Observation of Long Spin-Relaxation Times in Bilayer Graphene at Room Temperature

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Introduction

- Different spin scattering mechanism
- Fabrication
- Measurements
- Conclusion
Scattering mechanisms leading to spin relaxation

- **Elliott-Yafet:**

  \[ \tau_s \sim \tau_p \]
  \[ \frac{\tau_s}{\tau_p} = \text{const} \]

- **D’yakonov-Perel:**

  \[ \tau_s \sim \frac{1}{\tau_p} \]
  \[ \tau_s \tau_p = \text{const} \]

- Determining which effect dominates by measuring the dependence of \( \tau_s \) on \( \mu, \sigma_{\text{min}}, n, \) and \( T \)
Fabrication

- Exfoliation of graphene
- 1. global MgO samples
  - MBE of MgO
  - Ebeam for contacts
  - MBE of Co
- 2. global MgO samples
  - Ebeam for contacts
  - MBE of MgO, then Co
BLG after MgO deposition

Roughness of a BLG flake
Non-local measurements
Hanle measurement

\[ R_{nl} \propto \int_0^\infty \frac{1}{\sqrt{4\pi D_s t}} e^{-\left(L^2/4D_s t\right)} \cos(\omega_L t) e^{-(t/\tau_s)} \, dt \]

\[ D_s = 0.0032 \, \text{m}^2/\text{s} \quad \mu = \Delta \sigma / e \Delta n \]

\[ n = 1.5 \times 10^{12} \, \text{cm}^{-2} \quad \omega_L = g \mu_B B / \hbar \]

\( \tau_s = 135 \, \text{ps} \)

\( \tau_s = 2 \, \text{ns} \)

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\( \tau_s \) dependence on \( \mu, \sigma_{\text{min}} \) and \( n \)

\[
\tau_s \sim 1/\mu \sim 1/\tau_p \quad \tau_s \sim 1/\sigma_{\text{min}} \sim 1/\tau_p
\]

\[
\tau_p = \sigma m^*/n e^2
\]

\[
1/\tau_s = \Omega^2_{\text{eff}} \tau_p = 4\Delta^2 \tau_p / \hbar^2
\]

\[\Delta \sim 0.14 \pm 0.001\text{meV}\]

\[\Omega_{\text{eff}} = 407 \pm 25\text{GHz}\]

\[\Delta_{\text{intrinsic}} \sim 0.1\text{meV}\]
n and $\mu$ dependence of $\tau_s$ and $\tau_p$ at LT
T dependence of $\tau_s$ in BLG and SLG
Conclusion

- Long spin relaxation times were measured
- Spin relaxation mechanism at RT is probably D’yakonov-Perel like
- No clear mechanism for the spin relaxation could be determined at low temperature