2022 IBS-CALDES Seminar

- ✓ **Date & Time** 2:00PM, October 14 (Fri), 2022
- ✓ **Zoom ID: 899 7579 1050 / PW: 746176**
- ✓ **Speaker & Title**

02:00PM~ Prof. Takeshi Kondo (U. Tokyo)

Material design with the van der Waals stacking of bismuth-halide chains realizing a higher-order topological insulator

03:10PM~ Dr. Tetsuo Hanaguri (RIKEN)

Toward unambiguous identification of Majorana bound state in the vortex core

Organized by Dr. Jhin Hwan Lee (jhinhwan@ibs.re.kr, 054-279-9894)

- **02:00PM~**

Material design with the van der Waals stacking of bismuth-halide chains realizing a higher-order topological insulator

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Materials with quantum spin Hall insulator layers weakly coupled and stacked on top of each other form Z2 weak topological insulator (WTIs) [1,2], the sides of which are topologically non-trivial and flow a highly directional, non-dissipative spin current. The same concept holds for higher-order topological insulators (HOTIs), which are similarly constructed from stacking quantum spin Hall insulators but, in this case, yield topologically protected one-dimensional helical hinge states. HOTI is a new class of topological insulators predicted in compounds previously thought to as trivial insulators under the Z2 criterion by expanding the topological categorization to the Z4 topological index. The material first proposed to be in the higher-order topological phase is Bulk bismuth [3], which is, however, a semimetal and cannot be made insulating by a simple parameter tuning like carrier doping. The experimental realization of a higher-order topological insulator in a 3D material has been anticipated in materials science. If achieved, it will allow for exploring many quantum phenomena, such as spin currents around hinges and quantized conductance under external fields.

In my talk, I will introduce that the quasi-1D bismuth halides Bi4X4 (where X is either I or Br) provide an excellent platform to realize various topological phases that can be selected by different ways the chain layers are stacked. Bi4I4 with single-layered chains per unit cell consisting of A-stacking develops a WTI state, where quasi-1D topological surface states are realized on the crystal side surface. In contrast, a simple insulator phase is formed in Bi4I4, where the chains adopt a double-layered structure consisting of AA’-stacking. Bi4Br4 is a HOTI candidate in the form of double layers, one of which is flipped by 180 degrees in the unit cell (AB-stacking). Using this material design concept and angle-resolved photoemission spectroscopy, I will demonstrate that Bi4Br4 is a higher-order topological insulator in its three-dimensional bulk state [4].

[1] R. Noguchi et al., Nature 566, 518 (2019).
[2] P. Zhang et al., Nature Communications 12, 406 (2021).
[3] F. Schindler et al., Nature Physics 14, 918 (2018).
[4] R. Noguchi et al., Nature Materials 20, 473 (2021).

▪ **03:10PM~**

Toward unambiguous identification of Majorana bound state in the vortex core

Tetsuo Hanaguri
RIKEN Center for Emergent Matter Science

Majorana quasiparticles have attracted much attention because of their potential applications in fault-tolerant quantum computing. Although there are various theoretical proposals to realize the Majorana quasiparticles in solid, experimental implementations and verifications have been challenging. We argue how to identify the Majorana-bound state (MBS) in the vortex core of superconductors using scanning tunneling microscopy/spectroscopy (STM/STS). Since the Majorana particle is its own antiparticle, it should appear at exactly zero energy. This gives rise to the zero-energy peak in the tunneling spectrum. However, it is often difficult to distinguish the zero-energy MBS from the trivial low-lying states due to the limited energy resolution of STM/STS. Another issue is that the zero-energy peak is merely a necessary condition for the MBS. It is indispensable to search for a feature that is unique to the MBS. We show the results of ultrahigh energy resolution STM/STS in the vortex core of Fe(Se,Te) where we find a zero-energy state below any possible trivial-state energy [1]. We also discuss our attempts to clarify the Majorana character, a unique spin structure of the Majorana vortex core, using a Yu-Shiba-Rusinov-state-based spin-polarized STM/STS that can achieve 100 % spin polarization [2].

[1] T Machida et al., Nat. Mat. 18, 811 (2019).
[2] T. Machida, Y. Nagai, and T. Hanaguri, Phys. Rev. Research 4, 033182 (2022).