行政院國家科學委員會專題研究計畫　成果報告

自旋電子學中的 Aharonov-Bohm 干涉效應之研究

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結案報告

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計劃名稱:自旋電子學中 AB 干涉效應之研究

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Non-local Effect in Spintronics

Spintronics is the study of electron spin coherent states in solids, especially in semiconductors. There are three very actively researched areas. The most mature one is MRAM (magnetic random access memory), a new type of computer memory which would retain their state even when the power was turned off. Unlike present forms of nonvolatile memory, they would have switching rates and rewritability challenging those of conventional RAM. The second category is the spin-polarized currents which flow in semiconductors instead of metals. Achieving practical spintronics in semiconductors would allow a wealth of existing microelectronics techniques to be co-opted and would also unleash many more types of devices made possible by semiconductors' high-quality optical properties and their ability to amplify both optical and electrical signals. Examples include ultrafast switches and fully programmable all spintronics microprocessors. This avenue of research may lead to a new class of multifunctional electronics that combine logic, storage and communications on a single chip. The third category of spintronics is how to manipulate the quantum spin states of individual electrons. This category includes quantum logic gates that would enable construction of large-scale quantum computers, which would extravagantly surpass standard computers for certain tasks. Although several exotic technologies are aimed toward these three goals such as ions in magnetic traps, frozen light, ultra-cold quantum gases and nuclear magnetic resonance of molecules in liquid, nevertheless, we believe it makes sense instead to build on the extensive foundations of conventional electronic semiconductor technology. A key research question for the second and third categories of spintronics is how will electrons maintain a specific spin state when traveling through a semiconductor or crossing from one material to another. For instance, a spin FET will not work unless the electrons remain polarized on entering the channel and after traveling to its far end. Therefore, the question of how fast spin polarization decays becomes all the more acute if one is to build a quantum computer based on electron spins. That requires control over a property known as quantum coherence. It is known that the phase of wave function have a geometrical part besides the usual dynamical part. So the phase of wave function is closely connected with the topological or global properties of the physical system. It would not be surprising if one predicts that in the spintronics system global properties are essential, and it is possible to control spin coherence state via nonlocal A-B (Aharonov-Bohm) and A-A (Aharonov-Anandan) effects.

In this proposal, we will focus on the theoretical explanation of a possible control via nonlocal A-B, and A-A effects of the spin coherence states. We expect that the present plan in spintronics will be crucial for our understanding and design of nano as well as quantum computational devices.

研究成果:

感謝國科會對本計劃的支持，我們完成五篇相關文章(如下所列)，已經有四篇在國際著名期刊發表，其中第五篇審查專家要求修改，希望在明年能夠順利刊登出來。在這些工作中，我個人覺得最值得一提的是我們對自旋電子在 AB 磁通管的影響下的動力學行為，做了很深入的研究，我們希望在未來一年能夠建立自旋電子在 AB 磁通管下的來文生定理(Levinson Theorem)，這個大定理被物理大師楊振寧教授認為是量子力學中最美麗的定理之一，很高興我們能在此作出決定性的貢獻。

References

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