Electrical resistivity, dielectric and piezoelectric properties of $Ca_3TaGa_{3-x}Al_xSi_2O_{14}$ (CTGAS) single crystals as a function of Al content

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Piezoelectric langasite single crystals are attracting much attention for high temperature (HT) sensor applications. These compounds do not present any phase transition up to their melting points (1300-1500ºC), exhibit good piezoelectric properties, are non-pyroelectric, and can be grown by the Czochralski (Cz) technique [1]. Among the langasite family, $Ca_3TaGa_3Si_2O_{14}$ (CTGS) and $Ca_3TaAl_3Si_2O_{14}$ (CTAS) single crystals are particularly promising for HT sensor applications due to their relatively high resistivity. So far, the growth of mixed crystals $Ca_3TaGa_{3-x}Al_xSi_2O_{14}$ (CTGAS) has been reported to be difficult, and thus the influence of Al content on the electrical and piezoelectric properties hasn't been investigated systematically yet. In this work, transparent CTGAS single crystals (x=0~3) are successfully grown under same nominal conditions, namely with Pt crucibles under N_2+1%O_2 in order to suppress Ga evaporation. As an example, Figure 1 shows the CTGAS single crystal with x=2.25. It is colorless and crack-free. The piezoelectric constant d_{11} and resistivity (at 400ºC) as a function of the Al content are shown in Fig. 2. CTGS exhibits the lowest values for the d_{11} and the resistivity, with 4.0 pC/N and 3.0×10^{10} Ω cm, respectively. By the gradual substitution of Ga by Al, both parameters tend to enhance continuously, reaching the highest values for the fully substituted CTAS, with 4.5 pC/N and 6.5×10^{10} Ω cm, respectively. Therefore, we can conclude that CTAS presents better characteristics than CTGS for HT piezoelectric applications. This work has been partially supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) Elements Strategy Initiative to Form Core Center of Japan.

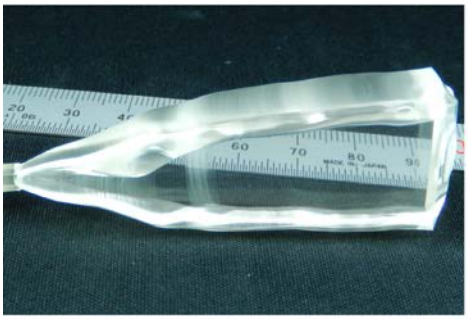

Fig. 1. Photograph of a CTGAS single crystal with x=2.25.

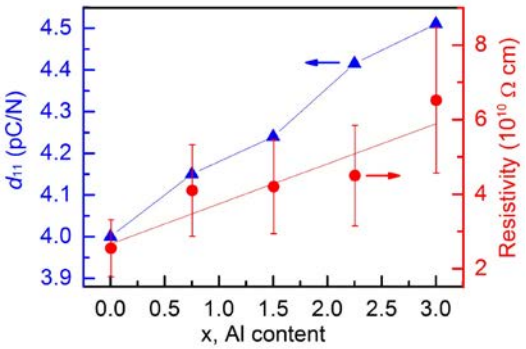

Fig. 2. Piezoelectric constant d_{11} and resistivity (at 400ºC) as a function of the Al content.

References

[1] X. W. Fu, E. G. Víllora, K. Shimamura, et al, J. Alloys Compd. 647 (2015) 1086-1090.