Transport in gapped bilayer graphene: the role of potential fluctuations

Ke Zou and Jun Zhu

Department of Physics, The Pennsylvania State University, University Park, PA 16802-6300

Online Supporting Information

1. The energy and size distribution of electron and hole puddles in bilayer graphene.

2. The calculation of $\langle \varepsilon_{ij} \rangle$.

3. Raman spectra on dual-gated bilayer graphene.
1. The energy and size distribution of electron and hole puddles in bilayer graphene:

![Figure S1](image1.png)

**Figure S1.** The histogram of $\Phi_{\text{NP}}$ in Fig. 3 of Ref. 1. The blue solid line is a Gaussian fit.

Figure S1 plots a histogram of the charge neutrality point (CNP) potential $\Phi_{\text{NP}}$ of bilayer graphene on SiO$_2$, extracted from scanning tunneling spectroscopy data reported in Fig. 3 of Ref. 1. The solid line is a Gaussian fit which yields $\Phi_{\text{NP}} = (20\pm19)$ meV.

![Figure S2](image2.png)

**Figure S2:** (a) $\Phi_{\text{NP}}$ data in Fig. 3 of Ref. 1. The map is 80 x 80nm. Each color represents a 10 meV step. (b) The histogram of puddle size $L$ from (a). The blue solid line is the best fit by a Gaussian distribution and yields $L = (13 \pm 8.4)$ nm.

Figure S2 (a) shows the spatial map of the same $\Phi_{\text{NP}}$ data in a false color plot. The white area corresponds to $20\pm2.5$ meV, representing a small gap separating electron
and hole puddles. We approximate each puddle as a polygon and estimate the lateral size $L$. Puddles of the same carrier type separated by a barrier of less than 5 meV are joined together and counted as one large puddle. The histogram of $L$ obtained from both electron and hole puddles and from both dimensions is shown as Fig. S2 (b). A truncated and normalized Gaussian fit yields a distribution of

$$P(L) = \frac{1.06}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(L - L_0)^2}{2\sigma^2}\right),$$  

where $L_0 = 13$ nm and $\sigma = 8.4$ nm for $L > 0$ and $P(L)=0$ for $L \leq 0$.

2. The calculation of $\langle \varepsilon_{ij} \rangle$:

We simplify the fluctuating potential as a network of cylindrical potential wells with a fixed depth $V_0$ but varying size $L$ (Fig. 5(a) in the text and Fig. S3) and solve for the eigenenergies of the bound states for different $L$. The resulting $\varepsilon_i(L)$ for $V_0 = 13$ meV and 43 meV are shown in Fig. 5 (b) of the text.

![Figure S3. Localized states in cylindrical potential wells. A narrower well has a higher ground state energy and a wider well may have more than one bound state.](image)

The average energy difference between neighboring states $\langle \varepsilon_{ij} \rangle$ is calculated using the following equation:

$$\langle \varepsilon_{ij} \rangle = \langle \varepsilon_i(L_i) - \varepsilon_j(L_j) \rangle = \int \int [\varepsilon_i(L_i) - \varepsilon_j(L_j)] P(L_i)P(L_j) dL_i dL_j.$$  

For wells with 2 bound states, the 1st excited state is used in the calculation.

3. Raman spectra on dual-gated bilayer graphene.
Figure S4 shows a Raman spectrum taken on sample A1. The spectrum shows the characteristic 2D band of bilayer graphene. No visible D band (1360 cm$^{-1}$) is observed.

Figure S4. Raman spectra on sample A1 taken with 514 nm laser excitation. The horizontal axis scale is different for the G (1580 cm$^{-1}$) and 2D (~2700 cm$^{-1}$) regions.

1 A. Deshpande, W. Bao, Z. Zhao, C. N. Lau, and B. J. LeRoy, Appl. Phys. Lett. 95, 243502 (2009).