FAR INFRARED CYCLOTRON RESONANCE OF TWO-DIMENSIONAL ELECTRON SYSTEMS WITH SHORT-RANGED ALLOY DISORDER

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Introduction

For an electron, lifetime measures the time scale between two scattering events. For different types of scattering, the lifetime can be very different. Conventionally, the transport lifetime is defined as $\tau\mu=\mu m^*/e$ from the electron mobility μ measured in transport experiments. Since only large angle scattering affects the mobility, the transport lifetime only takes into account large angle scattering events by the impurities. On the other hand, if scattering to all the directions is taken into account, the measured lifetime will be largely reduced, and this is of great interest because such a lifetime is directly related to the quantum dephasing time of electrons. Defined as "quantum lifetime", the scattering time to all directions cannot be measured directly by transport experiments, and is usually studied from the approach of the electron cyclotron resonance. Studies have shown that the quantum lifetime can be obtained by fitting the Shubnikov-de Hass oscillations to the Dingle formula, or by fitting the line shape of the electron cyclotron resonance to the Lorentz form.

It's intriguing to investigate the relation of the transport lifetime and the quantum lifetime. Systems with controlled disorder provide a good reference for this problem. Recent work on alloy systems of $Al_xGa_{1-x}As$-$Al_{0.32}Ga_{0.68}As$ heterostructures [1, 2] has shown a new way of controlling disorder in two-dimensional electron systems (2DES). In such systems, the disorder is dominated by alloy potential fluctuations providing x is large enough. Since the alloy impurities are neutral, the alloy potential range is of atomic size. The alloy scattering rate of 2DES is found to be temperature-independent and depends linearly on x, from which the alloy potential amplitude is extracted to be 1.13 eV [1]. On the other hand, in a conventional 2DES, disorder is mostly from the Coulomb potential of the charged impurities, with the range of micrometers and approximate amplitude of meV. Therefore the alloy disorder is short in range and strong in amplitude compared with the potential of ionized impurities. Study of electron cyclotron resonance in these systems directly shows the influence of short-ranged disorder to the electron lifetime.

Experimental

We have performed cyclotron resonance (CR) experiments of the 2DES with controlled disorder in a superconducting magnet with the infrared facility of NHMFL in Tallahassee. A Bruker 113 spectrometer is used to measure the CR at different magnetic fields from 4 T to 12 T. At 4.2 K, a sharp resonance peak is observed from each measurement [3].

Results and Discussion

We fit the line shape of the resonance to the Lorentz form and got the quantum lifetime of each sample at different magnetic fields. For samples with Al concentration x changes from 0 to 0.85%, we found that the measured quantum lifetime decreases from 6.8ps to 6.2ps, while the transport life decreases from 135ps to 35ps. The quantum lifetime we measured with cyclotron resonance is notably larger than the quantum lifetime we obtained earlier from the Shubnikov-de Hass oscillations, but both are affected little by the short-ranged disorder [3]. We proposed an explanation according to the nature of different types of disorder and scattering. The background Coulomb potential contributes most of the scattering event but does not affect the mobility much since most of the scattering events by Coulomb potential are small-angled. The short-ranged alloy disorder contributes mostly to the large-angled scattering, but does not contribute as much as the Coulomb potential to the total scattering rate.

Conclusions

We have found the short-ranged disorder affects the quantum lifetime very little, while it changes the transport lifetime a lot. This leads to an opportunity to grow samples with great quantum properties but low electron mobility, which is important for electron localization studies.

Acknowledgements

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References

[1] Li, W., *et al*., Appl. Phys. Lett., **83,** 2832 (2003).
[2] Li, W., *et al.*, Phys. Rev. Lett., **94**, 206807 (2005).
[3] Li, W., *et al*., *Lifetime of two-dimensional electrons in* $Al_xGa_{1-x}As$, Manuscript in preparation.