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Hall Effect Presentation Paragraphs

Theory (slide 2)

From the Lorentz force, we know that any charged particle in motion in a region with a magnetic field will experience a force orthogonal to the direction of its motion. This of course applies when we talk about a current of some number of charge carriers. When we run a current across a circuit in the presence of a magnetic field, the individual charge carriers all experience a magnetic force in a direction orthogonal to their motion. This means that if we have a current that runs horizontally across a circuit, then the presence of a magnetic field will result in a vertical deflection of the charge carriers. As these charge carriers accumulate on either vertical boundary, they will create a net electric force which repels other, like charge carriers that are themselves deflected by the magnetic field. The resulting voltage difference due to this first deflection by a magnetic field force, then repulsion by the accumulation of deflected charge carriers is called the Hall voltage. Using the Hall voltage, we are able to determine a variety of characteristics of both the circuit itself as well as the current.

In this experiment, we used this to determine the resistivity and mobility of a CMP-102 semiconductor chip from TeachSpin. These values then allowed us to determine the number and type of the majority charge carrier, as well as whether the chip was p-type (positive, hole majority charge carriers) or n-type (negative, electron majority charge carriers).

Instrumentation (slide 3)

The main piece of equipment used here was a Keither 2450 SourceMeter source measure unit. SMUs are a kind of 4-in-1 device which function as a voltage source, current source, voltmeter, and ammeter. This allows us to more easily perform tasks like generating a current while measuring a voltage, for instance.

Data Analysis (slide 4-6)

Our data analysis consisted of an initial stage where we determined the resistivity of the circuit. This was done by generating a voltage difference across the semiconductor chip and measuring the components that had a large horizontal distance from each other. Specifically, we generated a voltage difference form A to D and measured directly across from B to C and Q to R. When we did this, we found a solidly ohmic relationship between the voltage and current which allowed us to get the resistance. Then with the resistance, we used the length and area of the chip itself to determine the resistivity. This was given to us as about 7.3 milliOhm-meters +/- 1.3 milliOhm-meters.

While still generating a voltage difference horizontally across, we then placed the chip in a case with a magnetic field (a case with a north pole on the front facing side and a south pole on the backside). We then measured between components that had a clear and substantial vertical component across the chip: B-Q, B-R, C-Q, and C-R. After doing this, B-R and C-Q remained a relatively ohmic relationship, whereas B-Q and C-R had a strange, non-linear one. To account for this, we measured across those same terminals sans magnetic field and subtracted that data from the data with a magnetic field present. This ended up clearing a decent portion of the eccentric slope we initially got and gave us a workable relationship between the Hall voltage and current, which ultimately gave us a decent value of the Hall resistance.

Here we used the Hall voltage to determine that our majority charge carriers were positively charged holes and that we were working with a p-type semiconducting chip. From there we used our two calculated Hall resistances to solve for two different, but decently close charge carrier numbers.

Finally, we were able to use the charge carrier type, number, and resistivity to solve for the mobility.

Special Topic (slide 7)

Hall effect sensors have a host of uses in industry. One contemporary use that is especially common is as sensors in automobiles. This is because they are much less sensitive to dirt, dust, water, oil, or vibration when compared with optical or light sensors. This picture here is an example of a Hall effect sensor being used as a wheel speed sensor. On one side we have a permanent magnetic and Hall sensor up against a ferromagnetic wheel. As the wheel rotates, the magnetic field surrounding the Hall element will have a maximum when one of the teeth is directly aligned with it, and a minimum in the gaps between. The Hall element will then measure these changes in the surrounding magnetic field which can be read as information about the speed of rotation of the wheel.