TECHNICAL NOTE

Researchers at the Tata Institute of Fundamental Research in Mumbai crank up the pressure with the easyLab® Mcell Ultra.

Since its launch in the Spring of 2009, the easyLab® Mcell Ultra has proven a very popular product amongst the research community working on superconducting systems and strongly correlated electrons systems. Professor Sampathkumaran and his group from the Department of Condensed Matter Physics & Material Science (DCMPMS) TIFR/Mumbai have already carried numerous experiments under pressure using easyLab Technologies' pressure cells for the PPMS and the MPMS but they had the need to be able to go one order of magnitude higher in pressure. In comes easyLab ® with another first, the easyLab® Mcell Ultra, thus extending the maximum pressure from 1 GPa to above 10 GPa.

The use of piston cylinder, so called clamp cell, in conjunction with commercial SQUID magnetometers has been widely reported by research groups throughout the world and the predecessor of the easyLab® Mcell Ultra, the easyLab® Mcell 10 (10 kbar) has been used successfully in many laboratories. The Mcell Ultra is expanding the pressure boundaries in commercial SQUID magnetometers by enabling researchers to achieve pressures well above 10 GPa. Its design is based on the principle of diamond anvil cells (DACs) generating pressure by applying force on two opposite diamond anvils. In the case of the easyLab® Mcell Ultra, the force is applied using our new mechanical Mpress Mk2 which enables a very fine control of the applied force on the cell without the need for hydraulic systems.

A schematic view of the Mcell Ultra and its main components is shown in Figure 1. This DAC is made of non-magnetic BeCu down to its smallest parts - which include all the adjustment screws - in order to reduce the overall magnetic contribution of the cell. This, in turn, enables the measurements of magnetic moments down to below 10-5 emu.

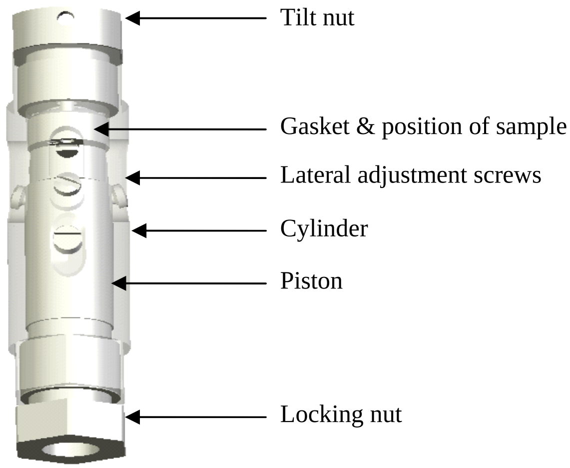

Figure 1: Mcell Ultra and its components

The Mcell Ultra has been designed to offer the end-user all the features usually only available in more advanced and larger cells. Notably (and despite the very small size of this cell), the end-user still can benefit from lateral and tilt adjustment screws enabling a perfect alignment of the two diamond anvils (a must when one wants to avoid damaging diamonds!).

The Mcell Ultra is at its best when fitted with diamond anvils culets in the range between 0.5 mm up to 1 mm (the smaller the culet's size, the higher the pressure but also the smaller the sample space). The table below provides an indication of the approximate maximum pressure as function of anvil.

Culet [mm]	0.5	0.6	0.8	1.0
Max P [GPa]	15	12	9	4

Table 1: Anvil - Pressure vs culet diameters

In this cell, the sample is confined in a hole drilled in a BeCu gasket and surrounded by the pressure transmitting medium. Typically this hole needs to be no more than half the size of the diamond culet with the gasket itself being around 0.1 mm thick. The Boehler microDriller is the ideal tool to drill such holes.

Typical forces required to increase the pressure in the Mcell Ultra range from 2,000 and 3,000N to achieve maximum pressures and are dependant on the anvil culet diameters. It is essential to be able to control the applied force to around 20N accuracy to vary the pressure gradually and in a controlled fashion on the Mcell Ultra. This is achieved by using the novel easyLab Mpress Mk2 which is equipped with a force gauge enabling the monitoring of the applied force as the end user increases the pressure in the Mcell Ultra (see Figure 2).

