19th INTERNATIONAL CONFERENCE ON DIFFUSION IN SOLIDS AND LIQUIDS
DSL2023
HERAKLION, CRETE | GREECE
26-30 JUNE 2023

ABSTRACT:

Structural and Electronic Properties of Germanene Synthetized by Segregation Through Thin Metallic Films

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Germanene is an artificial two-dimensional graphene-like germanium allotrope predicted to be a near room temperature topological insulator, belonging to the class of so-called Xenes. It was synthesized in 2014, exactly ten years after the isolation of graphene, and just two years after the archetype growth of silicene, the first Xene ever produced. The canonical germanene paper, described its top-down synthesis by Ge deposition onto a Au(111) crystal, but revealed multi-phases [1]. Instead, we will show that a single germanene phase, as evidenced in Scanning Tunneling Microscopy in situ imaging, is obtained by Ge segregation on top of a thin Au(111) film epitaxially grown under ultra-high vacuum on a Ge(111) template, that is, through a bottom-up approach. This segregation process was directly visualized ex-situ in high-resolution Scanning Electron Microscopy. The most striking signature of this single germanene phase is a characteristic Low Enery Electron Diffraction pattern, curiously featuring 24 spots in 12 doublets forming a ring. This intriguing LEED pattern was already observed in 1971 [2], but remained undeciphered for more than half a century. A first interpretation in terms of segregated germanium forming four epitaxial rotated germanene domains on top of flat Au(111) islands [3] was initially proposed by analogy with the formation of germanene layers the other way around, i.e., upon in situ deposition of germanium onto bulky Au(111) single crystals [1]. Since then, other interpretations involving intermixing [4] and two-dimensional germanium-gold surface alloys were suggested [5].
This unique germanene phase is characterized by sharp Ge 3d and Au 4f core-levels in synchrotron radiation PhotoElectron Spectroscopy, and the emergence in angle-resolved PES measurements of Dirac fermions around the Brillouin zone center with a Fermi velocity of ~0.8 106 ms -1, quite close to that of graphene [6].
Moreover, preliminary studies performed on thin gold film epitaxially grown on a Ge(110) template will be shortly presented.

[1] M.E. Dávila et al., New Journal of Physics, 16, 095002 (2014)
[2] G. Le Lay, Thesis, Marseille (1971)

[3] G. Le Lay et al., Surf. Sci., 123, 117 (1982)
[4] E.D. Cantero et al., Phys. Chem. Chem. Phys., 19, 18580 (2017)
[5] D. A. Muzychenko et al., JETP Letters, 106, 217 (2017)
[6] M. Minissale et al., Crystals 13, 221 (2023)