high-field domain formation and that for the occurrence of abrupt increase of the electric current $V_{\text{th}2}$ are shown by arrows. Above $V_{\text{th}2}$ the electric current oscillation vanishes after the delay time τ, where τ decreases with increasing applied voltage, and then an S-type negative resistance characteristic is seen as a result of a drastic decrease in the specimen resistance. As can be seen from Figs. 1 and 2, the sharp increase in the emitted light intensity accompanies the abrupt increase of the electric current at $V > V_{\text{th}2}$. This intensity is about 10^5 times as large as that of light emitted from acoustoelectric high field domain at $V < V_{\text{th}2}$.

This intense light has a line spectrum. In Fig. 3, the spectrum of emitted light from a CdS sample are shown along with the spectrum of a Cd-lamp (A) at air pressure of 760 (B), 3×10^{-3} (C), 1.4×10^{-4} (D) and 2.4×10^{-6} (E) Torr, respectively. The intensity profile of the line spectrum is obtained by a microphotometer, as shown in Fig. 3 F. The wavelengths and transitions of these spectral lines of the CdS sample identified with the spectral lines of the Cd-lamp are listed in Table 1. In the present experiment, however, the 6438 Å line of Cd(I) $[5^1D_2 - 5^1P_1]$ could not be observed. There are additional spectral lines: 1) 4102 and 4511 Å lines of

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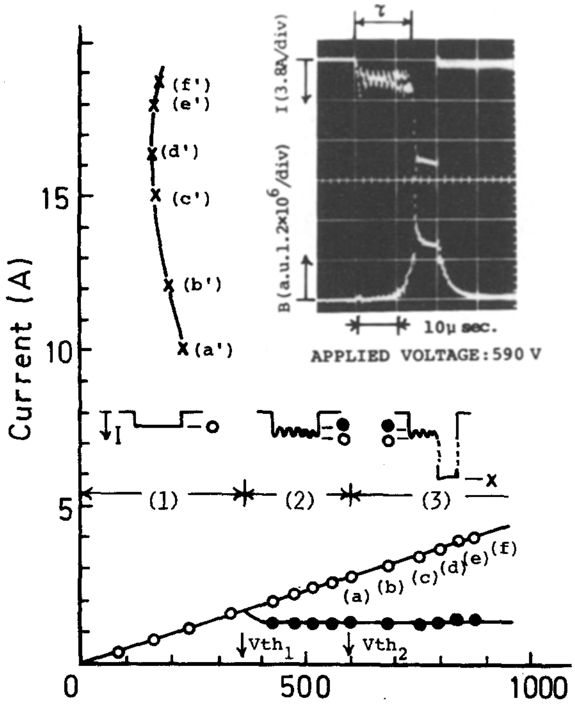

Fig. 1. Current-voltage characteristics and synchroscope traces of time variation of electric current and intensity of the emitted light. The current oscillation vanishes above V_{th2} after the delay time τ. With rapid increase of current, the applied voltage decreases as $(a)-(a')$, $(b)-(b')$, $(c)-(c')$, $(d)-(d')$, $(e)-(e')$, and $(f)-(f')$, respectively

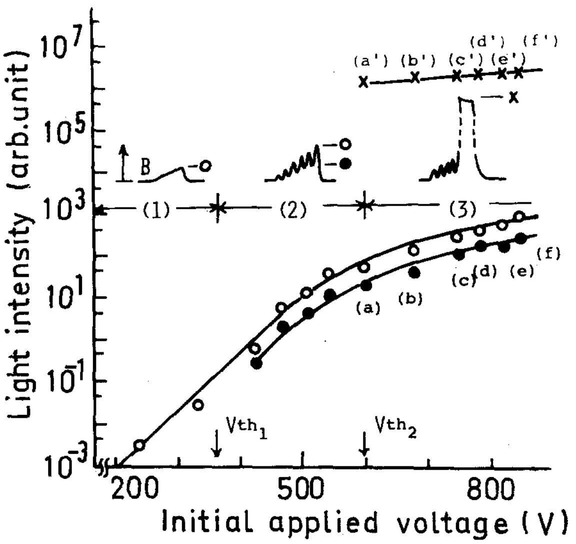

Fig. 2. Initial applied-voltage dependence of the intensity of emitted light. The applied voltages at the final stage of the pulse are shown in Fig. 1

