Crystal Growth

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In most present hot topics in physics the availability of high quality samples is crucial. The possibility within the SPSMS to have control over the whole process is an essential part of our competitiveness, and has contributed to the success of many of the studies in this report. The techniques of crystal growth, from metallic fluxes, Czochralski pulling, and floating zone techniques are well established with a high level of expertise. The possibility to grow uranium compounds is a specificity and top priority of the group, strengthened in 2008 by the installation of a dedicated tetra-arc furnace.

Many intermetallic strongly correlated systems can be grown from metallic fluxes. This technique uses the solubility of metallic systems in other low melting point metals (In, Sn, Bi, Sb, Ga) or salts (NaCl, KCl, $FeCl_2$) used as solvents. It presents many advantages, allowing growth at lower temperature, the possibility to obtain non congruent compounds, the absence of gradient at the growth interface, and the development of natural crystallographic faces. It usually produces strain free crystals, and uses lower quantities of rare or expensive starting materials. Particularly successful results include the growth of $PrOs_4Sb_{12}$ single crystals showing a single sharp transition, high quality single crystals of $YbCu_2Si_2$ having a residual resistivity ratio RRR>100 (whereas the best previous crystals had RRR = 20), and growth of large quantities of $CeCoIn_5$ crystals which could be assembled into oriented arrays for neutron scattering experiments.

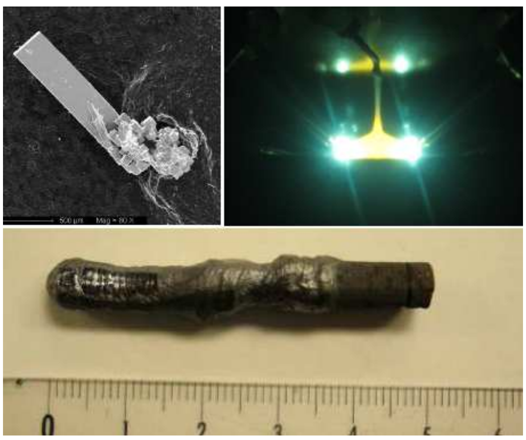

Fig. 1:$PrOs_4Sb_{12}$ single crystal grown out of Sb flux (top left), single crystal growth of UCoGe in the tetra arc furnace (top right)) and $Sr_{12}Ca_2Cu_{24}O_{41}$ crystal grown by the TSFZ technique (bottom).

The SPSMS is one of the few laboratories worldwide where uranium compounds can be grown in full safety conditions, and this activity is one of our main priorities as some of the most spectacular recent discoveries have been made on uranium systems. These include our discovery of the coexistence of ferromagnetism and superconductivity, and more recently reentrant superconductivity under high magnetic field in URhGe. High quality single crystals are essential for heavy fermion superconductors, since even non-magnetic impurities can destroy the superconducting pairing. Superconductivity in weak ferromagnets, is particularly sensitive. Single crystals of uranium systems are obtained by Czochralski pulling, either with an RF furnace, or since 2008, a new dedicated tetra-arc furnace. We plan in the future also to be able to grow uranium systems from flux. A major success was the growth of the first superconducting single crystals of URhGe. The first uranium growth in the tetra-arc furnace was a large single crystal of URu_2Si_2 which also proved to be of remarkably high quality.

The main activity of crystal growth is in the field of correlated electrons, but the group also provides samples for other themes. The Traveling Solvent Float Zone (TSFZ) with the image furnace is particularly adapted for oxides of low dimensional magnetism or frustrated systems. This technique has been used to grow large single crystals of $Sr_{12}Ca_2Cu_{24}O_{41}$ (allowing inelastic neutron scattering experiments). These single crystals were characterized by susceptibility and specific heat measurements under pressure exhibiting an optimum superconducting temperature of 9.9K at 5.4 GPa.

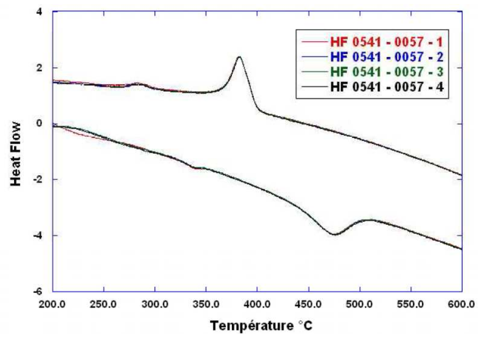

Fig. 2: DTA analysis of the phase transitions in FeSe.

An efficient crystal growth facility needs fast and effective sample characterization. We have extended our existing battery of characterizations (Xray, SEM, magnetization) by the installation in 2005 of automatic transport and specific heat measurements (Quantum Design PPMS), and DTG/DTA analysis to explore metallurgical phase diagrams.

The facilities and expertise available in the group allow us to tackle quickly and efficiently new subjects that emerge as illustrated by the rapid production of single crystals of FeSe, or the growth of Graphene layers from SiC sublimation (DRT/LETI collaboration). However, believing that many exciting discoveries in physics are in fact total surprises, we also devote some research time to exploratory studies, searching for new compounds with the chance of finding hitherto undiscovered phenomena.

Selected publication(s):	
Grant(s) : ANR CEXC-07 “CORMAT”, BLAN-08 “DELICE”	Collaboration(s) :
Patent(s) :	Contact : gerard.lapertot@cea.fr