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Growth of Erbium Rhodium Boride Crystals from Molten Copper Flux

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The single crystals of ternary borides in the system of Er-Rh-B were successfully grown by the flux method using a molten copper as a solvent. $ErRh_3B_2$ belongs to a monoclinic system and shows strongly magnetic anisotropy. $ErRh_4B_4$ has primitive tetragonal type structure. Superconductivity and ferromagnetism coexist in this compound. $ErRh_3B$ has cubic perovskite structure and shows paramagnetic behaviour.

KEYWORDS: ternary boride, crystal growth, crystal structure, magnetism, superconductivity

The crystal chemistry of Er-Rh-B system has received considerable attention from researchers in the fields of magnetism and superconductivity. As shown in Fig.1,three ternary borides exist at Rh-rich composition in the phase diagram. The present paper reports the crystal growth and crystal structure, and magnetic and superconducting properties of the ternary compounds.

The single crystals of ternary borides were successfully grown by the flux method using a molten copper as a solvent [1~2]. The reagents used were 99.9% pure Er, 99.9% pure Rh and 99.8% pure B. They were weighed in stoichiometric proportion and mixed with 99.999% pure Cu in a weight ratio between 1: 8 and 1:10. The mixture was placed in a recrystallized alumina crucible. The crucible was inserted in a vertical electric furnace. A purified He gas flow was used as a protecting atmosphere against oxidation. Fig. 2 shows the schematic arrangement of the growth apparatus. The mixture of starting materials was heated at a rate of 400℃h^{-1}, held at 1350℃ for 10h, and then slowly cooled down at a rate of 1℃h^{-1}. After the temperature reached at 1080℃, the furnace was rapidly cooled down to room temperature. The crystals were separated by dissolving Cu in dilute nitric acid.

$ErRh_3B_2$: Hexagonal rods of silver metallic luster (Fig.3-a) were obtained. The crystal structure of the $ErRh_3B_2$ belongs to a monoclinic syastem isomorphous with $ErIr_3B_2$ type structure. Lattice parameters of the $ErRh_3B_2$ are a=5.3547(3),b=9.2824(5), c=3.1017(2) Å, β=90.893(5)°, V=154.15(2)Å^3. As shown in Fig.4, this compound shows strongly magnetic anisotropy, and takes a ferromagnetic ordering at 27K with its easy axis along the c-direction.

$ErRh_4B_4$: Needle like rectangulars of silver metallic luster (Fig. 3-b)were obtained. The crystal structure is primitive tetragonal with the $CeCo_4B_4$ type. The lattice parameters are a=5.292(4) Å and c=7.379(3) Å. This compound is interesting because of the coexistence of superconductivity and ferromagnetism in it. From the electrical resistivity measurement, the superconducting transition temperature is found to be 8.55K with the transition width $\Delta Tc1$=30mK. The reentrant transition temperature Tc2 is 0.84K for cooling run and 0.90K for heating run. The residual resistivity ratio RRR=R(300K)/R(~Tc1) is 7.8. Properties are summarized in Table 1.

$ErRh_3B$: Silver metallic luster cubes(Fig.3-c) were obtained. This compound has cubic perovskite structure. The lattice parameter is a=4.146(1) Å. This compound exibits normal paramagnetic behaviour.

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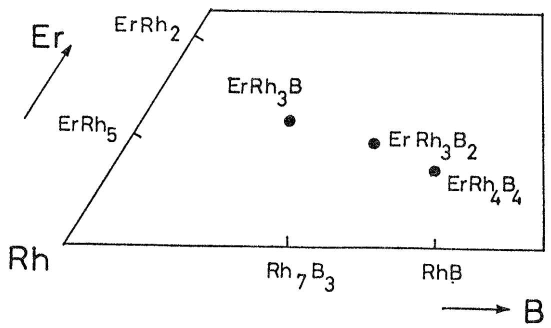

Fig.1. Phase diagram of the Er-Rh-B system(Rh corner).

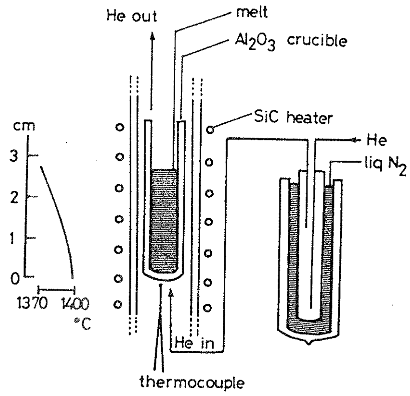

Fig.2. Schematic arrangement of the growth apparatus.

