DE HAAS-VAN ALPHEN EFFECT IN ALUMINIUM AND CARBON DOPED MAGNESIUM DIBORIDE

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Introduction

Magnesium diboride is a phonon mediated superconductors with several highly unusual properties, such as an extremely high transition temperature ($T_c \approx 39K$) and the existence of two superconducting gaps. First principles electronic structure calculations have been remarkably successful in explaining (and predicting) its properties. Previously, some of the present authors used the DC field facility at Tallahassee to investigate the electronic structure of MgB_2, using measurements of the de Haas-van Alphen (dHvA) effect [1]. We were able to verify the predicted topology of the Fermi surface and measure the quasi-particle effective masses, which in turn reveal the *k*-space dependence of the electron-phonon coupling constants (λ).

The aim of the present project was to use the dHvA effect to investigate the electronic structure of Al and C doped samples of MgB_2. Both these dopants reduce T_c but have very different effects on H_{c2} and its anisotropy (γ_H) [2]. Samples of nominal composition 1-4% Al and 3% C (having T_c reduced to 34K) were measured using a piezoresistive cantilever technique in the 33 Tesla Magnet [1]. The samples were grown in Zurich using a high pressure synthesis technique [2].

Results and Discussion

Quantum oscillations originating from the tubular σ sheets of Fermi surface were observed in two different Al doped samples. From the angular dependence of the measured dHvA frequencies we are able to calculate the extremal cross-sectional areas of these sheets (see figure). From this we are able to deduce that the σ bands have shrunk in volume by 11% and the effective mass is lighter by 9% (λ is reduced by ~20%), compared to pure MgB_2. The reduced T_c is likely driven by this lower hole carrier concentration. Signals from the π band sheets were not observed showing that the Al doping disproportionately reduces the quasi-particle mean-free path (ℓ) on these sheets. Although several carbon doped samples were measured, no quantum oscillations were observed, showing that ℓ in both the σ and π bands is much reduced in these samples. This indicates that for both for B||c and B||a, H_{c2} is governed by the σ bands.

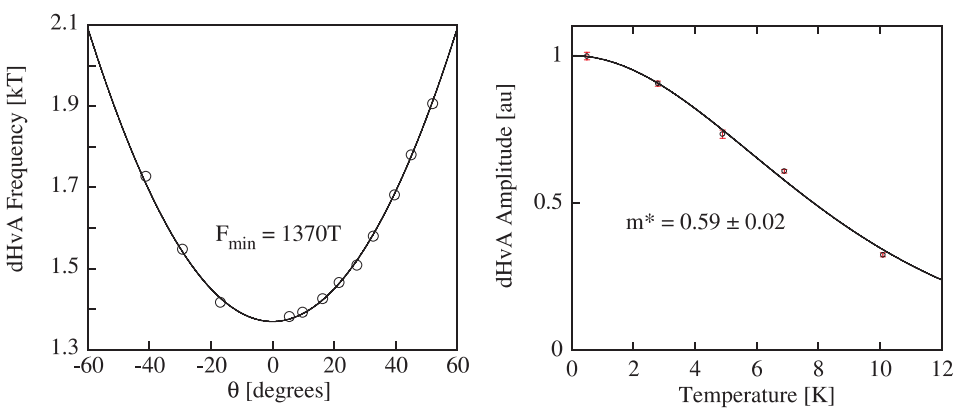

Figure 1: The left panel shows the dHvA frequency versus angle (rotating from the B||c to B||a) for one of the two σ orbits. The right panel shows the effective mass determination plot for the same obit.

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References

[1] Carrington A, *et al.*, Phys. Rev. Lett. **91**, 037003 (2003).
[2] Karpinski J., *et al.*, Cond-Mat/0411449 (2004).