Observation of an emerging equilibrium indirect exciton condensate in double bilayer graphene-WSe_2 heterostructures

Burg, G. William[1], Efimkin, Dmitry[2], Prasad, Nitin[1], Taniguchi, Takashi[3], Watanbe, Kenji[3], Register, Leonard F.[1], MacDonald, Allan H.[2], Tutuc, Emanuel[1,*]

[1]*Microelectronics Research Center, Department of Electrical and Computer Engineering, The University of Texas at Austin, Austin, Texas 78758, USA*
[2]*Department of Physics, The University of Texas at Austin, Austin, Texas 78712, USA*
[3]*National Institute for Materials Science, 1-1 Namiki Tsukuba, Ibaraki 305-0044, Japan*
**e-mail: etutuc@mail.utexas.edu*

Electronic double layers, consisting of two two-dimensional (2D) semiconductors separated by a dielectric, are an ideal platform for probing indirect exciton physics. When the two 2D layers are doped with equal and opposite charge densities, at a sufficiently small interlayer separation electrons and holes in opposite layers can couple and form equilibrium indirect excitons. We present here a study of rotationally aligned double bilayer graphene heterostructures, separated by bilayer WSe_2.

Rotational alignment of the graphene bilayers ensures that tunneling between layers conserves both energy and momentum, resulting in tunneling characteristics that agree well with single particle tunneling calculations. By using a dual gated structure with multiple contacts to each layer, we can electrostatically dope each graphene layer individually, and probe the intrinsic tunneling current-voltage characteristics. When the two graphene bilayers are doped with equal and opposite charge densities, the tunneling amplitude is dramatically enhanced relative to single particle expectations, showing a vertical onset at zero interlayer bias. The tunneling enhancement is strongly dependent on temperature, with the enhancement largely suppressed above T = 5 K. Furthermore, the enhancement is fully suppressed by applying an in-plane magnetic field. These experimental observations suggest the emergence of a nascent indirect exciton condensate in double bilayer graphene heterostructures (Fig. 1).

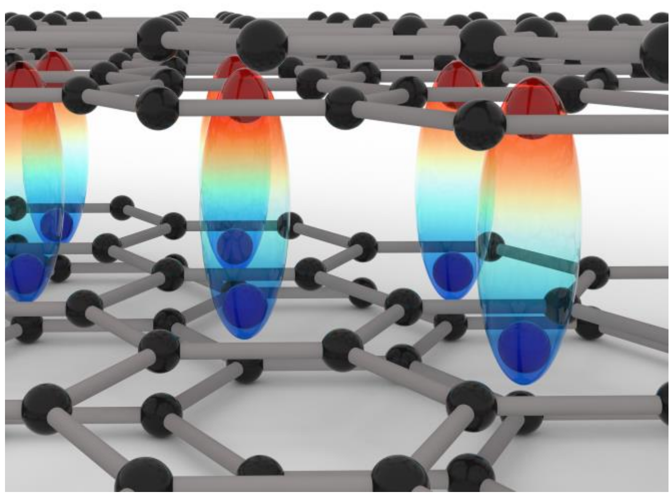

Fig. 1. Schematic illustration of indirect exciton formation in a double bilayer graphene heterostructure.