Negative resistivity leads to positive resistance in the presence of a magnetic field

December 11 2013

In a paper appearing in Nature's *Scientific Reports*, Dr. Ramesh Mani, professor of physics and astronomy at Georgia State University, reports that, in the presence of a magnetic field, negative resistivity can produce a positive resistance, along with a sign reversal in the Hall effect, in GaAs/AlGaAs semiconductor devices.

The electrical resistance is a basic property of components known as resistors that occur in electrical circuits. Usually, the resistor serves to limit the electric current – the flow of electrons - to the desired value within the circuit in electronic applications. However, a large current through a resistor can also help to generate heat, and this principle is used in toasters, ovens, space heaters, and window defrosters. Resistors also occur in sensing applications as in strain gauges, gas sensors, etc., when the resistive element exhibits sensitivity to external stimuli. The resistance of a material depends upon the material property called the resistivity. The material resistivity generally takes on positive values, which indicates that electrical energy is dissipated within the material, when a current is passed through it.

In research that is supported by grants from the U.S. Department of Energy and the U.S. Army Research Office, Mani examined the relation between the resistivity and the resistance of microwave photo-excited, very thin sheets of electrons in the presence of a magnetic field with his colleague Annika Kriisa from Emory University.

The motivation for this work came from the fact that, over the past decade, theoretical physics has concerned itself with the remarkable possibility that the material resistivity can take on negative values in special systems, called two-dimensional electron gases (2DEG), at low temperatures in the presence of a magnetic field, when the 2DEG's are illuminated with microwaves – the same type of microwaves that occur in microwave ovens. That is, scientists have suggested that cooking a 2DEG with microwaves in a magnetic field can help to produce negative resistivity. Yet, the consequences of a negative resistivity were not well understood. The work of Mani and Kriisa helps to clear up some mysteries.

The relation between the resistivity and the resistance is straightforward in the absence of a magnetic field: a positive resistivity will lead to a positive resistance and a negative resistivity will lead to a negative resistance. The application of a magnetic field generates something called a Hall effect in the sample that complicates the relation between the resistivity and the resistance at finite magnetic fields. The reason for the complication is that, in a small magnetic field, the Hall effect can be large compared to the resistive effect in very clean 2D electron systems. In such a situation, the Hall effect decides how the system is going to respond to the negative resistivity. This work by Mani and Kriisa shows that the 2D electron system can show a positive resistance in response to a negative resistivity as the Hall effect reverses its sign.

This result will help to further understand the proposed spectacular properties of systems exhibiting negative resistivity, as it also provides more insight into the intricacies of the Hall effect – an effect discovered by the American scientist E. H. Hall circa 1879.

Provided by Georgia State University