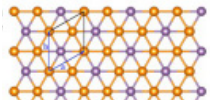

Cu_2Ge: a new 2D topological Semimetal

Among various metal/semiconductor systems, copper/germanium alloys have been studied since the 1990s to understand the formation mechanisms of Schottky barriers, fundamental to diodes of the same name. This system, which felt into disuse, has recently attracted renewed interest due to Density Functional Theory (DFT) calculations. Indeed, these calculations predict that the 2D alloy Cu_2Ge has a band structure with a 1D intersection of valence and conduction bands, characteristic of a topological semimetal with a Dirac nodal line. Members of the Spectroscopy of New Quantum States team at INSP have experimentally demonstrated for the first time that it is possible to synthesize Cu_2Ge on a copper crystal and that its electronic structure exhibits the expected characteristics for the purely 2D case. Its properties make this alloy a promising candidate for high-frequency electronic applications and an ideal system for studying exotic properties that can emerge in nodal line materials.

Two-dimensional materials are widely studied for their exceptional properties, which allow for potential applications in various fields such as photovoltaics, catalysis, microelectronics, and biomedicine. Additionally, some of these 2D systems exhibit topological properties, further increasing the possibility of discovering new electronic behaviors without a bulk equivalent.

Such is the case for Cu_2Ge, an alloy consisting of an atomic plane of copper and germanium. Although Cu/Ge alloys were studied several decades ago for Schottky barrier formation, more recent DFT calculations shed new light on these systems. They reveal that, in the case of a 2D Cu_2Ge layer, the band structure should exhibit three cones intersecting along two closed loops. These «loops» are known as Dirac lines. When these lines are close to the Fermi level, the material gains two noteworthy properties: the potential for higher carrier densities than graphene while maintaining very high carrier velocity.

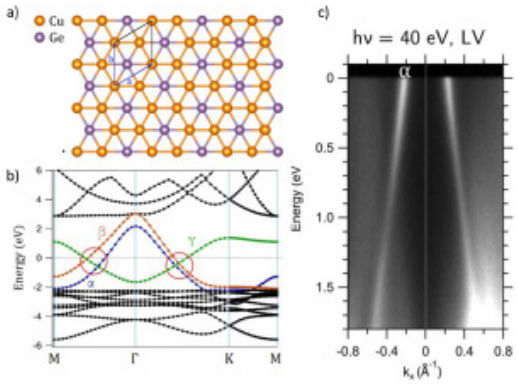

Figure
a) Cu_2Ge atomic structure.
b) Band structure calculated by DFT.
c) ARPES spectrum measured in the Γ-K direction. Only the α band is visible under these polarization and photon energy.

Our experimental results show for the first time that it is possible to synthesize a monolayer of Cu_2Ge by depositing germanium onto a single-crystal copper substrate. Angle-resolved photoemission spectroscopy (ARPES) measurements performed on the URANOS beamline at the Solaris synchrotron, combined with DFT calculations, confirm the stoichiometry of the alloy. Additionally, the measured band structure displays the expected characteristics for a "free-standing" Cu_2Ge layer, with two Dirac lines originating from the intersection of three linearly dispersing bands, demonstrating that 2D alloy/substrate interactions are very weak in this system.

Reference
Synthesis and characterisation of Cu_2Ge, a new two-dimensional Dirac nodal line semimetal
Cameau, Mathis; Olszowska, Natalia; Rosmus, Marcin; Silly, Mathieu G.; **Cren, Tristan; Malecot, Axel; David, Pascal; D'angelo, Marie**
2D Materials, 11 035023 (2024)

Contact
Marie D'angelo : dangelo(at)insp.jussieu.fr

Our work proves the interest of Cu_2Ge for high-frequency electronic components. Finding a suitable insulating substrate for its growth would be a decisive step towards these applications. Fondamentally, Cu_2Ge on copper appears to be a simple material for experimentally studying the emergence of exotic properties in nodal line systems.

Reference

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