C－4－3 Preparation of Nd^{3+} doped $Gd_3Ga_5O_{12}$ Films by Liquid Phase Epitaxy

T. Okuda, K. Ando, and N. Koshizuka
Electrotechnical Laboratory, Sakura-mura, Ibaraki 305.

Introduction: Epitaxially grown Nd^{3+} doped $Gd_3Ga_5O_{12}$(Nd:GGG) or $Y_3Al_5O_{12}$(Nd:YAG)[1] thin film laser will have a chance to be used in parallel with semiconductor lasers as signal source in optical communication systems because they can provide laser light of the wavelengths of 1.06 μm or 1.33 μm which lie in the low loss region of optical fiber. Furthermore, it will be possible to fabricate Nd:GGG thin film laser monolithically on GGG substrate together with isolator and modulator made of magnetic garnet films by using liquid phase epitaxy technique. This paper describes the growth procedure and the quality of Nd:GGG epitaxial films.

Film Growth Procedure: Nd:GGG films were grown by using the usual apparatus and technique of isothermal dipping in the supercooled melt with rotation of the substrate supported horizontally[2]. The garnet constituent oxides with composition of $[(1-x)Gd_2O_3+xNd_2O_3]:Ga_2O_3=1:2$ by mole which was settled by taking the segregation effects into account were melted with the flux composed of PbO and B_2O_3 in the ratio of 92 to 8 by mole. To find favorable conditions for growing the films of high optical quality with thickness of more than 100 μm, the following parameters were varied: the growth temperature, the degree of supercooling, the rotation rate, and the dipping time. As a result, Nd:GGG films were grown successfully up to 130 μm in thickness with a growth rate up to 2 μm/min. The growth data are summarized in Table 1.

Characterization of the Film: Segregation of Nd in GGG was determined to be about 0.3 from x-ray fluorescence analysis, therefore, Nd content of the films obtained in this study was found to be about 1.5% mole fraction.

The films were examined by measuring the fluorescence decay time of $^4F_{3/2}$ level of Nd^{3+} at room temperature. A noticeable dependence of the decay time on the growth temperature as shown in Fig.

Table 1. Nd:GGG film growth parameters

Run No.	Growth Temp. (°C)	Super-cool. (°C)	Rot. Rate (rpm)	Thick. (μm)	Growth Rate (μm/min)	Fluoles. Decay Time (μs, RT)
1	930	20	100	16	1.6	64
2	937	13	100	10	1.0	74
3	1014	18	300	55	5.0	118
4	1019	13	300	30	3.0	121
5	989	18	100	50	1.7	133
6	990	17	200	35	1.2	136
7	990	17	36	20	0.7	154
8	1037	20	100	130	1.3	140
9	1043	14	100	10	0.1	170
10	986	20	100	115	1.0	116
11	978	12	100	65	0.5	111

1 was discovered. The decay time of 170 μsec obtained here is sufficiently long for the excitation of stimulated emission.

The Raman spectra of the film and the substrate shown in Fig.2 were obtained by introducing an Ar laser (488.0 nm) into the respective part of the sample. Comparing the spectrum of the film with that of the substrate, there are no differences in the number of Raman lines, the width of each line, and the relative intensity ratio among the lines. Furthermore, were found no extra lattice vibration modes which may originate from impurity incorporation or other lattice defects.

Possibility of Nd:GGG Thin Film Laser: A relation between the refractive index of the film (n_f) and that of the substrate (n_s) which is required to hold the laser light in Nd:GGG film ($n_f > n_s$), was examined by comparing the refractive index of GGG with that of $Nd_3Ga_5O_{12}$(an end material of $(Gd_{1-x}Nd_x)_3Ga_5O_{12}$ system) at selected wavelengths. From the data given in Table 2, it was deduced that the refractive index of Nd:GGG film may be larger than that of GGG at the wavelength of laser oscillation. Considering this refractive index relation with the characteristics of the films described in the previous section, it is concluded that the epitaxially grown film of Nd:GGG possesses requisite material qualities for laser oscillation. The authors are indebted to Prof. M.Wakaki at Tokai University for the determination of refractive index of $Nd_3Ga_5O_{12}$.

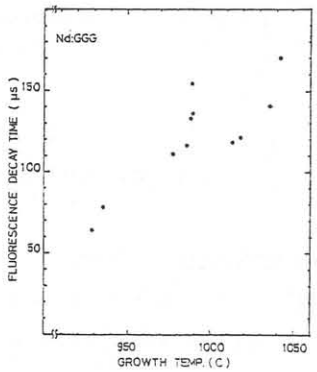

Fig. 1. Growth temperature dependence of fluorescence decay time.

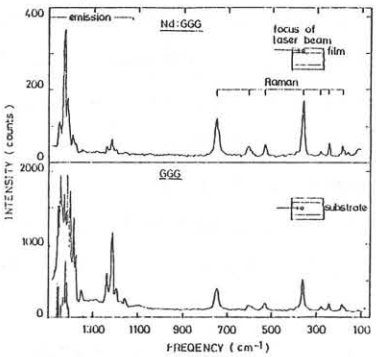

Fig. 2. Raman spectra of the film and the substrate.

Table 2. Refractive indices of $Gd_3Ga_5O_{12}$ and $Nd_3Ga_5O_{12}$.

Wavelength (μm)	$Gd_3Ga_5O_{12}$ [a]	$Nd_3Ga_5O_{12}$
0.488	1.9676	2.001
0.6328	1.9646	1.993
1.06	1.9436	1.960

(a) J.Bohm et al. Kristall und Technik 13,K10 (1978).

References:

(1) J.G.Grabmaier, R.D.Plättner, P.Möckel, and W.W.Krühler, J. Crystal Growth 34 (1976) 280.

(2) H.J.Levinstein, S.Licht, R.W.Landorf, and S.L.Blank, Appl. Phys. Letters, 19 (1971) 485.