Creation of 2D topological insulating states on graphene and few-layer MoS$_2$

Topological insulating (TI) states have attracted large attentions from viewpoints of both basic physics and applications to innovative spintronic devices with topologically protected spins. Three dimensional (3D) TI materials have been well studied, while research of 2D TI states, in which bulk have band gaps while they disappear and the quantum-spin-Hall phases (QSHP) due to helical edge states appear at edges, was rare and only semiconductor quantum wells (e.g., HgTe and InAs/GaSb) were mainstream. However, significantly large topological gaps and high-temperature QSHP have been recently reported in atomically thin layers (e.g., ~0.8eV bulk gap in bismuthene [1] and QSHP up to 100 K in short-channel WTe$_2$ [2]) and are attracting significant attentions.

Here, I will talk about novel two creation methods of 2D TI phases; i.e., Bi$_2$Te$_3$ nanoparticle decoration on graphene [3] and laser-beam irradiation to few-layer MoS$_2$ [4]. The former demonstrates that only 3 % coverage with Bi$_2$Te$_3$ nanoparticle leads to the bulk gaps and QSHP due to the extremely uniform graphene Dirac states. In the latter, on-demand patterning of the bulk gaps with the QSHP on few-layer semiconducting MoS$_2$ is shown by creation of the 1T’ phase due to heat effect by laser-beam irradiation. Moreover, observation of the possible room-temperature (RT) QSHP will be presented, realized using the optimized conditions for laser irradiation. This method must establish the feasible application to RT topological quantum devices by easily patterning QSHP as one wants by laser beam irradiation, such as Majorana-fermion based topological quantum bits.

References

Figure 1: Resistance plateau demonstrating a room-temperature quantum-spin-Hall phase. Inset; laser-beam patterned rectangular topological region with four electrodes for the resistance measurements in main panel.