Fabrication of transition metal doped sapphire single crystal by high temperature and pressure acceleration method

Eui-Seok Choi, Choong-Ho Jung, Moo-Kyung Kim,
Yootaek Kim*, Jung-Yoo Hong*

National Institute of Ceramic Technology, 233-5, Gasan-dong, Kumcheon-gu, Seoul, Korea
*Division of Advanced Industrial Engineering, Kyonggi University, Suwon, Korea 442-760

Abstract

Metallic chromium was diffused in the {0001}, {11$\bar{2}$0} white sapphires which were grown by the Verneuil method to enhance the physical properties of the sapphires. Chromium metal vapour pressure and N_2 pressure were kept by 1×10^{-4} torr at 2150℃ and 6 atm in the quartz-tube, respectively. The color of the Cr-doped sapphires was changed to light red. Chromium was diffused faster in the {11$\bar{2}$0} than in the {0001} plane. It was speculated that the planar density was one of the factors determining diffusion coefficient.

Introduction

The Sapphire, a single crystal of α-Al_2O_3, is mined in natural or arificially grown by melt process. Pure Al_2O_3 powders is used for the growth of sapphire single crystal. Many researches already have been done with great efforts.

As development of the growing techniques, it is able to obtain the large and high quality crystal. The sapphire crystal is applied various industrial fields with its mechanical, optical and electrical properties.[1)]

The sapphire crystal doped on transition metal is very useful for optical material like laser generator, UV protector and mechanical shield etc. It is very difficult to grow color sapphire crystal because it needs incubating conditions to the temperature and pressure. In this study, we try to dope a transition metal in transparent sapphire by high temperature and accelerating pressure method.

The diffusion of atoms in crystal which contain defects occurs by the motions of the defects and diffusion takes place by vacancy, interstitialcy or semi-interstitialcy mechanisms. In addition, diffusion in principle can take place by direct exchange and ring mechanisms the existence of which has not been confirmed experimentally. As progressing the atom movements in the lattice, diffusion is more effective in order of surface〉 grain boundary〉 grain matrix.[2)]

To control experimental conditions as temperature, pressure and atmosphere, it is possible to substitute or saturate Cr^{3+} or Fe^{3+} to Al^{3+} of sapphire crystal and diffuse some depth of layer in crystal.

Experimental Procedures

White sapphire crystals grown by Verneuil method were used.[3-4)] The content of Cr_2O_3 was 5%, 10% to the Al_2O_3. Cr-Al_2O_3 powder which Cr_2O_3 is doped solid solution in Al_2O_3 were synthesized to improve reaction diffusion effect. Cr-Al_2O_3 powder was synthesized by precipitation from Al^{3+} and Cr^{3+} aqueous solution. The high frequency induction furnace was used for heating Ir metal crucible in center of quartz tube. Ir crucible was heated in the zirconia refractory crucible that was covered with Al_2O_3 after heater system. The α-Al_2O_3 powders were filled in the bottom of the crucible and Cr-Al_2O_3 powders were filled above the α-Al_2O_3 powders. The sapphire crystal pellet was set on the last layer with in Cr-metal and Cr-Al_2O_3 compound powder. For minimizing the atmospheric change, the pellet and metal compound powders were covered with an Al_2O_3 crucible.

Sample were heated at 2000~2200℃ in 6 atm N_2 gas atmosphere. During heat treatment the atmospheric condition was varied. Also we compared the depth of diffusion to a, c plane and the characteristics were analyzed by XRD, SEM, and optical microscope.

Result and Conclusions

1. The optimum conditions of diffusing transition metal in sapphire crystal were as follows: composition of synthetic powder was Cr_2O_3 10% content to Al_2O_3 90%, temperature was 2055~2060℃ between liquidus and solidus line in complete solid solubility, vacuum of 2×10^{-5} torr and pressure of 6 atm N_2 atmosphere.

2. In case of using Al_2O_3-Cr metal compound powders, metallic vapour occurred in the crucible and diffusion effect of Cr^{3+} solid solution in sapphire come out red color at limit decrement and accelerating pressure conditions.

3. The surface density of sapphire was 0.2254 and 0.1199 atom/$Å^2$ of c and a plane to growing direction, respectivley. The depth of diffusion in c-plane seems to be deeper than that in a-plane.

References

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