Development of growth technology for large size bulk and shaped growth on scintillator, piezoelectric and halogen single crystals

Within my stay at ICC-IMR as invited professor during 1 month few new crystals for scintillator and piezoelectric applications were grown at a first time by the Czochralski technique. The application of such crystals can help with the development of new generation of high sensitive X-ray identification devices and for new generation of combustion sensor for car engines with the aim of efficiency increase of combustion rate (and the reduction of emission amount).

The main reason of my invitation was the further development of bulk crystal growth technique. At last 10-15 years a lot of interesting discoveries in the field of crystals were made in the area related to miniaturization of films and fibers up to nano size. As a result a lot of crystal growth researchers changed their activity direction in accordance with this modern tendency. Unfortunately a lot of expertise related to bulk crystal growth was simply lost in the world at that time. However, the need of industry in the big variety of high quality and big size bulk crystals has been increasing. And I was very glad to accept the invitation of ICC-IMR for work during 1 month as invited professor in the area related exactly to development of crystal growth technology of big bulk crystals.

My main attention during stay at IMR was focused on 2 big groups of bulk crystals – for scintillatior applications and for piezoelectric applications. Both of these groups of crystal are very important for Japan now. I worked for the development of bulk crystal growth technology by the Czochralski technique during many years [1-2] and I expected that my experience would be useful for joint research work at ICC-IMR.

The Scintillator crystals for the application in new generation of dosimeters became extremely important after 2011 great earthquake in Japan and followed incident at Fukushima nuclear power plant. In the IMR laboratory of professor Yoshikawa the very promising material for such application – Ce-doped Gd-Al-Ga garnet single crystal was developed before [3]. During my stay in IMR I was happy to join the experiments for the improvement of crystal growth technology with the final aim of growth of such crystals with the size up to 2-3 inch in diameter and stable set of parameters acceptable for the application in the new generation of X-ray high sensitive devices.

The second big group of bulk crystals (piezoelectric) also became a very hot topic now. At present all highly developed countries in the world are involved into vast actions for the decrease of air pollutions caused by cars emission. Recently it was found that the direct sensing of the torque oscillation in the engine section by use of the combustion sensor in comparison with traditional oxygen sensors can improve efficiency of combustion rate (and the reduction of emission amount) up to 10 %. However the wide application of such systems is limited by the lack of crystals which can work in combustion sensors at very high temperature. Recently, 2 new piezoelectric crystals were suggested for this application –$Ca_3TaGa_3Si_2O_{14}$ and $Ca_3NbGa_3Si_2O_{14}$. These 2 crystals can work as sensors up to 1400 C. During my stay at IMR jointly with the researchers and students of Yoshikawa laboratory we paid a big attention to the development of stable growth technology of these two crystals. One of the results of our joint experiments ($Ca_3NbGa_3Si_2O_{14}$ crystal) is shown on Fig. 1 In opposite with known reports [4-5] this crystal was grown in Air atmosphere using Pt crucible (usually researchers tried to use of Ar atmosphere and Ir crucibles) .Such conditions can simplify such crystals production in future. Also, I investigated the possibility to substitute some amount of Ga ions in $Ca_3TaGa_3Si_2O_{14}$ crystal by Al ions for further improvement of piezoelectric properties and decreasing of

Fig. 1 As-grown $Ca_3NbGa_3Si_2O_{14}$ crystal

production cost. The most successful result of these experiments is shown on Fig. 2 It is expected that the piezoelectric properties of this crystal ($Ca_3Ta(Al_{0.2}Ga_{0.8})_3Si_2O_{14}$) will be higher than for usual one. It was confirmed that it is possible to produce this crystal by the conventional Czochralski technique with the size and quality acceptable for the future commercial application.

Of cause, during so short time (1 month) a lot of our joint ideas were not realized. However,

Fig.2 as-grown $Ca_3Ta(Al_{0.2}Ga_{0.8})_3Si_2O_{14}$ crystal

I am sure that we will continue the fruitful scientific cooperation with my colleagues at IMR for the successful development of important and interesting research which we have started.

References

[1] T. Fukuda, K. Shimamura, V.Kochurikhin, V. I. Chani, B. M. Epelbaum,
S. L. Baldochi, H. Takeda, A. Yoshikawa, J. Mat. Sci.: Materials in Electronics 10 (1999) 571-580

[2] A. Yoshikawa, M. Nikl, H. Ogino, J.B. Shim, V.V. Kochurikhin, N. Solovieva, T. Fukuda
Nuclear Instruments and Methods in Physics Research A 537 (2005) 76–80

[3] Kei Kamada, Takayuki Yanagida, TakanoriEndo, KousukeTsutumi, YoshiyukiUsuki, Martin Nikl, YutakaFujimoto, AkihiroFukabori, AkiraYoshikawa
Journal of Crystal Growth 352 (2012) 88–90

[4] Zengmei Wang et al., Journal of Crystal Growth 253 (2003) 378–382

[5] Hiromitsu Kimura, Satoshi Uda, Oleg Buzanov, Xinming Huang, Shinji Koh
J Electroceram 20 (2008) 73–80

Keywords: Crystal growth, piezoelectric, Scintillator

Full name: Vladimir Kochurikhin, General Physics Institute, Moscow, Russia
E-mail: kochurikhin@mail.ru
http://www.gpi.ru