Strain induced resistivity change of a conductive plastic composite

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Abstract

There are three goals for this project. First, we investigate the resistivity of the mixture of PU and carbon black. It can be obtained by the finding the slope of the voltage VS current graph of the plastic. Moreover, we investigate the relation of resistivity of plastic when it is under strain. Since it can change the concentration of the carbon black. Therefore, the resistivity of the plastic will be varied by the change of length, force and pressure.

Finally, we investigate the relation of resistivity of the plastic by change the volume fraction of carbon black to PU. The introduction of graphite powder into PU increases its conductivity but decrease its plastic nature. Hence, an appropriate ratio of graphite and PU is required. From our experiment, it is true that addition of graphite powder can help PU conduct electricity. Besides, the increase in length of the sample or a force applied to the sample can increase its resistivity.

Theory:

Electrical resistivity is a measure of the resistance of a conductor against electric current. It is given by the formula

$R=\rho * l / A$

ρ: resistivity of a conductor
A: cross-section area of a conductor
l: length of a conductor
R: resistance of a conductor

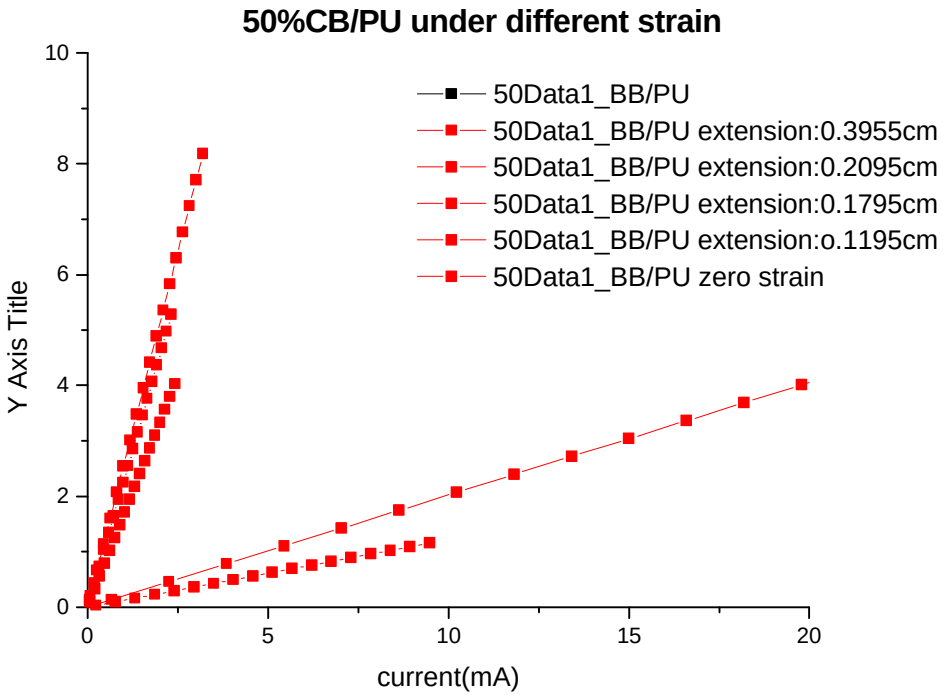
Polyurethane (PU) is a plastic. It has no mobile electron. Hence, it cannot conduct electricity. Graphite is a conductor. The even distribution of the graphite powders in PU allows the plastic having the same conductivity when a current flows through it in any direction. Hence, a mixture of the PU and the powdered graphite can conduct electricity and have elastic property. Furthermore, the distribution of the powdered graphite in PU has direct effect on the elasticity and conductive properties of the composite. There is a critical concentration of graphite powders such that the particles just connect together in the mixture. If the concentration of graphite powders is below this critical value, the resisitivity is very large since there is no complete conducting path provided by graphite powders. However, a slightly increase of graphite powders would connect the separated conducting particles such that the resistivity of the composite will

