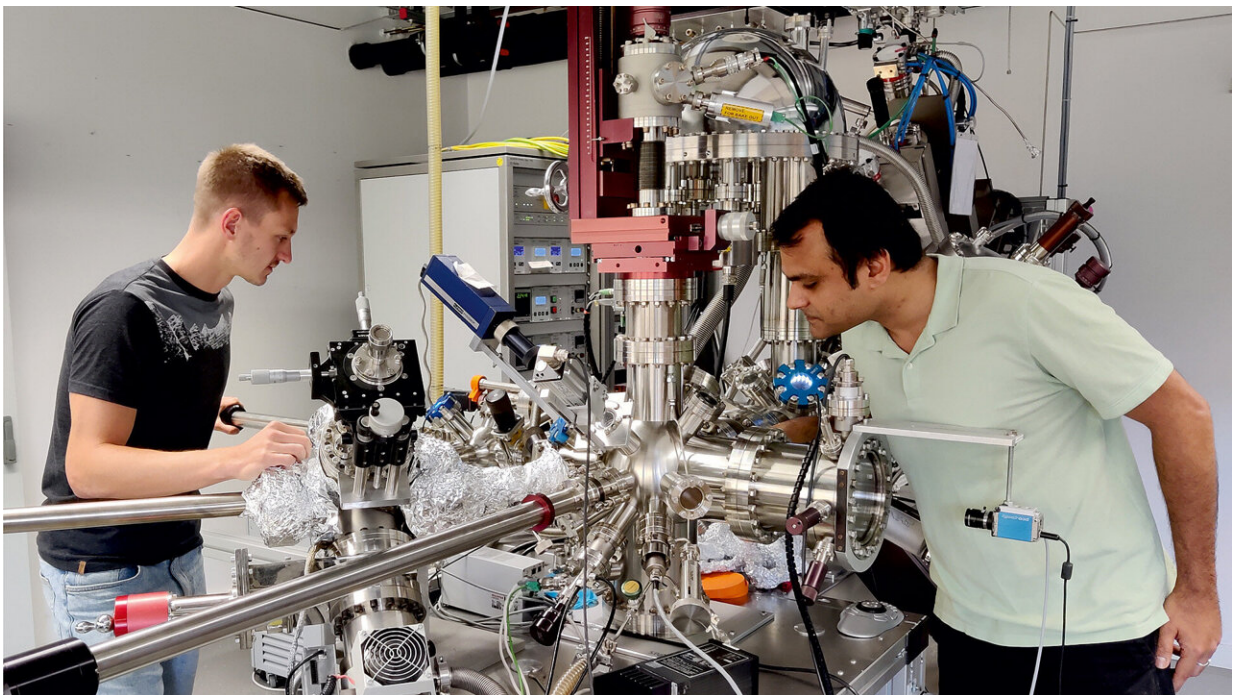


Study demonstrates construction of monoatomic lead layers with specially developed method for the first time

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Chritran Ghosal (r.) and Dr Philip Schädlich examine the electronic properties of the 2D meat layers in a laboratory at the TUC's Institute of Physics. Credit: Franziska Schölzel, Chemnitz University of Technology

In a recent publication in the journal *Advanced Materials Interfaces*, the research team led by first author Dr. Philip Schädlich, a research

associate at the Professorship of Experimental Physics, presents a method for the detailed structural analysis of synthesized two-dimensional lead layers on a specially manufactured system for the first time.

The approach has also made it possible to produce samples of sufficient quality to comprehensively describe the structures. The new insights from this research could become relevant in the development of novel electronic systems and in the development of quantum materials for quantum computing.

"Our synthesis, together with a meticulous data analysis by the various groups, has now achieved this comprehensive picture of the two-dimensional lead layers," says Philip Schädlich. "The controlled coupling of functionalized graphene to 2D electron gases opens up the possibility to investigate and control correlation effects and mesoscopic phenomena in 2D materials—for example superconductivity, spin or charge density waves and novel magnetic phases," says Seyller.

To investigate these kinds of systems, the researchers work across disciplines and locations. Partners from Jülich, Lund (Sweden), Hamburg, Regensburg, Göttingen, Stuttgart, and Braunschweig were involved. "The high degree of mixing with different professional competencies in our research group is necessary to be able to explore all facets of such complex problems in detail. Only in this way can structural and electronic properties of the self-made systems be linked," says Prof. Dr. Christoph Tegenkamp, spokesman for the DFG research group.

Trick of nature: Domain boundaries in response to unsaturated bonds

"The structure formation of the 2D lead layer is based on motifs that we know from previous experiments on the adsorption of lead on silicon surfaces," explains Dr. Philip Schädlich, who coordinated most of the experiments. However, the flexibility of the lead bonds leads to a great variety in the phase diagram, for which the term "devil's staircase" has been established.

In contrast, in the current experiment, the lattice mismatch between the substrate and the lead layer results in a shortage of lead atoms per silicon atom of the substrate, resulting in strains in the lead and unsaturated bonds on the substrate surface.

The researchers now know why this is. "It's a trick of nature. The lead layer forms domains in which the lead atoms relax locally to their favorite distance and which are small enough so that the total offset between the lead and substrate lattice is not too large," Schädlich explains.

"To do this, the centers of neighboring domains have to be slightly offset against each other, so that the resulting boundaries of the domains just contain enough lead atoms to automatically also compensate all unsaturated bonds," explains Chitran Ghosal, a doctoral student in Prof. Tegenkamp's working group.

Great importance of domain boundaries

The structure of the lead layer also has an impact on the graphene. Because the evaluation of the data showed a vanishingly low charge carrier concentration, which is about 1,000 times lower than in epitaxial graphene. "Unlike significantly more efficient intercalants such as hydrogen, the lead layer also manages to shield or compensate the spontaneous polarization of the substrate and thus provide for quasi-charge neutrality," Ghosal continues.

In addition, with the help of scanning tunneling microscopy at low temperatures of 4 Kelvin (approx. -269° Celsius), the fingerprint of a so-called Kekulé ground state was revealed. Here too, the domain boundaries play a major role, as the electrons scattered on them, due to charge neutrality, only have a limited phase space available.

More information: Philip Schädlich et al, Domain Boundary Formation Within an Intercalated Pb Monolayer Featuring Charge-Neutral Epitaxial Graphene, *Advanced Materials Interfaces* (2023). [DOI: 10.1002/admi.202300471](https://doi.org/10.1002/admi.202300471)

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