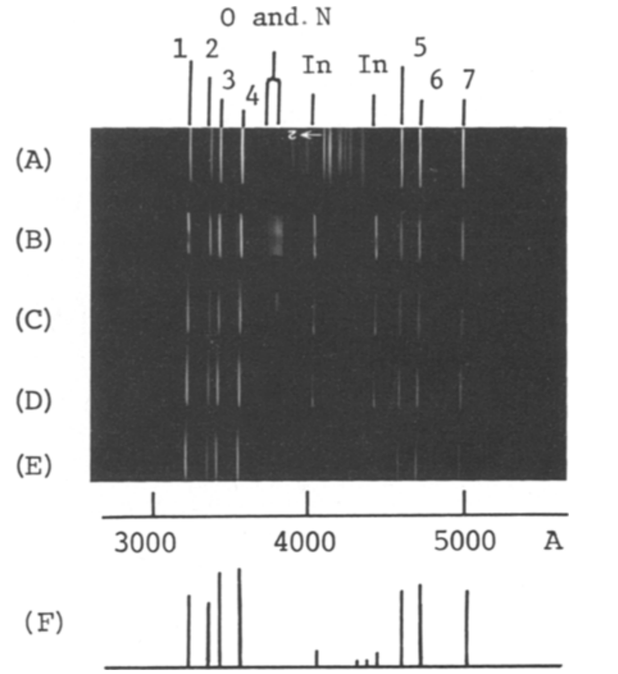

Fig. 3. A–E. Emission spectra obtained under the various conditions. (A) Cd-lamp as reference, (B) 760 Torr, (C) 3×10^{-3} Torr, (D) 1.4×10^{-4} Torr, and (E) 2.4×10^{-6} Torr. The intensity profile of the line spectrum at 2.4×10^{-6} Torr is also shown as (F)

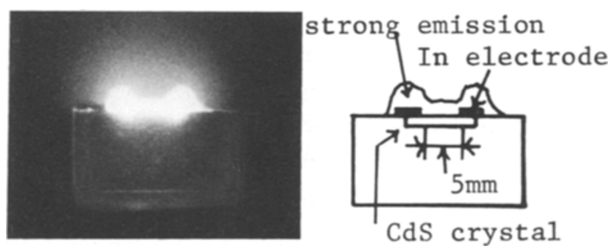

Fig. 4. Side view of the emitting CdS sample

Table 1. Wavelengths and transitions for the spectral lines of the CdS sample which coincide with the lines of the Cd-lamp

Line no.	Wavelength [Å]	Transition
1	3261	$5^3P_1-5^1S_0$
2	3404	$5^3D_1-5^3P_0$
3	3466, 3468	$5^3D_{1,2}-5^3P_1$
4	3611, 3613	$5^3D_{1,2,3}-5^3P_2$
5	4678	$6^3S_1-5^3P_0$
6	4800	$6^3S_1-5^3P_1$
7	5086	$6^3S_1-5^3P_2$

In(I), 2) several lines between 3900 and 3960 Å which disappear when the CdS sample is operated in a sufficiently evacuated vessel. Their coincidence lines can be found among N- or O-lines in the spark spectrum of the air.

The photograph (Fig. 4) shows a side view of the emitting CdS sample and indicates that a very strong emission occurs in the thin layer on or outside the CdS crystal surface. This fact suggests that generation of Cd vapor occurs on the crystal surface provided the

applied pulse voltage is higher than V_{th2} and the vapor induces flashover along the crystal surface.
All the results showed good reproducibility even after the operations of several thausands times.

3. Conclusion

From the experimental results presented above, we can conclude that the emission of intense light with a line spectrum differs essentially in its mechanism from the light emission associated with the high-field domain [1–4]. The emission arises from Cd atoms excited through the electric discharge induced along the surface of the CdS crystal. The detailed mechanism of these phenomena will be reported in near future.

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