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TWISTRONICS

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Annotation. With the development of technology, new fields of science appear. One of these fields is twistronics. This article will examine the essence of twistronics, its history, the application of twistronics for bulk systems and its future perspective.

Keywords: twistronics, material properties, material layers, research, development.

Introduction. Twistronics is a field of study that emerged from the intersection of nanotechnology and materials science. This novel field has introduced innovative implications for our understanding of physics and the potential development of futuristic technologies.

The term Twistronics comes from two words – twist and electronics. It was first presented by the research group of Efthimios Kaxiras at Harvard University. So, Twistronics is the field of science that examines how the twist angle between layers of two-dimensional materials can aler their electrical properties.

Main part. The unusual aspect of Twistronics is that it allows manipulation of electronic properties through the twist angle, resulting in dramatically different behavior in the same material. This control is unprecedented and could open up new pathways in electronics and materials science. For example, bilayer graphene (Figure 1) has been shown to have vastly different electronic behavior, ranging from non-conductive to superconductive, that depends sensitively on the angle between the layers. The basic principle of twistronics comes from the Moiré patterns that form when two regular patterns are overlaid at a slight angle. A Moiré pattern is a large-scale interference pattern that can be seen with the naked eye. In the context of twistronics, these patterns form when two 2D lattices of atoms are overlaid with a small twist angle, causing the lattice to stretch and deform at a larger scale [1].

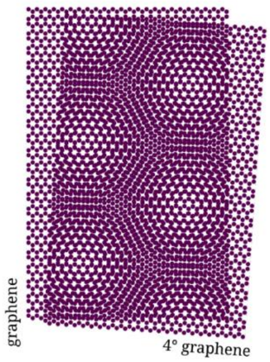

Figure 1 – Atomic scale moiré pattern created by overlapping two skewed sheets of graphene, a hexagonal lattice composed of carbon atoms

National University of Singapore physicist Antonio Castro Neto in 2007 suggested that squeezing two misaligned sheets of graphene together could produce new electrical properties, and separately suggested that graphene might be a route to superconductivity, but he did not combine these two ideas.

In 2010 researchers from Federico Santa María Technical University (Universidad Técnica Federico Santa María) in Chile discovered that for a certain angle close to 1 degree the band of the electronic structure of twisted bilayer graphene became completely flat, and because of that theoretical property, they hypothesized the possibility of collective behavior.

In 2011, Allan McDonald (of the University of Texas at Austin) and Rafi Bistritzer, using a simple theoretical model, found that for a previously identified «magic angle» the amount of energy required for a free electron to tunnel between two sheets of graphene changes radically.

In 2017, the research group of Efthimios Kaxiras at Harvard University used detailed quantum mechanics calculations to reduce uncertainty in the twist angle between two graphene layers that can induce extraordinary behavior of electrons in this two-dimensional system.

In 2018, Pablo Jarillo-Herrero, an experimentalist at MIT, found that the magic angle resulted in the unusual electrical properties that Allan MacDonald and Rafi Bistritzer had predicted. At 1.1 degrees rotation at sufficiently low temperatures, electrons move from one layer to the other, creating a lattice and the phenomenon of superconductivity.

Publication of these discoveries has generated a host of theoretical papers seeking to understand and explain these phenomena, along with numerous experiments using varying numbers of layers, twist angles and other materials. Subsequent works showed that electronic properties of the stack can also be strongly dependent on heterostrain, especially near the magic angle, enabling potential applications in straintronics [2].

Current Twistronics methods rely on laying down thin, individual film monolayers, which is time-consuming. The question is whether moiré-like phenomena can be detected in thicker, three-dimensional film-like structures at room temperature. MIT scientists have discovered that the optical properties of multilayer hexagonal boron nitride (hBN) films thicker than 100 nm can be continuously tuned by changing their relative twist angles. It was found that at room temperature, the relative twist angles of stacked hBN thick films could be used to continuously alter both intensity and colour, with intensity increasing by more than 40-fold [3].

The results pave the way for new ways to control the optical properties of thin films that go beyond conventional structures, especially for applications in medicine, the environment and information technology. Twistronics has opened the door to an entirely new field of research in which the properties of materials can be changed simply by twisting layers of material.

Electronic circuits, for example, are made up of a limited number of components, such as metallic conductors, insulators, semiconductors, and magnetic elements. This method requires the incorporation of a number of different materials and can be a significant engineering challenge. On the other hand, a single twistronic device that can be locally «twisted» to implement each of these components could open up new important engineering possibilities.

In addition, twistronics can help develop new switching technologies such as tunable sensors and tunable electro-optical systems. Exotic quantum phenomena such as correlated phases of dielectrics, superconductivity, and ferromagnetism on twistronics are especially appealing to quantum physics.

Conclusion. In conclusion, it can be underlined that twistronics is currently being used in some areas of science, but at the same time this branch of physics is being actively studied, and the future research results will be used in the development and creation of new technologies for use in human life. The significance of twistronics lies not only in its current discoveries but also in its vast untapped potential. With the appropriate strategies and collaborative effort, twistronics can pave the way for unparalleled scientific insights and transformative applications, reshaping our understanding of quantum phenomena.

References

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