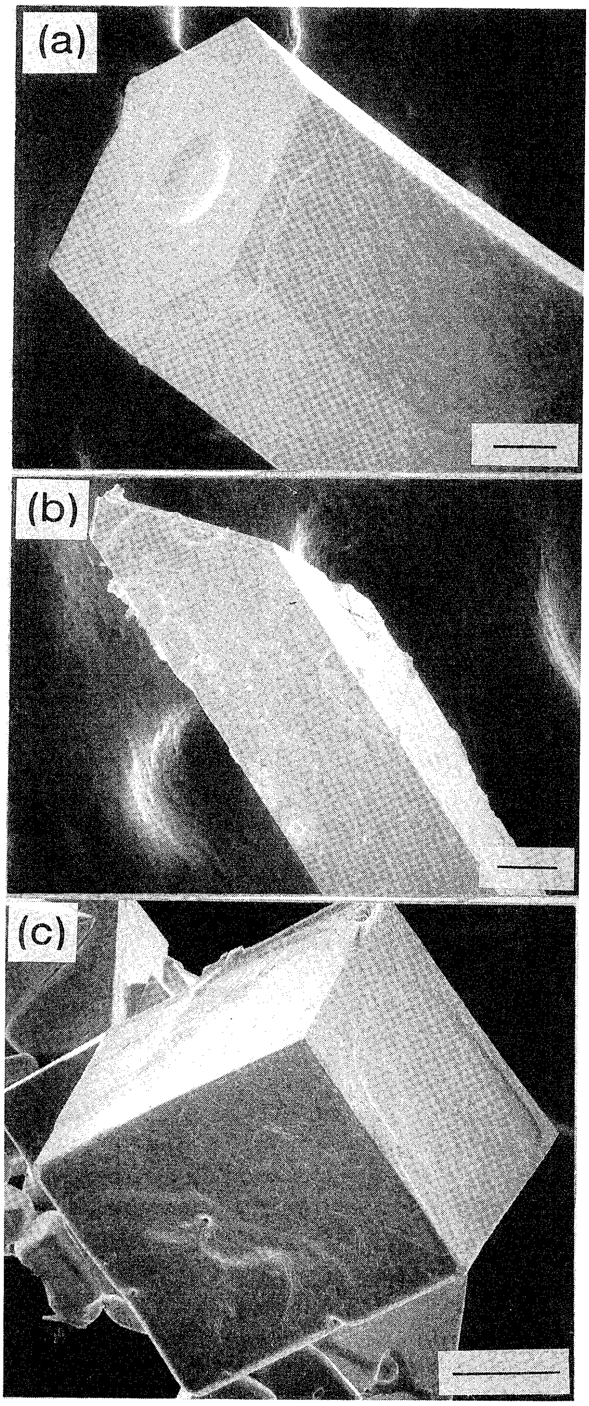

Fig.3. Single crystals extracted from the Cu flux: (a)$ErRh_3B_2$,(b)$ErRh_4B_4$,(c)$ErRh_3B$, bar represents 100 μm.

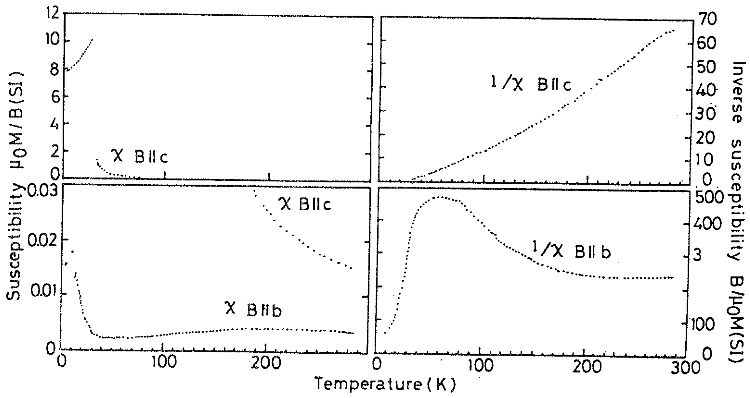

Fig.4. Magnetic properties of the $ErRh_3B_2$.

Table 1. Structural and superconducting properties of the $ErRh_4B_4$.

Crystallographic data:	
Crystal structure	Primitive tetragonal
Space group	$P4_2$ / nmc
Lattice parameter	a=5.292(4) Å
	c=7.379(3) Å
Density	d_m(293K) 10.21 gcm^3
	d_x 10.00 gcm^3
Superconductivity:	
T_{c1}	8.55K
ΔT_{c1}	30mK
T_{c2}(cooling run)	0.84K
T_{c2}(heating run)	0.90K
RRR	7.8 R(300K)/R(Tc1)