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# AC susceptibility of current carrying whiskers: Effect of the current variation

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## 1. Introduction

The ac susceptibility measurement has a great advantage to deduce the domain structure inside the {100} iron whisker while current and external field are applied along the principal axis The magnetic response of the {100} whisker can not be solved easily even in a simplest situation. This response depends on the current I, on an external field applied along the axis H, and the past history of each. To understand the magnetic response, we have to consider all kinds of fields and the eddy current makes it more difficult. The domain structure in the {100} whisker with external field and current has been deduced from the ac response recently. The basic structure consists of five domains, four of which form a sheath about the central domain. Based on the suggested model, the ac response while varying the external field has been well-explained. But the response with the variation of currents is not understood, yet. In this presentation, experimental data as a function of currents will be presented with and without external field. These data will be compared with our calculation based on the previous model[1].

## 2. Experiment

The well-grown {100} iron whiskers have square cross sections and bound by {100} planes. The {100} whisker used for our measurement has the dimensions 200 μm x 200 μm x 1.5 cm. Lead wires for current are connected to the edges of the whisker with GaIn solder to reduce the stress. Detailed ac susceptibility measurements have been described in Ref. 2. Currents applied along the principal axis vary in the range of 200 mA with and without external field. The out-of-phase components of the ac signals are obtained as a function of applied currents.

## 3. Result and discussion

The {100} whisker having the simple Landau domain structure shows a characteristic response. The out-of-phase and in-phase component of the ac response is well-described in Ref. 2. The ac response with the variation of currents is shown in Fig. 1. The measurement is done without any external field. As the current changes from the negative to the positive value, the domain structure of the whisker is changed from the rotated, to the Landau, and to the rotated structure. The ac response with small external field is shown in Fig. 2. The applied external field is strong enough to make the central core large and domain walls around the core induce the ac signal. The magnitude of the ac response depends on applied currents.

The micromagnetic treatment includes the energy from the external field and the applied current, the demagnetizing energy, the wall energy, and the magneto-elastic energy. The applied field H is balanced by the magneto-elastic field $H_{elas}$, the wall field $H_{wall}$, the field from the current $H_I$, and the demagnetizing field $H_D$. These fields are plotted in Fig. 3 in terms of the magnetic moment per unit length, m. The relation between the applied current and the magnetization for a fixed field is given by

$$I = \frac{h}{\sqrt{m}} - D_o\sqrt{m} + \frac{\sigma}{m} + \frac{b}{\sqrt{m}}(\log m + cm).$$

The corresponding dc susceptibility for varying currents is given by

$$\frac{1}{\chi_o} = -\frac{h}{2m} - \frac{D_o}{2} - \frac{\sigma}{m^{3/2}} + b\frac{2 - \log m + cm}{2m}.$$

The ac susceptibility is approximately given by

$$\frac{1}{\chi} = \frac{1}{\chi_o} + \frac{\omega}{\omega_1}\log(\frac{m}{d})$$

where d is the width of the whisker.

The constants $D_0$, $\sigma$, b, and c appearing in the ac susceptibility are solved for finding the ac response to change in the independent variables H and I. The result of the calculation for the ac susceptibility will be presented at the conference.

**4. Reference**


[1] J.-G. Lee and A.S. Arrott, J. Appl. Phys. **75**, 7006(1994).
[2] D.S. Bloomberg and A.S. Arrott, Can. J. Phys. **53**, 1454(1974).


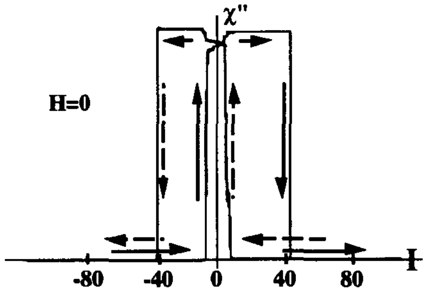


Fig. 1 Out-of-Phase signal while varying currents without external field.

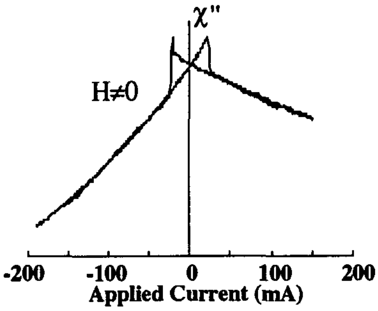


Fig. 2 Same as Fig. 1 with small external field.

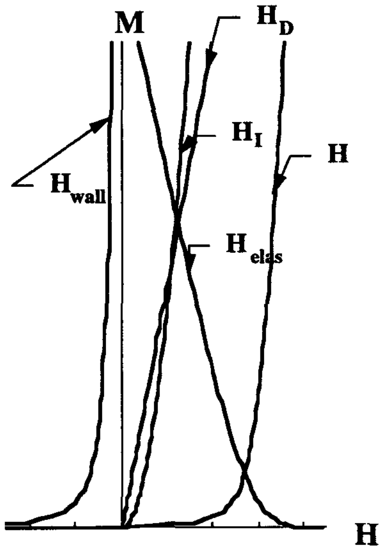


Fig. 3 Calculated relation between fields and magnetization.