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THE IMPACT CROSS SECTION OF ErF_3 CENTERS IN ZnS THIN FILM

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We used quasi-molecular beam epitaxial method to prepare ZnS:ErF_3 thin film and obtained ErF_3 Lumocen in ZnS thin film. It was found for the first time that the impact cross section of ErF_3 Lumocen, about 8 X $10^{-16}cm^2$, was larger than that of Er^{3+} centers.

1. INTRODUCTION

The impact cross section of luminescent centers is a very important parameter for electroluminescence in which direct impact excitation by hot electrons is the dominant excitation mechanism. Up to now, only Mullar et al.[1] and Xu Xumou et al.[2] obtained the cross sections of Mn^{2+} and Er^{3+} in ZnS thin films experimentally. The concept of Lumocen was proposed in 1968 by Kahng. The molecular centers, such as ErF_3, are expected to have larger impact cross section than ion centers in favor of higher efficiency and brightness. But so far there are no experimental results about the impact cross section of Lumocen. In this work, the samples of Lumocen, ZnS:ErF_3 thin films, were prepared. We have used high-resolution spectroscopy under laser selective excitation (LSE) and electric field excitation to study ZnS:ErF_3 and ZnS:Er^{3+} thin films, distinguished two kinds of luminescent centers, ErF_3 Lumocen and Er^{3+} ion centers. The impact cross section of ErF_3 Lumocen was deduced for the first time to be about 8 X $10^{-16}cm^2$ which is larger than that of Er^{3+} ion centers.

2. RESULTS AND DISCUSSION

2.1 Preparation of ErF_3 Lumocen

To avoid a decomposition of ErF_3, we used quasi-molecular beam epitaxial method to prepare ZnS:ErF_3, ZnS:Er^{3+} and ZnS:EuF_3 thin films, by means of a rotating substrate holder and appropriate masks to seperate ZnS and C (C = ErF_3, EuF_3, Er) vapors. The AC EL Spectra of ZnS:ErF_3 and ZnS:Er^{3+} thin films have been measured at 77K, shown in Fig.1. Some lines are common in spectra of ZnS:ErF_3 and ZnS:Er^{3+}, and some lines only appear in the spectrum of ZnS:ErF_3. We expect that common lines are related to Er^{3+} centers, the latter lines are related to ErF_3 Lumocen.

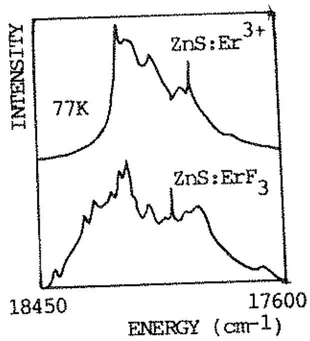

FIGURE 1
EL spectra of ZnS:ErF_3 and ZnS:Er^{3+}

To prove the expectation, EL of ZnS:EuF_3 thin film which was prepared by quasi-molecular beam epitaxial method was measured. The red electroluminescence was observed. It is known[3] that europium ions in metallic form exist in the divalent state in ZnS, which emission is blue. When europium is introduced in EuF_3 form, europium ions are in trivalent state, emission is red. Since our preparation method produced ZnS:EuF_3 samples which have red emission, EuF_3

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Lumocen is expected to exist in our sample, so does ErF_3 Lumocen.

2.2. Different centers in $ZnS:ErF_3$

We know there are two kinds of centers in $ZnS:ErF_3$. We used LSE technique to distinguish the emission spectra and excitation spectra of ErF_3 Lumocen and Er^{3+} centers. ErF_3 Lumocen (center A) only exists in $ZnS:ErF_3$ and Er^{3+} centers (center B) exist in both $ZnS:ErF_3$ and $ZnS:Er^{3+}$. Their emission spectra are shown in Fig.2.

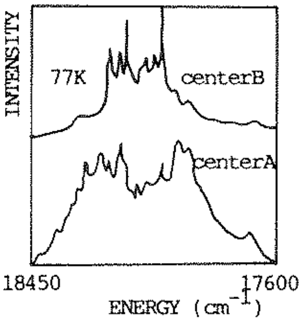

FIGURE 2
Emission spectra of center A and center B

By comparing the emission intensities of two kinds of centers, the ratio of the concentrations of two kinds of centers was deduced as follows:[2]

$$\frac{N_A}{N_B} = \frac{I_A \, P_{rB} \, F_B \, \nu_A^3}{I_B \, P_{rA} \, F_A \, \nu_B^3}$$

where I, Pr, F, ν are emission intensity, radiative transition probability, laser excitation intensity and frequency respectively, A and B denote ErF_3 and Er^{3+} centers respectively.

TABLE 1

center	F(r.u.)	Pr($\times 10^4$/s)	I(r.u.)	ν($\times 10^{14}$/s)
A	0.9	2.51	0.397	5.75
B	1.1	2.45	1.0	5.72

Measured data are shown in Table 1, we obtained $N_A/N_B = 0.48$. The ratio indicates that only one third ErF_3 exist in ZnS lattice in form of Lumocen.

2.3. Impact cross section of ErF_3 Lumocen in ZnS.

The EL spectrum of $ZnS:ErF_3$ thin film can be decomposed into emissiom spectrum of ErF_3 centers and that of Er^{3+}centers. The ratio of intensities of two kinds of centers can be deduced, $I_{EL}^A/I_{EL}^B = 4.9 I_A/I_B$, where $I_A/I_B = 0.397$ (see Table.1).

Thus, we have[2],

$$\frac{\sigma_A}{\sigma_B} = \frac{I_{EL}^A \, N_B}{I_{EL}^B \, N_A} = 4.9 \frac{I_A \, N_B}{I_B \, N_A}$$

Using the value in Table.1 and the value of the impact cross section of Er^{3+} centers[2], the impact cross section of ErF_3 Lumocen was deduced to be approximately $8 \times 10^{-16} cm^2$ (±45%)

In reference 4, we know, $\sigma = \sigma_1 + \sigma_2$,

$\sigma_1 = a \cdot Pr$, $\sigma_2 = b \cdot \langle r^2 \rangle^2$,

where Pr is radiative transition probability, $\langle r^2 \rangle = \int R_f^* \, r^2 \, R_i \, r^2 dr$, R is the radial part of the 4f electrons wave function.

Since the Pr of two kinds of centers are approximately same, the difference of the cross sections of two kinds of centers is originated from σ_2. As an approximation, $\langle r^2 \rangle$ of Er^{3+} ion centers is taken to be 0.88Å, ErF_3 molecular radius is taken to be about 3.6Å. The σ_2 of ErF_3 centers is 280 times bigger than that of Er^{3+} centers. σ_2 of Er^{3+} centers is about 300 times smaller than σ_1 of Er^{3+} centers[4], but σ_1 and σ_2 of ErF_3 centers are in the same order. Thus, the larger geometic cross section $\langle r^2 \rangle$ of ErF_3 Lumocen may make their impact cross section be larger than that of Er^{3+} centers.

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