Electron-pseudophonon interaction and inelastic scattering in suspended graphene

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The suspended graphene sheet has been one of the systems with strain effects on electronic properties of graphene due to the high flexibility[1]. When a graphene sheet is clamped at two parallel leads as illustrated in Fig. 1(a), the deformation of the sheet is induced by applying an electric field which can influence on quantum transport. Especially, it has been reported that a uniform effective vector potential can be induced by considering the elastic deformation[2]. In this study, we show that a time-periodic strain of the suspended graphene produces inelastic scattering of electrons as a consequence of an interaction between electrons and pseudophonons.

We consider the effective vector potential induced by the time-periodic strain is given as

$$\vec{A}(\vec{r},t) = \frac{\beta h_0^2}{6a_0L^2}\left[\theta\left(x+\frac{L}{2}\right)-\theta\left(x-\frac{L}{2}\right)\right]\cos\omega t, \tag{1}$$

where $\beta = C\left(\partial \ln t/\partial \ln a_0\right) \approx 2$ with $C \sim 1$, $t \approx 3\,eV$, $a_0 \approx 1.4\mathring{A}$, $h_0 = \left(4h_0/L^2\right)\left(x^2 - L^2/4\right)$ is the vertical deformation, L is the length of the suspended region, and ω is the frequency of the time-periodic strain. By using Floquet scattering theory, eigenstates of the system is given as

$$\Psi(\vec{r},t) = e^{ik_y y}\sum_{n,m=-\infty}^{+\infty} c_m e^{ik_x^m x} J_{n-m}(\chi)\, e^{-i(E-n\hbar\omega)t}, \tag{2}$$

where $k_x^m = \sqrt{\left[(E+m\hbar\omega)/(\hbar v_F)\right]^2 - \left[k_y + (n\omega)/(v_F\Lambda)\right]^2}$ with $\Lambda = \psi^\dagger\sigma_y\psi$ and $J_{n-m}(\chi)$ is the Bessel function of the first kind with $\chi = \left[(ev_F\beta\Lambda)/(6a_0\hbar\omega)\right](h_0/L)^2$. Electrons can be scattered from pseudophonons by gaining or losing both energy and momentum quanta; $n\hbar\omega$ and $(n\hbar\omega)/(v_F\Lambda)$, as shown in Fig. 1(b). The strength of the electron-pseudophonon scattering is determined by $J_{n-m}(\chi)$.

Our main finding in this study is that the electron-pseudophonon interaction depends on the incident angle of electron since $J_{n-m}(\chi)$ has the angle-dependence. The angle-dependent feature of the electron-pseudophonon interaction allows normally incident electrons to propagate through suspended region without any inelastic scattering despite of the existence of the strain.

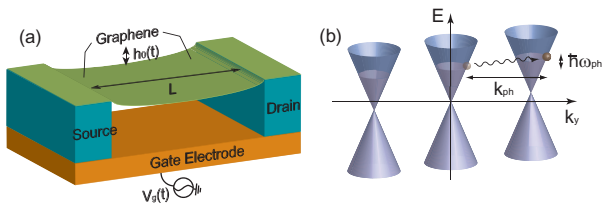

Figure 1: (a) Schematic view of the system. (b) Graphitic diagram of inelastic scattering as a result of the electron-pseudophonon interaction.

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