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CRYSTALLOGRAPHIC DATA FOR RARE-EARTH ALUMINUM GARNETS: PART II

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The rare-earth aluminum garnets may be represented by the general formula $R_3Al_2Al_3O_{12}$ where R represents the rare-earth ion. The crystallographic properties of the rare-earth aluminum garnets from terbium to thulium in the periodic table were reported by Rubinstein and Barns (1964). This note presents the indexed *x*-ray powder data and index of refraction for gadolinium, ytterbium and lutetium aluminum garnets which will hereafter be referred to as GdAlG, YbAlG and LuAlG. In addition, the growth habit of YbAlG is reported.

All the crystals used in this study were grown by a technique discussed by Van Uitert *et al.* (1965). The crystals varied in size from fractions of a millimeter to a full centimeter in cross-section. The total impurity concentration in the crystals is estimated to be 0.1 per cent. The powder diffraction photographs were taken with a Straumanis-Type Norelco camera of 114.6 mm diameter using CuKα radiation and an Ni filter. Corrections were made for film shrinkage. The data so obtained are given in Table 1.

The lattice parameters used to calculate the spacings reported in Table 1 are given in Table 2. The color, *x*-ray density and index of refraction are also given in Table 2. For convenience, our previously reported lattice parameters, *x*-ray densities and colors are also included in Table 2. The refractive indices were determined with a Rayner refractometer equipped with a sphalerite prism. The indices previously reported by Rubinstein and Barns (1964) were redetermined by this, more accurate, method. A conservative estimate of the error for the lattice parameter gives 3σ limits of ± 0.003 Å and an estimate of the probable error for the index is ± 0.001.

Table 1. X-Ray Powder Data for Rare-Earth Aluminum Garnets, CuKα (λ = 1.5418A) Radiation.

hkl	I visual	GdAlG d (A) obsd	GdAlG d (A) calcd	YbAlG d (A) obsd	YbAlG d (A) calcd	LuAlG d (A) obsd	LuAlG d (A) calcd
211	9	4.932	4.944	4.865	4.870	4.856	4.863
220	4	4.277	4.282	4.217	4.216	4.205	4.212
321	7	3.230	3.237	3.184	3.188	3.175	3.184
400	6	3.020	3.028	2.980	2.982	2.958	2.978
420	10	2.697	2.708	2.663	2.667	2.659	2.664
422	4	2.464	2.472	2.430	2.435	2.429	2.432
521	5	2.207	2.211	2.174	2.178	2.172	3.175
611,532	6	1.959	1.964	1.933	1.935	1.930	1.932
631	3	1.783	1.786	1.758	1.759	1.758	1.756
444	4	1.745	1.748	1.718	1.722	1.719	1.719
640	5	1.676	1.679	1.651	1.654	1.651	1.652
721,633,552	3	1.646	1.648	1.620	1.623	1.620	1.621
642	4	1.615	1.618	1.592	1.594	1.591	1.592
732,651	2	1.537	1.538	1.513	1.515	1.511	1.513
800	3	1.511	1.514	1.490	1.491	1.488	1.489
840	1	1.351	1.354	1.332	1.334	1.330	1.332
842	3	1.319	1.321	1.300	1.302	1.298	1.300
921,761,655	1	1.305	1.306	1.285	1.286	1.284	1.285
664	1	1.291	1.291	1.270	1.272	1.270	1.270
1040,864	3	1.124	1.124	1.108	1.108	1.106	1.106
1121,1051,963	1	1.079	1.079	1.062	1.063	1.061	1.061
880	2	1.071	1.070	1.054	1.054	1.053	1.053
1222,1064	1	.9824	.9823	.9682	.9676	.9665	.9662
1244	1	.9132	.9129	.8996	.8992	.8981	.8979
1260,1084	3	.9033	.9027	.8890	.8891	.8873	.8879
1440,1282	2	.8318	.8318	.8191	.8193	.8180	.8181
1442,1266,10104	1	.8239	.8240	.8116	.8117	.8104	.8105
1521,1453,1365	1	.7985	.7986	.7866	.7866	.7855	.7855
11103,1097							
1532,1196	1	.7850	.7850				
12100,1286	8	.7753	.7753				

TABLE 2. CRYSTAL PROPERTIES OF THE RARE-EARTH ALUMINUM GARNETS

Sample	Color[1]	Lattice parameter[2] (Å)	Calculated x-ray density (g/cm^3)	Index of refraction[3]
GdAlG	Colorless Pale Yellow	12.111	5.971	1.866
TbAlG	Colorless Pale Yellow	12.074	6.063	1.873
DyAlG	Pale Yellow	12.042	6.193	1.868
HoAlG	Golden Yellow	12.011	6.297	1.863
ErAlG	Pink	11.981	6.397	1.853
TmAlG	Pale Green	11.957	6.476	1.854
YbAlG	Colorless Pale Yellow	11.929	6.619	1.848
LuAlG	Colorless Pale Yellow	11.912	6.692	1.842

[1] The color exhibited by some samples may be modified due to lead impurities from the flux in which the crystal was grown.