Figure 2: Mr Karthik Iyer with Dr Kulkarni (easyLab) applying pressure with the Mpress Mk2

Professor Sampathkumaran's group who also acquired an Optiprexx PLS in order to be able measure the in-situ pressure in the Mcell 10. As such they were able to calibrate their new Mcell Ultra as part of the training provided by Dr S. Kulkarni from easyLab. Results are shown in Figure 3.

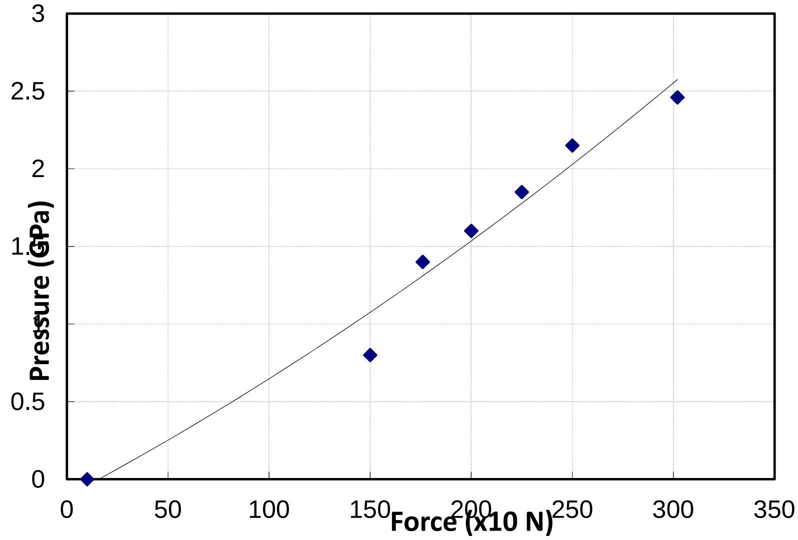

Figure 3: Room temperature pressure – culet size of 1mm.

Once the required pressure has been achieved, the Mcell Ultra can be mounted on a SQUID magnetometer using the purposely designed holder and extension rods and included as part of the Mcell Ultra module. The probe is then loaded in the magnetometer as with any usual sample. Figure 4 shows Mr Iyer loading the Mcell Ultra into a MPMS® XL-7 in TIFR.

Figure 4: Mr Iyer loading the Mcell Ultra in a MPMS-XL7.

The low temperature pressure was measured by recording the superconducting transition (100 Oe) of a lead sample mounted in the Mcell Ultra. The pressure dependence of Tc is well established as function of pressure of around dTc/dP = -360mK/GPa. Results are shown in Figure 5.

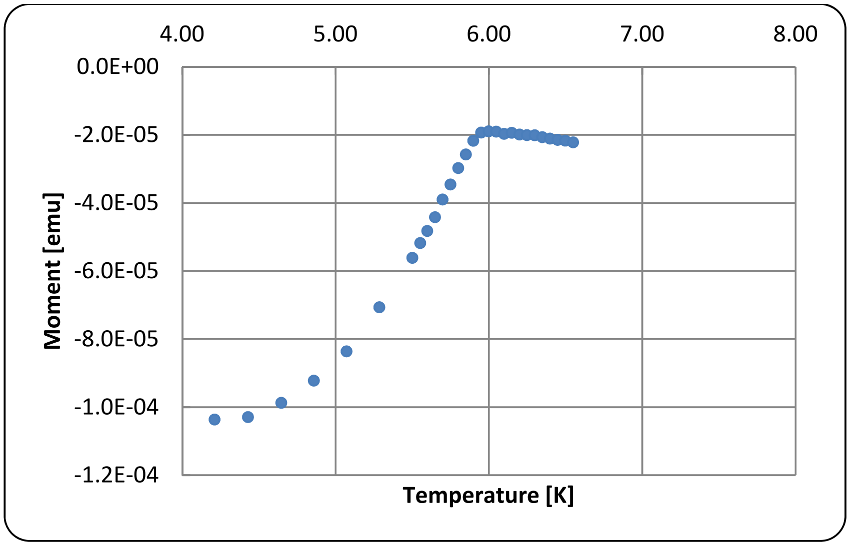

Figure 5: Lead superconducting transition at 2.3 GPa.