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OPTICAL PROPERTIES OF YAG AND YAP SINGLE CRYSTALS IN VUV

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The optical spectra of $Y_3Al_5O_{12}$(YAG) and $YAlO_3$(YAP) single crystals in the VUV region to 40 eV are interpreted in terms of atomic levels of Y and Al. The excitation spectra are presented for Ce^{3+} emission from YAG:Ce and YAP:Ce powder phosphors at room temperature in the VUV region, and they are compared with the optical functions of the host crystals, especially in the exciton region.

1. INTRODUCTION

YAG and YAP have been widely used as a host of the rare earths doped lasers or phosphors[1], but their fundamental spectra have received less attention up to now. In this paper, several optical properties in the fundamental region of these species in single crystalline state are presented.

2. EXPERIMENTAL RESULTS AND DISCUSSION

The measurements were mainly made at the Synchrotron Radiation Laboratory, ISSP. Single crystals of YAG and YAP were purchased from the Nippon Electric Co., NEC. Ce-activated phosphors were synthesized at the Matsushita Research Institute Tokyo Inc.[2]

The absorption constant A(E,T) in the tail region is expressible by the well known Urbach rule:

$$A(E,T) = A_0 \exp [- \sigma_s(T)(E_0 - E)/kT],$$

$$\sigma_s(T) = \sigma_{so} \frac{2kT}{\hbar\omega} \tanh \frac{\hbar\omega}{2kT},$$

where e.g. ($A_0 = 5.27 \times 10^5$ cm^{-1}, $E_0 = 8.018$ eV) and ($\sigma_{so} = 0.478$, $\hbar\omega = 32.5$ meV) for $\vec{E} \parallel \langle b \rangle$ of YAP in the region of T = 300 K to 10 K, $\vec{E}$ being the electric field vector of a light wave.

Figure 1 shows the reflectivity spectra R(E) from the (111) planes of Y_2O_3[3] and YAG as well as the spectrum of YAP at room temperature for the light $\vec{E} \parallel \langle a \rangle$. The spectrum of YAG is determined via comparisons of the spectra measured at the Synchrotron Radiation Lab., ISSP[4], at the Photon Factory, KEK, National Lab. for High Energy Physics[3] and at University of the Ryu-

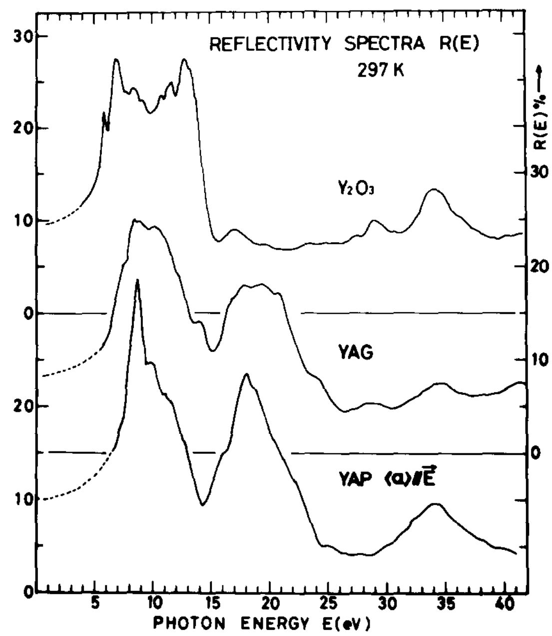

FIGURE 1
The reflectivity spectra of Y_2O_3[3], YAG and YAP.

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kyus[5]. The spectrum of YAP is also revised from that of ref. 4.

Three prominent structures found in the fundamental regions of YAG and YAP are interpreted as follows, referring to the results of Y_2O_3[3]:
(1) The 1st structure lying over the region of 6 to 15 eV is due to the transitions from the O^{2-} $2p^6$ to Y^{2+} $4p^6(4d + 5s)$ levels.
(2) The 2nd structure in the region of 15 to 25 eV is due to the transitions from the O^{2-} $2p^6$ to (i) Y^{2+} $4p^6(md + ns)$ with $m \geq 5$ and $n \geq 6$ and (ii) Al^{2+} 3s, 3d,... bands. The latter is conducted because the corresponding structure is missing in the spectrum of Y_2O_3 except the plateau which was interpreted along (i)[3].
(3) The 3rd part above 25 eV is due to the inner core transitions of Y^{3+}: $4p^6$ to $4p^5(4d + 5s)$ [4].

In Fig. 2 are shown the excitation spectra Q(E) for Ce^{3+} emission from YAG:Ce and YAP:Ce powder phosphors[6] which were chemically etched beforehand in HNO_3 solution to minimize extrinsic effects such as due to the flux. A steep rise of Q(E) is seen to occur just in the region where the intrinsic tail is measured[4]. In the case of YAP, the peak of Q(E) and the shoulder of the spectra of R(E) and $\varepsilon_2(E)$ are located at the same position, 8.05 eV, as indicated by arrows. This value is nearly equal to E_0 = 8.018 eV, the convergence position of the tails measured with $\vec{E} \parallel \langle b \rangle$ which lies at the lowest energy compared with those measured with $\vec{E} \parallel \langle a \rangle$ or $\langle c \rangle$. Therefore, the tail is conceived to be the lower energy branch of the shoulder. On the other hand, the structure at 7.7 eV seen on the R(E) and $\varepsilon_2(E)$ spectra of YAG is located at the higher energy side of the peak of Q(E) at $\sim$ 7.0 eV. The intrinsic tails of YAG converges towards the point at E_0 = 7.012 eV which is very close to the peak position of Q(E). This strongly suggests that the intrinsic tail of YAG is the lower energy branch of the yet unresolved structure around 7.0 eV which may be responsible for the transitions giving rise to the exciton formation. The structure at 7.7 eV might correspond to the manifestation of other origins, e.g. the interband transitions. This interpretation does not appear to be in conflict with the experimental curve of photocurrent in ref. 7.

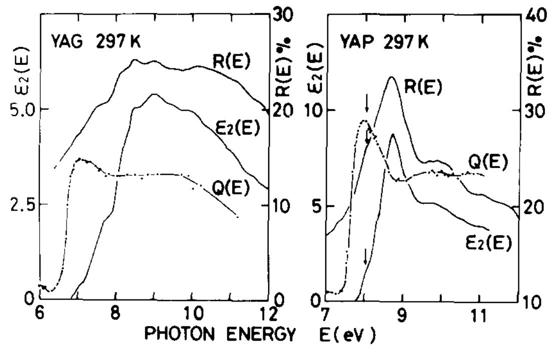

FIGURE 2
The excitation spectra Q(E) for Ce^{3+} emission in comparison with the spectra of R(E) and $\varepsilon_2(E)$.

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