Andreev Reflection in N-S junction embedded on hexagonal lattice (Graphene)

Keywords:

I. DISCRETE BDG EQUATION

The BdG equation is

$$E\begin{bmatrix}u(i,\uparrow)\\u(i,\downarrow)\\v(i,\uparrow)\\v(i,\downarrow)\end{bmatrix}=\sum_j H_j\begin{bmatrix}u(j,\uparrow)\\u(j,\downarrow)\\v(j,\uparrow)\\v(j,\downarrow)\end{bmatrix}\equiv\sum_j\begin{bmatrix}-T-\tilde{\mu} & 0 & 0 & \tilde{\Delta}\\0 & -T-\tilde{\mu} & -\tilde{\Delta} & 0\\0 & -\tilde{\Delta}^* & T+\tilde{\mu} & 0\\\tilde{\Delta}^* & 0 & 0 & T+\tilde{\mu}\end{bmatrix}\begin{bmatrix}u(j,\uparrow)\\u(j,\downarrow)\\v(j,\uparrow)\\v(j,\downarrow)\end{bmatrix}. \tag{1}$$

Here $u(i,s)$ and $v(i,s)$ refers to electron and holes localized at site i with spin s. In Eq. (1) we have defined the quantities

$$T=t\sum_{\boldsymbol{\delta}}\delta_{i,j-\delta}+t\delta_{i,j+\delta},\quad \tilde{\Delta}=\Delta\delta_{i,j},\quad \tilde{\mu}=\mu\delta_{i,j}. \tag{2}$$

Here t, μ, and Δ refers to the hopping parameter, Fermi energy, and superconducting gap respectively. In T the sum is over nearest neighbours $\boldsymbol{\delta}=\boldsymbol{\delta}_{1,2,3}$ where,

$$\boldsymbol{\delta}_1=\frac{a}{2}\left(1,\sqrt{3}\right),\quad \boldsymbol{\delta}_2=\frac{a}{2}\left(1,-\sqrt{3}\right),\quad \boldsymbol{\delta}_3=\frac{a}{2}\left(-1,0\right). \tag{3}$$

The Hamiltonian exhibits the particle-hole symmetry

$$PH_j^*P^{-1}=-H_j,\quad \text{with}\quad P=\tau_x\otimes s_0 \tag{4}$$

where $\boldsymbol{\tau}$ and $\boldsymbol{s}$, denote the pauli matrices acting on the charge and spin subspace respectively.