Growth and characterization of Weyl semimetal single crystals and single crystals of oxides for optoelectronic applications

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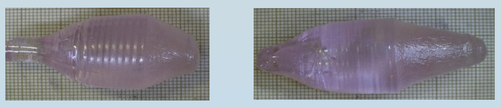
Single crystals and $(Gd_{1-x}Lu_x)_2SiO_5$ grown by the Czochralski method

Single crystals of $(Gd_{1-x}Lu_x)_2SiO_5$ with x = 0.3 doped at Gd site with: 0.5% at Er, and 2, 5, 7 % at Yb, were grown by the Czochralski method in order to test optical pumping with a blue laser diode.



$(Gd_{0.7}Lu_{0.3})_2SiO_5$: doped with 0.5% at Er (left) and 0.5% at Er + 2% at Yb (right)

$(Gd_{0.7}Lu_{0.3})_2SiO_5$: doped with 0.5% at Er + 5% at Yb (left) and 0.5% at Er + 7% at Yb (right)

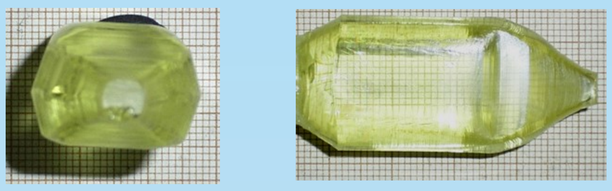
$LiNbO_3$ grown by modified Czochralski method

First crystallization with congruent composition was carried out on Pt nucleus. Obtained crystal was oriented and cut into seeds. Subsequent crystallization was carried out on the nucleus of $LiNbO_3$. Correction of entering composition by introducing the excess of Li_2O was done. Subsequent crystallization were performed by modified Czochralski method with a composition close to the stoichiometric one with reducing the crystal growth rate.

Pure $LiNbO_3$ single crystal (left) and dopped with 0.5% at Pr

As the dopant introduced into the matrix is optically active in the visible range, the obtained crystals are promising sources of laser radiation.

Single crystals of $SrLaAlO_4$ for substrates

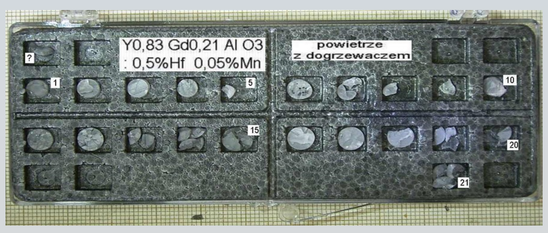


Single crystals of $SrLaAlO_4$ used as substrates for epitaxial growth of HTSC thin films

$Y_{1-x}Gd_xAlO_3$: Mn, Hf single crystals grown by the Czochralski and floating zone methods

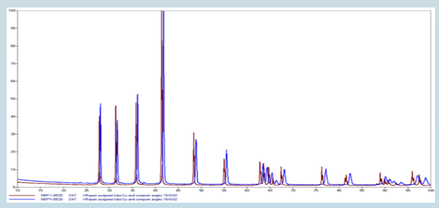
Gd^{3+} ions were introduced into the crystal matrix partially substituting Y^{3+} ions and Mn^{2+} oxidation state was stabilized by co-doping with Hf^{4+} ions. Single crystals of $Y_{1-x}Gd_xAlO_3$ (0.05% at Mn i 0.5% at Hf for x = 0.15) solid solution were grown using Czochralski method from the iridium crucible in nitrium atmosphere and by the floating zone method in air.

Obtained crystals were investigated as a candidate for thermoluminescent (TL) or optically stimulated luminescent (OSL) dosimetry of ionizing radiation (Prof. A. Suchocki, dr hab. Ya. Zhydachevskii).



Doping NbP Weyl semimetal with magnetic ions

In order to investigate expected strong interplay between magnetism and electronic properties around the Weyl points, single crystals of NbP doped with V were grown.



First single crystals of NbP:V with V concentration up to 20% at (EDX confirmed) were obtained. XRD confirmed good quality of the crystals. Preliminary SQUID measurements did not show long range ferromagnetic order. Further magnetic studies are underway (antiferromagnetic order?), ARPRES investigations will be performed in April 2021.

