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Crystals and Substrates for Semiconducting Oxide Applications

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In this presentation, we provide an overview of the preparation of transparent semiconducting oxide (TSO) bulk single crystals [1] for use as substrates in novel oxide electronic applications. The main focus is on beta gallium oxide (β-Ga_2O_3) which is a very promising material for power electronics and currently receives a steep increase in worldwide interest. We have developed a Czochralski growth technique to produce β-Ga_2O_3 boules with 2-inch in diameter and up to 80 mm in length. To obtain such boules, the formation of volatile gallium suboxides and of metallic gallium in the melt must be carefully controlled [2]. Growth of n-type doped β-Ga_2O_3 features additional stability challenges that are also of high interest for growing other oxide compounds. Our current research focuses on incorporation of other dopants (Mg, Al, Ce, Cr) [3] and the preparation of gallates with spinel structure ($MgGa_2O_4$ [4], $CoGa_2O_4$, $ZnGa_2O_4$, $InGaZnO_4$) for improved properties as well as for novel applications, e.g. as neutron detector, scintillator, electroluminescent materials or as substrate for ferromagnetic thin films.
The second part of the presentation will provide the status and perspectives of other TSO bulk crystals such as indium oxide (In_2O_3), tin dioxide (SnO_2) [1] and barium stannate ($BaSnO_3$) [5]. The latter is an oxide featuring a very high electron mobility with 2DEG formation at interfaces when doped with lanthanum. $BaSnO_3$ bulk crystals could be used as substrates for homoepitaxy to provide benchmark properties.
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Gallium oxide bulk crystals with different dopants.

Single crystal material	Growth method	E_g [eV]
$MgGa_2O_4$	Melt - Czochralski	4.90
β-Ga_2O_3	Melt - Czochralski	4.85
$ZnGa_2O_4$	Melt - Solidification	4.60
SnO_2	Gas - PVT	3.75
$InGaZnO_4$	Melt - Solidification	3.46
ZnO	Melt - Bridgman	3.37
$BaSnO_3$	Melt - Solidification	3.00
In_2O_3	Melt - LASSCGM	2.76

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