STUDYING MAGNETORESISTANCE AND HALL EFFECT OF BISMUTH

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In this experiment we will study the various solid properties of Bismuth like Magnetoresistance and Hall Effect.

Magnetoresistance: When the magnetic field is turned on, the resistance of a sample varies. Magnetoresistance is a material's capacity to alter the value of its electrical resistance when subjected to an external magnetic field. The amplitude of the impact is fairly small ($\approx 1\%$) at normal temperature, but increases to roughly 50% at low temperatures in gigantic magneto resistive multilayer systems. In certain perovskite systems, effects of more than 95% change in resistivity have recently been discovered.

Hall Effect: The Hall effect is the phenomenon of appearance of a potensial difference perpendicular to the direction of curent flow if a perpendicular magnetic field is applied. In the operating region, the Hall effect is a linear effect, which means that the voltage is proportional to the current and the magnetic field. The Hall coefficient is a measure of the Hall effect. It is defined as the ratio of the Hall voltage to the product of the current and the magnetic field. The Hall coefficient is a material property and is independent of the geometry of the sample.

I. THEORY

A. Magnetoresistance

Under the influence of a magnetic field, the resistance of some materials change significantly. This effect is popularly known as magnetoresistance of the material. This effect can be observed due to the fact that the drift velocity of the carriers is not same. In the presence of the Magnetic field, the carriers drift in the direction of the field. In this condition, the hall voltage compensates the lorentz force for carriers with average velocity. The slower carriers are overcompensated and the faster carriers are undercompensated. This disturbs the flow of electrons along the direction of flow of current; hence reducing the mean free path and increasing the resistance of the material. In this condition, the hall voltage is given by the formula:

$$V = E_y t = |v \times H|$$

where E_y and H are the electric field and the magnetic fields, t is the thickness of the sample, and v is the drift velocity of the carriers.

The change in resistivity $\Delta\rho$ is positive for both magnetic field parallel $\Delta\rho_\parallel$ and transverse $\Delta\rho_T$ to the current direction with $\rho_T > \rho_\parallel$. There are three different kinds of magnetoresistance, depending on the structure of the electron orbitals at the Fermi surface:

1. The magnetic field has the effect of raising the cyclotron frequency of the electron in its confined orbit in metals with closed Fermi surfaces where the electrons are restricted to their orbit in k-space.
2. The magnetoresistance for metals with an equal number of electrons and holes rises with magnetic field up to the highest observed fields and is unaffected by crystallographic orientation. These materials include bismuth.
3. In some crystallographic orientations, Fermi surfaces with open orbits will show significant magnetoresistance for applied fields, but the resistance will saturate in other crystallographic directions where the orbits are closed.

B. Hall Effect

The Hall effect is the production of a voltage across a conductor when an electric current is passed through it. The Hall voltage is proportional to the current density and the magnetic field perpendicular to the current. The Hall voltage is given by the formula:

$$V = E_y t = |v \times H|$$

where E_y and H are the electric field and the magnetic fields, t is the thickness of the sample, and v is the drift velocity of the carriers.

The Hall effect is a direct consequence of the Lorentz force on the charge carriers in a magnetic field. The Hall effect is a linear effect, meaning that the Hall voltage is proportional to the current density and the magnetic field perpendicular to the current. The Hall coefficient is the ratio of the Hall voltage to the product of the current density and the magnetic field perpendicular to the current. The Hall coefficient is a material property and is independent of the applied current density and the magnetic field. The Hall coefficient is a measure of the mobility of the charge carriers in the material. The Hall coefficient is given by the formula:

$$R_H = \frac{V}{I \times B}$$

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II. OBSERVATION AND ANALYSIS

A. Magnetoresistance

1. I=198.5mV

The magnetoresistance data for $I = 198.5mA$ is shown in Table 1 and the graph of $\frac{\Delta R}{R}$ vs H is shown in Figure.1. The graph of $\log(\frac{\Delta R}{R})$ vs $\log(H)$ is shown in Figure.2.

2. I=101.0mA

The magnetoresistance data for $I = 101.0mA$ is shown in Table 2 and the graph of $\frac{\Delta R}{R}$ vs H is shown in Figure.3. The graph of $\log(\frac{\Delta R}{R})$ vs H is shown in Figure.4.

B. Hall effect

I=197.3mA

H(gauss)	Voltage(mv)	Resistance	deltaR/R
0	0.036	0.000183861	0
390	0.037	0.000188968	0.026291892
2410	0.038	0.000194076	0.051915789
3480	0.041	0.000209397	0.121287805
4090	0.043	0.000219612	0.16215814
4380	0.044	0.000224719	0.1812
4520	0.046	0.000234934	0.2168
4560	0.048	0.000245148	0.249433333
4700	0.049	0.000250255	0.26475102
4920	0.05	0.000255363	0.279456
5060	0.051	0.00026047	0.293584314
5130	0.052	0.000265577	0.307169231
5290	0.053	0.000270684	0.320241509
5360	0.054	0.000275792	0.33282963