BAs - compoud with high thermal conductivity

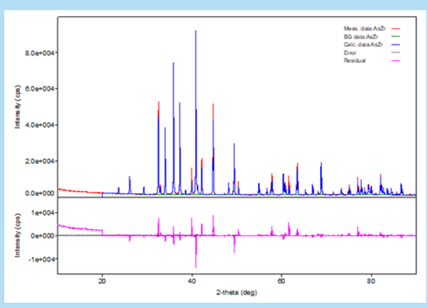
Cubic boron arsenide (BAs) is predicted to have ultrahigh thermal conductivity comparable to that of diamond. The main challenge: synthesizing high-quality crystals, as defects and impurities degrade the thermal properties. BAs is an appealing candidate for thermal management for high–power density devices: chemically inert, with a coefficient of thermal expansion similar to that of Si, compatible with GaN and GaAs.

First single crystals were successfully grown by Chemical Vapour Transport method, the synthesis and crystal growth were performed in a quartz vessel in a iodine vapor and arsenic vapor.

$ZrAs$ and $ZrAs_2$

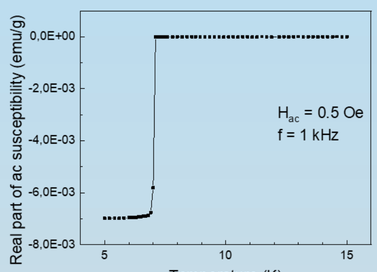
ZrX and ZrX_2 (X = P, As) compounds were recently identified as topological materials. DFT band structure calculations (C. Felser *et al.*) show a Dirac like band crossing close to the Fermi level as well as a nodal line in the k_x=0 plane.

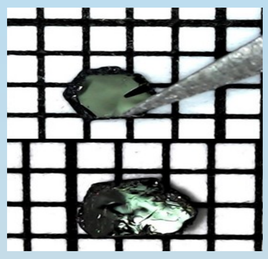
First growth processes of ZrAs and $ZrAs_2$ single crystals were performed, $ZrAr_2$ single crystals up to 1 mm long were obtained.



$NbSe_2$

Single crystals of $NbSe_2$ with a diameter of up to 3 mm (susceptible to exfoliation) were obtained. They may be used for homoepitaxial growth in MBE as well as for fabrication of topological superconductor heterostructures e.g. $Bi_2Te_3/NbSe_2$. High quality of the crystals was confirmed by XRD and sharp transition to superconductivity at 7 K.

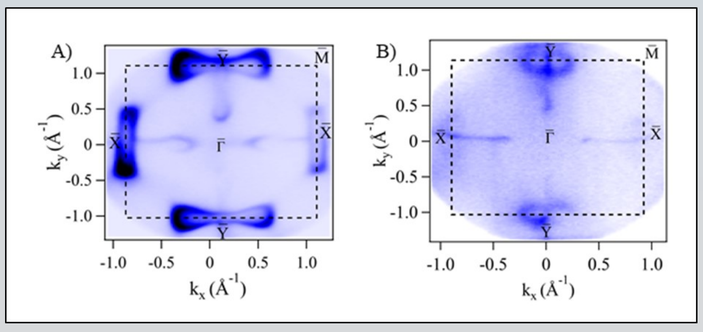




ARPES measurements

When Weyl (WSM) is coupled with a superconductor, superconductivity penetrates the sub-interface layer of WSM (Grabecki et al. PRB 101, 085113 (2020). It may lead to exotic phenomenon such as emergence of 'Majorana modes'. Therefore, we use ARPES (at Solaris) to study the Nb/NbP interface formation.

Nb was deposited in-situ on freshly cleaved (001) surface, experimental proof of quantitatively evolving Fermi surface and electronic states at Nb/NbP interface was found. Shrinking of spoon and bowtie shaped Fermi arcs was observed. Despite of evolution of Fermi surfaces, WPs are robust. This indicates that WSM properties of NbP survive the interface formation and superconductivity penetration into NbP can be expected.



A) Fermi surface of pristine P-terminated NbP with spoon and bowtie shaped Fermi arcs
B) Modified Fermi surface of P terminated NbP by depositing Nb layer

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