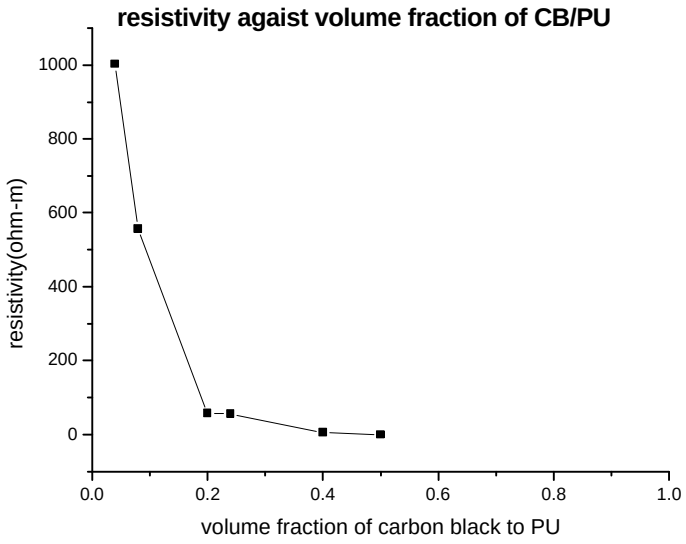
drop significantly. This critical phenomenon is called the percolation.

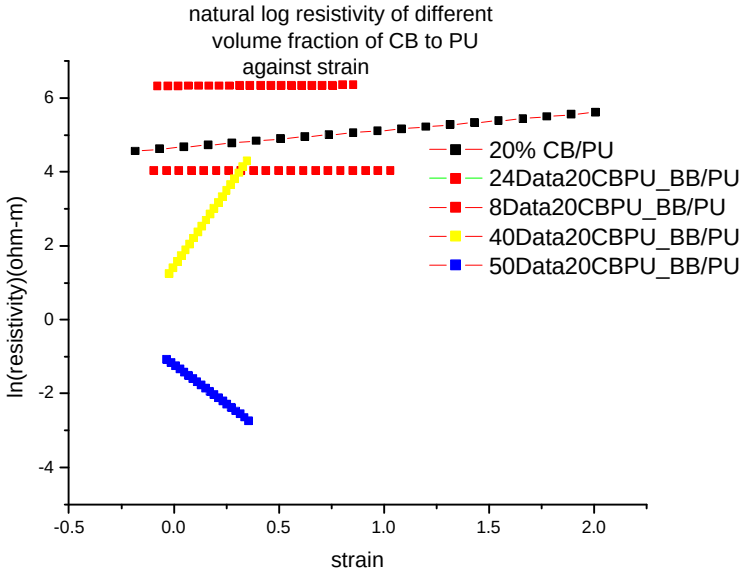
On the other hand, according to Hooke's law, F=k e, when a sketching force is applied to a plastic material, it will extend in length. This affects the distribution of the graphite powder. In other words, the graphite concentration becomes lower. It means that extension will increase the resistivity of the graphite plastic composite.

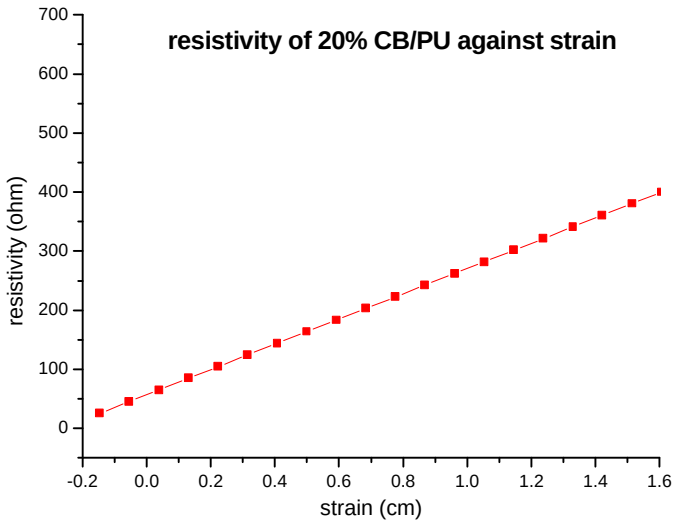
In this project, we have used the carbon black powders, which is one kind of graphite as the conducting particles.

