A.8: Effect of Pressure on the Functional Properties of Ni-Mn based Heusler Alloys

The Heusler alloys, named after the German engineer Friedrich Heusler, are known for various interesting physical properties of technological importance. The Magnetic and Superconducting Materials Section (MSMS) of RRCAT has been studying various Ni-Mn based Heusler alloys having functional properties like large magnetoresistance (MR, the change of resistance due to applied magnetic field), large magnetocaloric effect (MCE, the change of temperature or entropy because of the application of magnetic field), and large magnetostriction (the change of length because of applied magnetic field). These functional properties are associated with a first order martensitic transition observed in these alloys. The effect of external pressure on the MR and MCE of these alloys were studied in the MSMS, using experimental set-ups commissioned recently, which led to the observation of interesting novel features.

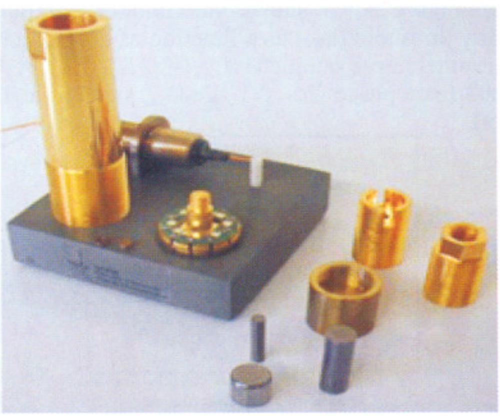

Fig. A.8.1: Different components of the pressure cell arrangement used for the measurement of electrical resistivity at low temperatures and in high magnetic fields. The rectangular block is used for building-up the pressure cell arrangement.

The electrical resistivity and magnetization of the samples were measured in different experimental set-ups, in two different pressure cells, as functions of three different control variables: temperature (2-300 K), magnetic field (up to 80 kOe), and pressure (hydrostatic, up to 10 kbar). The components of the pressure cells (Fig. A.8.1) are non-magnetic, and have high thermal conductivity. The samples were sealed in PTFE capsules filled with liquid pentane. The hydrostatic pressure was applied with the help of a hydraulic press, by moving hard pistons squeezing the PTFE capsules in the pressure cells. The pressure was measured using Manganin manometers. For the measurement of electrical resistivity under pressure, the electrical leads from the sample and temperature sensors were taken out of the pressure cell using specially designed electrical feed-through. The MR was calculated from the electrical resistivity measured in different magnetic fields, and the MCE was estimated from the magnetization results using standard techniques reported in literature.

The combined effects of hydrostatic pressure, magnetic field and temperature on the MR and MCE across the martensitic transition observed in the $Ni_{50}Mn_{34}In_{16}$ and $Ni_{49}CuMn_{34}In_{16}$ alloys were investigated in detail. Magnetic field and pressure were found to have opposite effects on the martensitic transitions in these alloys, though the effects are not exactly similar on both the alloys at all temperatures and magnetic fields. The temperatures at which the above functional properties are observed were pushed closer to room temperature because of the application of pressure. Fig. A.8.2 shows that the temperature at which the peak of MR is observed (TMR-PEAK) in the $Ni_{49}CuMn_{34}In_{16}$ alloy reaches ambient temperature with the application of external pressure without diminishing the magnitude of MR to a large extent.

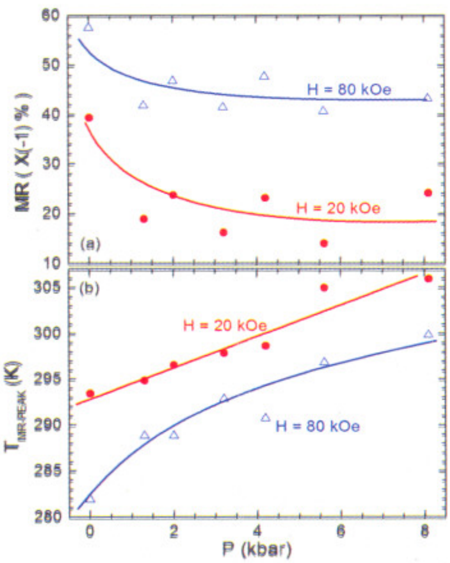

Fig. A.8.2: The effect of external pressure on the magnitude of magnetoresistance and the temperature at which its peak value is observed in the $Ni_{49}CuMn_{34}In_{16}$ alloy.

The pressure studies also indicate a volume change of about ~0.4% across the martensitic transition in these alloys, which shows their potential in near room-temperature actuator applications. Additionally, the present results will be useful for finding a guideline for generating chemical pressure (obtained through the partial substitution of atoms in the system) leading to newer Ni-Mn-In alloys with functional properties at room temperature.

The full details of this work are available in Phys. Rev. B **84** (2011) 064417 and J. Phys.: Condens. Matter **23** (2011) 366001.

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