TABLE I: Magnetoresistance Data for $I = 198.5mA$

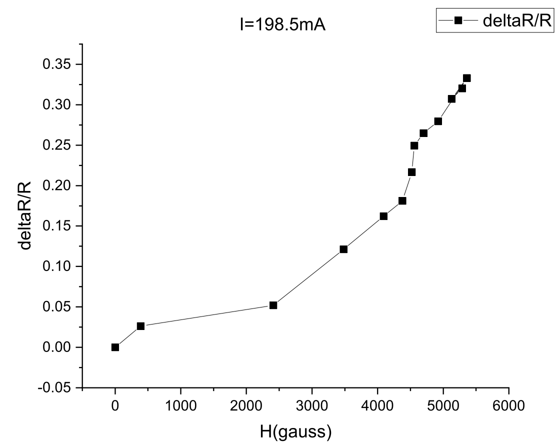

FIG. 1: $\frac{\Delta R}{R}$ vs H

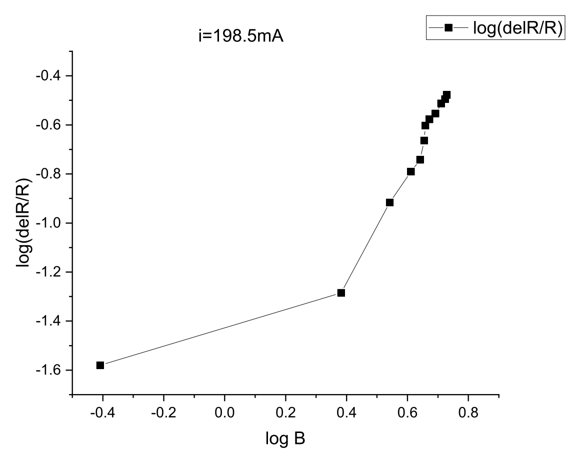

FIG. 2: $\log(\frac{\Delta R}{R})$ vs $\log(H)$

H(gauss)	Voltage(mv)	Resistance	deltaR/R
0	0.036	0.000183861	0
3330	0.037	0.000188968	0.026291892
4260	0.038	0.000194076	0.051915789
4670	0.041	0.000209397	0.121287805
4950	0.043	0.000219612	0.16215814
5120	0.044	0.000224719	0.1812
5380	0.046	0.000234934	0.2168
5800	0.048	0.000245148	0.249433333

TABLE II: Magnetoresistance Data for $I = 101.0mA$

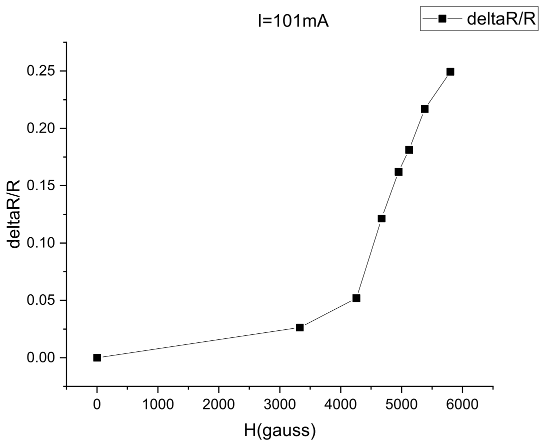

FIG. 3: $\frac{\Delta R}{R}$ vs H

Room temperature=25°C
Thickness(z)=0.5mm

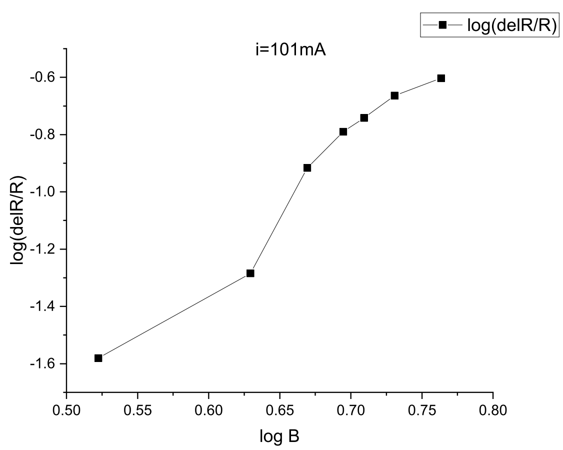

FIG. 4: $\log\left(\frac{\Delta R}{R}\right)$ vs H

H(gauss)	V(mV)
2390	-0.061
2540	-0.062
3160	-0.063
3480	-0.064
4200	-0.065
4500	-0.066
4780	-0.067
5200	-0.068
5180	-0.069

TABLE III: Magnetoresistance Data for $I = 101.0mA$

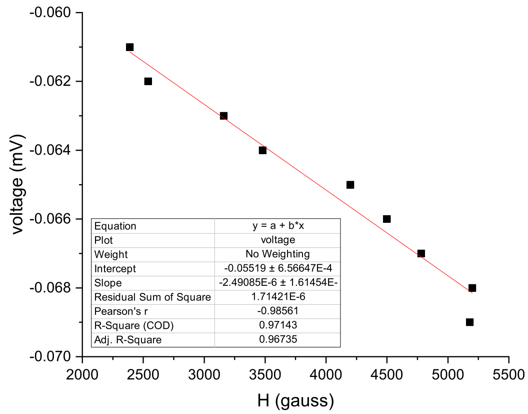

FIG. 5: hall voltage vs H

C. Data analysis

We see that when the magnetic field strength increases, so does the magneto-resistance value. At low magnetic field intensities, the transition is gradual, but it speeds up as the strength rises. An increase in the Lorentz force on charge particles may be the cause. We can see that in the high magnetic field, Bismuth's resistance changes by 35 percent (i=198.5mA) and 25 percent (i=101mA). As the quantity of charge carriers diminishes, the change in magneto-resistance reduces along with it. Furthermore, as a result of a lack of charge carriers, we can see that the curve deviates from the predicted curve shape at low working current and saturates at high temperatures.

We can see that there is a 6 percent inaccuracy in the value of the Hall coefficient. The next data point's variation could be the result of equipment heating up from prolonged usage and changes in the ambient temperature. The residual magnetic field in coils at zero current (3 Gauss) and variations in operational current may also be contributing factors. The charge density in metals is large as one could anticipate given that $R_h = 1$.