EFFECT OF APPLIED MAGNETIC FIELD ON THE ESTIMATION OF
SPIN POLARIZATION FROM POINT CONTACTS

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ABSTRACT

A generalized BTK model for charge transport in ferromagnet/superconductor point contacts can be used to estimate spin polarization in a ferromagnet. We demonstrate the effect that an applied magnetic field or the spontaneous magnetization field has on the reliability of the model parameters as fitted from conductance experiments.

Keywords: Point Contact, Spin Polarization, Andreev Reflection

1. INTRODUCTION

Modifications to the BTK model [1] for charge transport in normal metal/superconductor point contacts have incorporated inelastic scattering [2] and spin polarization [3] in order to describe contacts for which the normal metal is a ferromagnet. Recently the model has been generalized to include the effects of an applied magnetic field. [4] With each modification the number of parameters utilized in the model increases.

This paper discusses the effect an applied magnetic field has on the reliability of the parameter values extracted from transport data. Specifically, we estimate the intrinsic variation of the spin polarization with field and the nature of the difficulty in determining its value.

2. THE ESTIMATION TECHNIQUE

Input for the BTK model includes two materials properties, the BCS gap potential and the critical temperature, both easily determined from the data, and one model parameter, Z, the barrier strength, related to the transparency of the contact. Inelastic scattering is introduced via the Bogoliubov equations by incorporating a term linear in the scattering parameter, Γ, which is inversely proportional to the quasiparticle lifetime between collisions. The polarization parameter P is used to model the current in the contact as the sum of a fully unpolarized part and a fully polarized part. Appropriate expressions for Andreev and ordinary reflection probabilities are calculated using the BTK formalism, with fully polarized Andreev reflection forbidden.

The effect of an applied magnetic field, H, is modeled as

\[ Y(V) = hY_N + (1 - h)Y_S(V) \]  \[ (1) \]

In this linear two channel model, Y_N is the contribution to the total conductance Y(V) by the normal channel and Y_S(V) by the superconducting channel. Here, \( h = H/H_c \).

To obtain an estimate of the effect an applied magnetic field has on the reliability of the values of the model parameters Z, Γ, and P, we generate conductance values as a function of reduced temperature for a range of known values of Z, Γ, P, and h. We then fit this simulated experiment in zero field and obtain new effective values of the parameters, to be compared to the actual known values. To reduce a large computational problem to a manageable task, we carry out the simulation at \( t = 0.50 \) for \( Z = 0.50 \), \( \Gamma = 0.20 \) and vary P and h from 0.00 to 0.50. This reduces a four dimensional parameter space to a two parameter surface, in P and h. This surface is shown by the large dots in Figure 1. The parameter surface for the \( h = 0 \) fit is generated for the same value of \( Z \). (Except for field dependent spin flip inelastic scattering, Γ is generally insensitive to the applied magnetic field.) This Z, P surface is shown in Figure 1 by the small dots. It is only where these two surfaces overlap that a fit for \( h = 0 \) is possible. As a condition on the quality of the fit, the value of the zero bias conductance and its first derivative with reduced temperature for the \( h \neq 0 \) simulation must equal those for the corresponding \( h = 0 \) fit. (Fitting the model using
a parameter surface has been shown to be a very effective technique. [5])

![Diagram](image)

**Figure 1.** Normalized zero bias conductance Y at \( t = 0.50 \) and \( \Gamma = 0.20 \) vs its temperature derivative is shown for two parameter surfaces. Large dots map applied magnetic field h with polarization P, each in steps of 0.05 from 0.00 to 0.50. Small dots map barrier strength Z with polarization P, each in steps of 0.05 from 0.00 to 1.00, for fixed h = 0.

3. RESULTS AND CONCLUSIONS

Figure 2 is a graph of effective polarization, \( P_e \) vs effective barrier strength, \( Z_e \), parametrically with applied magnetic field, where h increases from right to left. For low actual polarization, e.g., the \( P = 0.10 \) line, \( P_e \) increases from the known value of 0.10 and \( Z_e \) decreases from the known value of 0.50, as magnetic field increases. This would lead to an over-estimation of the spin polarization, even when the quality of the fit to the data is very good. For high actual polarization, e.g., the \( P = 0.50 \) line, the opposite effect occurs. The effective spin polarization decreases as the field increases, leading to an under-estimation of the spin polarization. The cross-over for this simulation occurs for \( P \approx 0.35 \). One can see from Figure 2 that at \( t = 0.50 \), the model parameters can be shifted by as much as tens of percent and that the tendency to shift is intrinsic to the formulation of the model itself. These changes in parameter values with applied field become more pronounced for higher values of reduced temperature.

This simulation may also explain why estimates of P, whether measured in an applied field or the stray self-field at the contact due to the spontaneous magnetization of the ferromagnet are close to band calculation values for the elemental ferromagnets since they happen to have P values in the cross-over range. On the other hand, for the case of high spin materials, like Heusler alloys and half metals, the model almost always yields an under-estimate of P.

![Diagram](image)

**Figure 2.** Effective polarization \( P_e \) vs effective barrier strength \( Z_e \), at \( t = 0.50 \). For each line, applied magnetic field increases from the right in steps of 0.10 from 0.00 to 0.50. At \( Z_e = 0.50 \), \( P_e \) increases from the bottom in steps of 0.10 from 0.00 to 0.50.

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