[2] $CuK\alpha_1 = 1.54050$ Å.

[3] Sodium D ($\lambda = 5890$ Å).

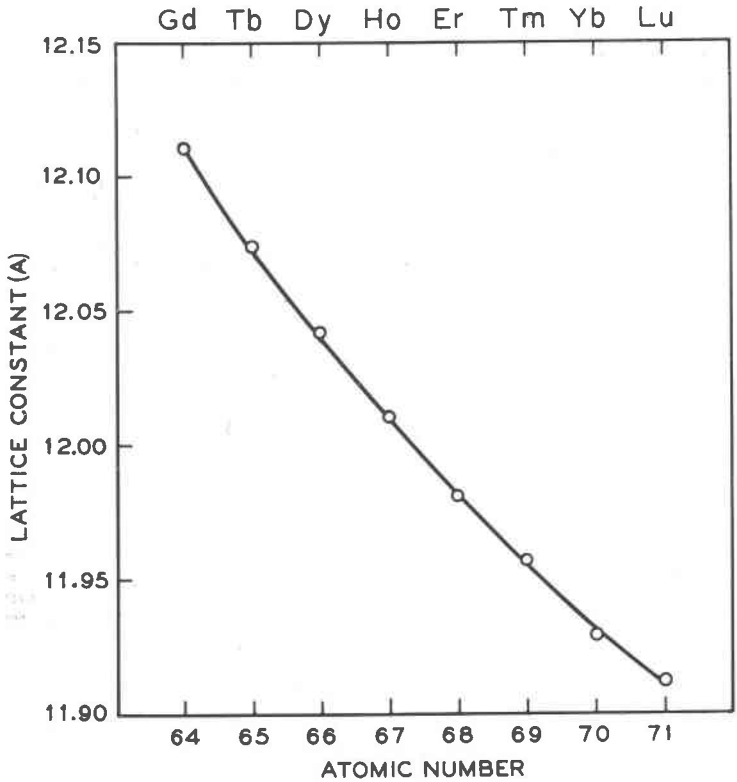

FIG. 1. Lattice constant versus atomic number for the rare-earth aluminum garnets.

The GdAlG lattice parameter 12.111 Å agrees with the value 12.11 Å determined by Bertaut and Forrat (1956), but it does not agree with the value 12.122 Å extrapolated by Geller *et al.* (1964a) from their data on the system $Gd_3\ Fe_{5-\chi}\ Al_x\ O_{12}$. In this mixed system the lattice constant versus χ is linear over the ranges $0<\chi\leq 1.0$ and $1.0<\chi\leq 3.0$ and the extrapolation was made from the latter range. However, in the system $Y_3\ Fe_{5-\chi}\ Al_\chi\ O_{12}$ which was investigated by Geller *et al.* (1964b) the lattice constant versus χ behavior is linear up to $\chi=2.5$, but beyond this point there is an inflection toward the abscissa. A similar inflection might occur in the $Gd_3\ Fe_{5-\chi}\ Al_\chi\ O_{12}$ system for $\chi>3.0$ which would explain the discrepancy between the extrapolated value and our measured value.

Figure 1 contains a plot of the lattice constant versus atomic number for all the rare-earth aluminum garnets investigated. The resulting curve is similar in form to one drawn for the rare-earth iron garnets by Espinosa (1962) and unlike the straight line relation reported by Bertaut and

Forrat (1957) for the rare-earth aluminum garnets. An explanation of the shape of the curve is given by Espinosa (1962).

The growth habit of YbAlG was examined by optical goniometry. All the growth faces were found to be of the dodecahedron [110] and trapezohedron [112] types. The crystal is similar in appearance to Fig. 135 by Ford (1958).

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NEW ANALYSIS OF GENTH'S VOLBORTHITE[1]

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Genth's Analyses of Volborthite

In 1877 Genth published a paper giving the results of his analysis of volborthite from Woskressenskoi, Perm, U.S.S.R. Genth recognized his analyses as very imperfect, because in the material he worked with volborthite occurred as a crystalline coating on the grains and pebbles, and in the cavities of an argillaceous conglomerate. He found it impossible to pick out the volborthite, so crushed the whole mass to separate the grains of the conglomerate. The material was then treated with very dilute nitric acid. He does not specify the strength of acid used nor the duration or temperature of treatment. The insoluble matter, which amounted to more than 80 per cent of the sample treated, was filtered off, and the solution was analyzed. After such a treatment of an argillaceous

[1] Publication authorized by the Director, U. S. Geological Survey.