FLIP-FLOPPING PHASES

1. GROW THE MATERIAL
   Before you can study cool behavior, you have to create an environment where you’re likely to find it, like a heterostructure.

2. COOL IT DOWN
   Using a cryostat, scientists lower the temperature around the material so they can slow down the atoms and observe the subtle quantum behaviors inside. It’s like looking for a shivering person at a disco. You have to stop the music so the other people quit dancing before you can detect that much more subtle movement. The chillier temps also make the electron gas an even better metal, with the electrons moving more freely.

3. TURN ON THE MAGNET
   The scientists will gradually increase the field strength over the course of the experiment and observe what happens. The negatively charged electrons in the gas respond to the magnetic field by spinning around it. The higher the field, the faster this cyclotron motion, and the more kinetic energy used by the electrons. So begins a tug-of-war between kinetic and potential energy in the system.

4. ELECTRONS LIKE EASY STREET
   There’s no free lunch for electrons. They have to spend energy either moving around, or sitting still on a crystal lattice and overcoming the repulsive force of their neighbors. They default to whichever option requires less energy.

5. ELECTRONS GET WEIRD
   But before this electron gas transitions to another phase, another kind of change occurs. This happens just as the magnetic field reaches a value of about 14 teslas: The electrons turn into composite fermions.

6. WHAT’S A COMPOSITE FERMION?
   As electrons interact with a magnetic field, they can sometimes steal, or spin down, a part of it. In a sense, they become a kind of hybrid particle: a composite fermion.

7. LIQUID TO SOLID
   The liquid’s life is brief. As the magnetic field continues to climb, the liquid transitions into a type of solid called a Wigner solid. The resistance of the system shoots back up. The colder the system, the higher its resistance, i.e., the better an insulator it becomes.

8. SOLID TO LIQUID
   But as the magnetic field reaches about 15 teslas, it’s déjà vu: The resistance takes another nosedive, and the solid reverts to a liquid.

9. WHAT’S A WIGNER SOLID?
   Named after Hungarian-American scientist Eugene Wigner, who first predicted it in 1934, it’s a solid-like state that can occur in electrons in a 2D material at a high magnetic field.

10. WHAT’S A MAGNET?
    The presence of Mg at the interface between ZnO and MgZnO creates an electric field that traps electrons, resulting in a gas of freely moving electrons between the two layers. That in-between gas layer, or heterojunction, is what interests the scientists.

FLIP-FLOPPING PHASES

BY KRISTEN COYNE

Physicists love when matter changes phases. It’s understandable: Even the most mundane of phase changes — water turning solid at 0 degrees Celsius and gaseous at 100 degrees Celsius — are fascinating when you think about them.

Nature has loads of other phase-changing tricks up its sleeve. They can be driven by temperature, as is the case with H2O, or other parameters, such as high magnetic fields.

In an experiment published last year involving scientists from the TWENT Center for Emergent Matter Science, the University of Tokyo in Japan and the High Field Magnet Laboratory (HFML) in the Netherlands, scientists created a material featuring a special two-dimensional gas layer, then subjected it to both high fields and extremely low temperatures. They wanted to see what combinations of field and temperature would prompt that gas to change to a liquid and then a solid. Anytime physicists can provoke a phase transition, they learn a little more about how the world works while gaining knowledge that could one day translate into an advance in electronics, energy or other applications.

What they discovered surprised them. Named this “Slow Train to Science” and check out the stops along the way to learn more.

Science Advisor: Uli Zeitler