Novel Features of Graphene-based Josephson Junctions

Hu-Jong Lee
Department of Physics and Center for Topological Matter,
Pohang University of Science and Technology (POSTECH), Korea
Email: hjlee@postech.ac.kr

High carrier mobility up to a few tens of thousands cm^2/Vs at room temperature and the gate tunability of the carrier density and the carrier type in graphene are very promising and convenient factors of merit. Graphene-based Josephson junctions, consisting of a graphene layer in contact with two closely spaced superconducting electrodes, provide a unique platform to study superconducting proximity effect [1], phase coherence, superconductor-insulator (S-I) transition, etc., with in-situ gate-tunable Josephson coupling strength. In this talk, I will introduce diverse features of pair transport observed in S-graphene-S proximity Josephson junctions in different device configurations: *i.e*., lateral junctions consisting of i) homogeneous monolayer graphene and p-n junction-type bipolar monolayer graphene, and ii) top-gated bilayer graphene. I will also introduce Josephson junctions consisting of iii) monolayer graphene vertically sandwiched between two superconducting electrodes. For junctions of type i) I will focus on the gate tuning of the Josephson coupling strength, switching current distribution including the macroscopic quantum tunnelling [2,3], and gate-tuned complete switching off of the supercurrent [3]. This feature offers a novel route to manipulate the macroscopic quantum states and provides essential components for developing a superconducting quantum bit (qubit) based on graphene technology. For junctions of type ii) clear manifestation of the S-I transition and its gate tunability will be focused, which confirms the bosonic nature of the S-I transition. For junctions of type iii) I will discuss the short-ballistic Josephson junction characteristics observed in the monolayer vertical junctions and the highly skewed current-phase relation that is in conformation with the short-ballisticity of the junction [4]. All these features in various types of graphene-based Josephson junctions demonstrate the high versatility of graphene both for fundamental studies on phase coherence and for possible quantum-device applications .

[1] H. B. Heersche *et al*., Nature **446**, 56 (2007);
D. Jeong *et al*., Phys. Rev. B **83**, 094503 (2011).
[2] G.-H. Lee *et al*., Phys. Rev. Lett. **107**, 146605 (2011).
[3] J.-H. Choi *et al*., Nat. Commun. 4:2525 DOI:10.1038/ncomms 3525 (2013).
[4] Submitted