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REMANENCE EFFECT FOR LOW-FIELD MEASUREMENTS

In Sec.3.3.3 we showed how our magnetoresistance measurements were affected by a systematic offset, with opposite sign when going from positive to negative field or the other way around. As a result, when sweeping the magnetic field from positive fields, the resistance curves present a dip before the zero is crossed. The same happens for the other sweep direction. This would correspond to an "inverted" hysteresis magnetic loop, namely a loop measured in the clockwise direction, where the energy is absorbed rather than dissipated. Such a phenomenon, reported for some particular cluster systems with interface exchange [1, 2], is certainly not possible for our simple layers. The reason for our "inverted" magnetoresistance curves is , instead, the mismatch between the set value of the magnetic field and the actual one, due to the presence of a remanent field. This problem is extensively reported in the Application Note 1070-207 of Quantum Design® for PPMS Superconducting Magnets [3]. In a PPMS system the magnetic field H is set by applying an electric current I through a superconducting coil. The read-out value is not measured directly but extrapolated by multiplying the set I by the H/I conversion factor, specific for the particular coil. Therefore possible stray effects, such as a remanence field, are not taken into account and the actual field experienced by the measured sample can differ from the value reported by PPMS. The effect is illustrated in Fig.A.1.

Initially the magnet is in the virgin state (Fig.A.1(a)). When the power supply is connected to the magnet, a current starts to circulate around the superconducting coil, generating a magnetic field along the central axis, in the hollow space (Fig.A.1(b)). If the applied field is sufficiently high (a few Tesla's), magnetic flux lines can penetrate the superconducting windings, where they get pinned to the defects of the material. Once the current is reduced back to zero, these flux lines, with the same direction as the original applied field, are responsible for generating a stray field, which in the core

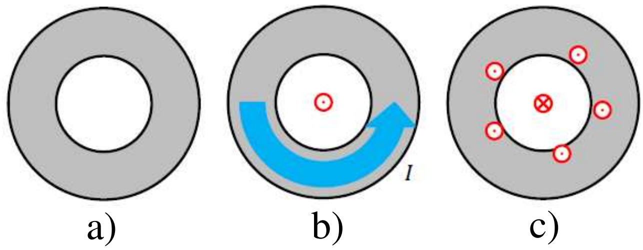
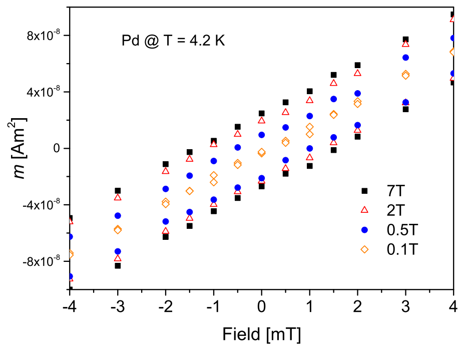


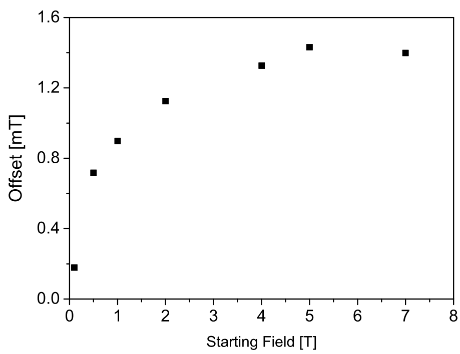
Figure A.1: Illustration of the mechanism giving rise to a remanent field. The magnet is initially in the virgin state (a); when the magnet is connected to the power supply (b) a current flows around the coil generating a magnetic field at the center; if the current is set back to 0 (c), the magnetic fluxes pinned inside the magnet produce a stray field with opposite direction to the original one.

of the magnet have the opposite sign (Fig.A.1(c)). As a result, when the applied current (and therefore the reported magnetic field) is zero, the real field experienced by the sample is negative. The same thing happens when approaching the zero, sweeping from a high negative field: trapped flux lines will generate a positive field not included in the reported field value. The systematic offset from the real value is therefore positive for backward sweeps (from positive to negative fields) and negative for forward sweeps. Since higher applied fields yeld larger amounts of magnetic flux penetrating the coil, the offset value is proportional to the starting field. However this value (for a 9 T cryostat, like ours) never exceeds a value of 20 Oe.

To verify this effect we performed a test on our SQUID system (also from Quantum Design®), where a similar superconducting magnet (max field 7 T) is mounted. We measured $M(H)$ curves for a reference Palladium (Pd) sample. Since Pd is paramagnetic, it should show a linear behavior, with intercept equal to zero. As can be seen from Fig.A.2(a), the curves present an horizontal offset which is positive for backward sweeps (lower curves) and negative for forward sweeps (higher curves). The higher the starting field is, the larger the offset value, as summarized in Fig.A.2(b). These results cannot be directly used to correct our magnetoresistance curves, because of the different magnet, but are useful to confirm our hypothesis and have an idea of the order of magnitude of the effect.



a)



b)

Figure A.2: a) $M(H)$ curves for a Palladium sample, with different starting field. For every field value, the backward and forward sweep are presented. b) Offset value as function of the starting field (values extrapolated from a)).