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Graphene Carrier Control and Band Gap Formation through Stacked Graphene Sheets

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Graphene's use in RF transistors and frequency doublers is attractive since its high mobility and high saturation velocity translate into operation at high frequencies while utilizing little power. However, further graphene development for device applications is hindered by high metal contact resistance, poor control of channel conductivity, and the absence of a band gap. In this talk, I will present our efforts at NRL to address these challenges using two strategies: 1) substitutional insertion of group III-V atoms into graphene's lattice to control the carriers and 2) through a synthetic means to create bilayer graphene with a band gap. Substitutional incorporation of atoms into graphene can result in doping, if their concentration does not drastically affect the π-network. Using selective oxidation to remove C atoms from the graphene lattice, we are able to backfill the C vacancies using molecular beam deposition of dopants with controllable ultra-low fluxes. We will show that boron and phosphorus dopants can provide extra holes and electrons to the graphene π-network, respectively, modifying the carrier concentration in transport measurements. Bernal-stacked graphene bilayers have a relatively small band gap ($\sim$few meV). However, if the symmetry of the system is broken by the application of a large applied electric field, the band gap can be increased ($\sim$250 meV). Alternatively, we find it is possible to obtain such large built-in electric fields when graphene sheets of opposite doping are stacked. By bonding a p-type, CVD-grown graphene monolayer transferred from Cu to an n-type, epitaxially grown graphene monolayer on SiC, we formed a p-n graphene bilayer. Transport measurements and modeling of the resulting electric field generated by opposite doping of the graphene sheets indicate the creation of a 100-300 meV band gap in the synthetic bilayer.

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