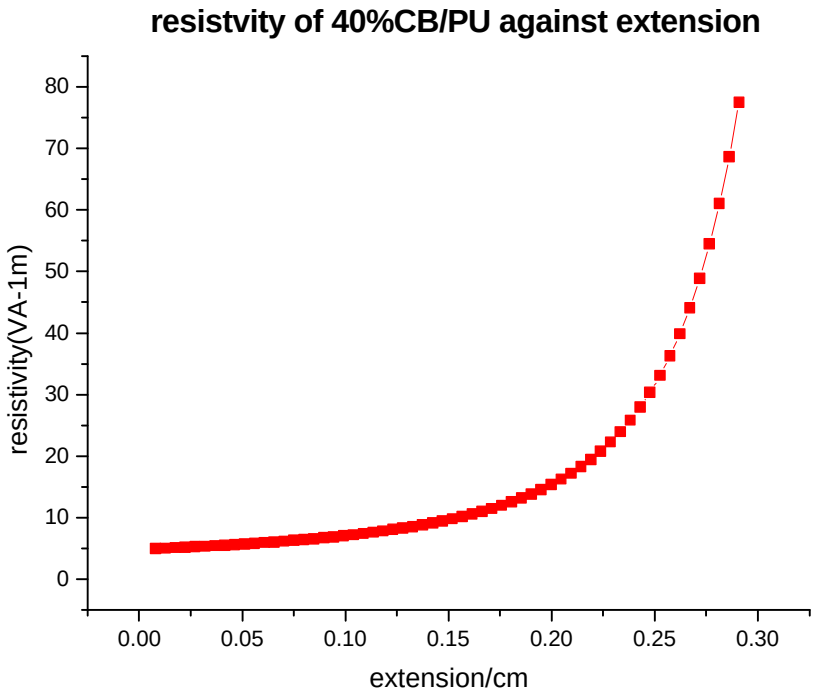
Result




resistivity agaist volume fraction of CB/PU
resistivity(ohm-m)
1000
800
600
400
200
0
0.0
0.2
0.4
0.6
0.8
1.0
volume fraction of carbon black to PU


natural log resistivity of different
volume fraction of CB to PU
against strain
ln(resistivity)(ohm-m)
6
4
2
0
-2
-4
-0.5
0.0
0.5
1.0
1.5
2.0
strain
20% CB/PU
24Data20CBPU_BB/PU
8Data20CBPU_BB/PU
40Data20CBPU_BB/PU
50Data20CBPU_BB/PU


resistivity of 20% CB/PU against strain
resistivity (ohm)
700
600
500
400
300
200
100
0
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
strain (cm)



Conclusion

When the ratio of the volume of graphite to that of PU is below 20%, the resisitvity is extremely large. However, when the ratio is over 20%, the resistivity is extremely small. Hence, 20% is the critical concentration of the carbon black to PU. Moreover, the strain of the sample increase, the resistivity increases.

Discussion

Experimental error

The tensile stress was made of copper, good conductor. It allowed more current to flow through the ammeter since it decreased the resistivity of the set-up. Hence, the resistivity of a sample was overestimated unless the tensile stress would be isolated from the set-up.

Moreover, heat was produced when the current flows through the sample. The heat increased the resistance of the sample. Hence, the resisitvity was overestimated if a lot of heat was produced.

1. Amendment

   The resistivity of a sample under zero strain is measured without the tensile stress. Similarly, The resistivity under zero strain is measured with the tensile stress, too. The ratio of the two values is obtained. Assume, the ratio would not change when the sample extends. Hence, the resistivity of

a sample without the conductive effect of tensile stress can be obtained.

2. Precaution

3.1 the voltage applied to the sample should not be so large. Otherwise, the current becomes too large and hence a large amount of heat is produced.

3.2 the silver paint on the sample should not have a direct contact with the tensile stress.

3.3 the silver paint on the sample should be refilled within two to three weeks.