Correlation between Spin Distance and Spin Lifetime of Graphene Spintronic Transistors

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Abstract

The size of CMOS transistors are near their minimum size and Moore's law is near its limit, so it is paramount to look at different types of transistors to use for computer chips. One prominent type of transistor is the spintronic graphene transistor, which promises high performance and efficient energy conservation. In this report, the spin distance and spin lifetime of various graphene transistor models from peer-reviewed papers were gathered and analyzed to see if a correlation exists between the two variables. Various regression tests were performed as well as a standard error of regression test. All the R squared values and the S value indicates that there is little to no correlation between the variables.

Introduction

Graphene's high-speed conductivity makes it a strong candidate for high-performance electronics. A study by Birkner (2013) found that graphene has a theoretical charge carrier mobility higher than 200,000cm2/V·s while silicon only has a charge carrier mobility of 450cm2/V·s.Because graphene can transport more electrons over a small course of time, it will speed up how fast electronics work. However, because of graphene's structure, it is impossible to use it in traditional computer chips.

Graphene in spintronics, rather than electronics, however, holds much promise. pintronics is a branch of electronics that holds much promise. Currently, in electronics, a transistor reads the charge of an electron. A spintronic device or component would read another property of an electron: its spin. Graphen holds a very small SOC, which should theoretically lead to long spin relaxation times. It also has shown remarkable spin distance. Additionally, its high electron mobility would lead to it to be able to do more calculations per second. Lastly, it has a gate-tunable carrier concentration which allows for it to alternate the spin of electrons and thus strong spin manipulation.

Methodology

A systematic literature review was used for this paper. This method was chosen because I lacked the materials and experience to perform an experiment. Also, I did not have access to a lab at my school. I could not conduct a survey because that would not give me relevant information on this topic.

The databases used to gather articles were Google Scholar, Nature, ResearchGate,ScienceDirect, and JSTOR. The College Board version of the database EBSCOhost was also used. Additional articles were also gathered from the reference section of already chosen articles. From these articles, quantitative data on spin-lifetime and spin-distance was extracted. To get additional information on electrical engineering, important definitions were taken from passages of the "All about Circuits" textbook, which is available for free online. Another incredibly important source of information was the Graphene Flagship Program. The Graphene Flagship Program is the single largest research grant in the world. The European Union commissioned a total of one billion euros to investigate the potential of graphene and to make it more usable and viable commercially. One of the many major fields the graphene flagship program is the field of spintronics. As such, I was able to find many peer-reviewed papers on the field. Lastly, information about graphene spintronics was used from Chapter 11 of the University of Cambridge's textbook on 2D materials, which focused on 2D spintronics.

20 articles were identified to be useful based on title and abstract. All the papers data was gathered from were peer-reviewed. They are also from the last ten years in order to keep the data as current as possible. 12 articles were then excluded because the research papers were either too old or had an emphasis on enhancing other properties of graphene spintronic transistors, such as spin injection. The eight articles chosen were specifically trying to increase the spin lifetime of electrons. Spin lifetime and spin distance was extracted, recorded and analyzed.

Results

All the papers used attempted to increase the spin lifetime of electrons by applying a variety of methods. They introduced a different material near graphene and observed the effect it had on the spin lifetime. There was a wide consensus among all the articles that the greater the spin orbital interactions of the new material, the greater the desired result. The aim was that the large SOI of new material would increase the spin lifetime while the small SOI of graphene extends the spin distance. A majority of the papers used cobalt to test this because it had a high intrinsic SOI. Two papers also used Molybdenum Disulfide because it had a similarly high SOI. Lastly, two other papers used 2D materials for ease. One paper used a layer of silicene, a material similar to graphene except it is made of silicon atoms rather than carbon atoms, and another paper just used another layer of graphene.

It appeared to seem that there were no major outliers in the data so all of the final eight papers were used in the graph.

Table 1. This table shows the data that was collected from eight different peer-reviewed research articles. Data includes complementary material used, spin lifetime, and spin distance.

	Complementary Material	Spin Lifetime (ps)	Spin Distance (μm)
Tombros et al.	Cobalt	170	2
Yang et al.	Bilayer Graphene	135	.7
Guimarães et al.	Cobalt	150	4.7
Birkner et al.	Epitaxial SiC	88	1.18
Józsa et al.	Cobalt	150	1.5
Dankert and Dash	Molybdenum Disulfide	40	1.2
Yan et al.	Molybdenum Disulfide	10	.020
Han et al.	Cobalt	50	2

Conclusion

Table 2. This table shows all the R squared values and equations. It is organized from smallest to greatest R squared values. The greatest value observed was .6766. The closer the R squared value is to 1, the more accurate it is

Regression	R squared value	Equation
Linear	.2577	$y = 22.003x + 62.545$
Exponential	.2887	$y = 39.687e^{0.3756x}$
Polynomial (2nd)	.3298	$y = -7.4762x^2 + 59.31x + 33.85$
Logarithmic	.3966	$y = 23.072\ln(x) + 100.8$
Power	.6766	$y = 76.763x^{0.4859}$

This systematic literature review provides evidence supporting the null hypothesis proposed in this study that there is little correlation between spin lifetime and spin distance. Yet, there is still some positive correlation meaning that it is impossible to rule out that there is no correlation between them. All papers analyzed in this systematic review support this hypothesis, suggesting that there are likely other variables, not just spin distance, that affect spin lifetime. An equation could not be proposed relating the two variables because the R squared values are too low and the standard error of regression value is too high.

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