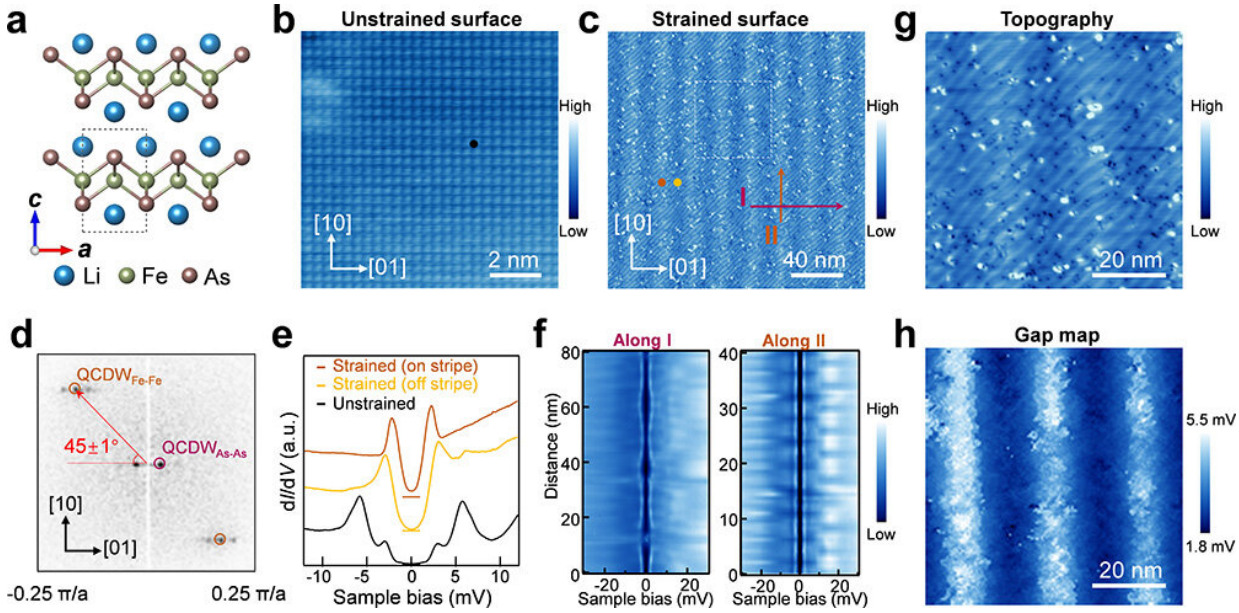
Scientists observe large-scale, ordered and tunable Majorana-zero-mode lattice

June 10 2022, by Zhang Nannan



Characterization of biaxial CDW region. Credit: Institute of Physics

In a study published in *Nature* on June 8, a joint research team led by Prof. Gao Hongjun from the Institute of Physics of the Chinese Academy of Sciences (CAS) has reported observation of a large-scale, ordered and tunable Majorana-zero-mode (MZM) lattice in the iron-based superconductor LiFeAs, providing a new pathway toward future topological quantum computation.

MZMs are zero-energy bound states confined in the topological defects of crystals, such as line defects and magnetic field-induced vortices. They are characterized by scanning tunneling microscopy/spectroscopy (STM/S) as zero-bias conductance peaks. They obey non-Abelian statistics and are considered building blocks for future topological quantum computation.

MZMs have been observed in several topologically nontrivial iron-based superconductors, such as Fe $(Te_{0.55}Se_{0.45})$, $(Li_{0.84}Fe_{0.16})$OHFeSe, and $CaKFe_4As_4$. However, these materials suffer from issues with alloying-induced disorder, uncontrollable and disordered vortex lattices, and the low yield of topological vortices, all of which hinder their further study and application.

In this study, the researchers observed the formation of an ordered and tunable MZM lattice in the naturally strained superconductor LiFeAs. Using STM/S equipped with magnetic fields, the researchers found that local strain naturally exists in LiFeAs. Biaxial charge density wave (CDW) stripes along the Fe-Fe and As-As directions are produced by the strain, with wavevectors of $\lambda 1$~2.7 nm and λ_2~24.3 nm. The CDW with wavevector λ_2 shows strong modulation on the superconductivity of LiFeAs.

Under a magnetic field perpendicular to the sample surface, the vortices emerge and are forced to align exclusively along the As-As CDW stripes, forming an ordered lattice. The reduced crystal symmetry leads to a drastic change in the topological band structures at the Fermi level, thus transforming the vortices into topological ones hosting MZMs and forming an ordered MZM lattice. Moreover, the MZM lattice density and geometry are tunable by an external magnetic field. The MZMs start to couple with each other under high magnetic fields.

This observation of a large-scale, ordered and tunable MZM lattice in

LiFeAs expands the MZM family found in iron-based superconductors, thus providing a promising platform for manipulating and braiding MZMs in the future, according to the researchers.

These findings may shed light on the study of topological quantum computation using iron-based superconductors.

More information: Meng Li et al, Ordered and tunable Majorana-zero-mode lattice in naturally strained LiFeAs, *Nature* (2022). DOI: 10.1038/s41586-022-04744-8

Provided by Chinese Academy of Sciences