Heterostrain physics in twisted graphene layers

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PhD may follow: Yes

Summary :

The study of twisted graphene layers (graphene layers stacked with a rotation between the layers) has been recently boosted by the discovery of new correlated states of matter (superconductivity and Mott insulator) in this full carbon system. Such new physics occurs due to electron-electron interactions boosted at peculiar rotation angles between the layers. We have recently shown that the electronic properties of such not only depend on the rotation between the layers but also on relative deformations of the layers which we have called heterostrain. The aim of the present project is to control and study heterostrain, hunting for potential new states of matter.

Full description :

We are looking for a motivated candidate for a Phd project preceded by a master's training on heterostrain in twisted graphene layers.

A moirÃ© appears in twisted graphene layers which results from the superposition of the two atomic lattices with a rotation angle (See figure below). The resulting moirÃ© potential has been shown to lead to a pletora of new physical phenomena. From van Hove singulatities which energy is tunable by the twist angle [1], to electron localization by the moirÃ© potential [2] and the creation of topologically protected one-dimensional states in systems with very low rotation angle [3]. Year 2018, was very fruitful for this system with the report of three important resultsÂ :

1) Superconductivity was demonstrated to emerge in twisted graphene layers when the rotation angle is carefully adjusted to a precise â€˜magic' value [4].

2) The system was reported to be a quasi-cristal (system with rotational symetry but no translationnal symmetry) when the rotation angle is 30Â° [5]

3) The electronic properties of the system were shown to be determined not only by the rotation angle between the layers but also by relative deformations of the layersÂ : heterostrain [6].

This last discovery was made in our group using a formalism developed by a former PhD student to quantify heterostrain and performing scanning tunneling microscopy measurements on samples where the heterostrain was native (resulting from the growth). While these have opened a new area of research by demonstrating the impact of heterostrain we have at present no control of this parameter. The Phd project therefore aims at developing ways to control heterostrain to be able to study its influence on the electronic properties by low temperature STM and possibly discover new states of matter. The attendee with a strong background in condensed matter physic will be involved at all steps: sample preparation, design and fabrication of the system allowing to tune heterostrain, STM measurements and analysis. The analysis will be done in collaboration with the Theoretical team of Cergy Pontoise which has a long experience in twisted graphene layers.

References

[1] G. Lucian et al. Nature Physics 6, 109 (2010)

[2] G. T. de LaissardiÃ¨re et al. Nanoletters 10, 804 (2010)

[3] S. Huang et al. Phys Rev. Lett. 121, 037702 (2018)

[4] Y. Cao et al. Nature 556, 43 (2018)

[5] S. J. Ahn et al. Science 361,782 (2018)

[6] Huder et al. Phys Rev. Lett. 120, 156405 (2018)

Requested skills :

Condensed matter physics, experiments