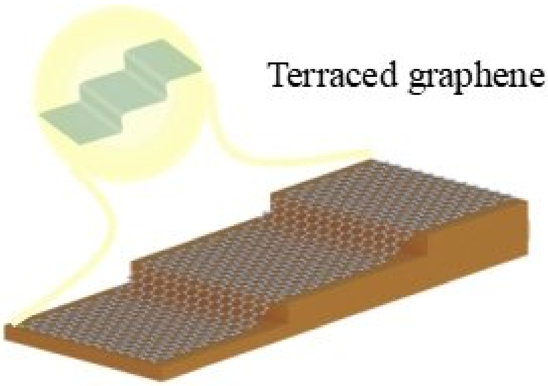
Terraced graphene for ultrasensitive magnetic field sensor

September 28 2020



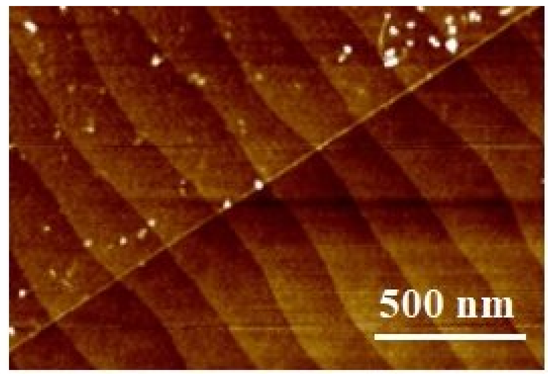


Figure shows (left) the concept of the terraced single-layer graphene formation. This is similar to the terraced paddy fields used widely in Asia for agriculture. (Right) Atomic force microscopy image of the terraced morphology for graphene on strontium titanate (STO, top left) and bare STO substrate (bottom right). Credit: Advanced Materials

National University of Singapore physicists have developed a sensitive two-dimensional (2-D) magnetic field sensor, which can potentially improve the detection of nanoscale magnetic domains for data storage applications.

Magnetoresistance (MR), the change in the electrical resistance of a material due to the influence of an external magnetic field, has been widely used in magnetic sensors, magnetic memories and hard disk drives. However, in traditional three-dimensional (3-D) material-based magnetic sensors that use giant MR (GMR) or tunneling MR (TMR) spin-valves, the detectable signal of the magnetic field decays exponentially with the thickness of its sensing layer. This limits the spatial resolution and sensitivity of the sensors. Therefore, a 2-D-based sensor can potentially improve the detection of minuscule magnetic fields, as the decay is limited to only one atomic layer thickness.

Graphene is an atom-thick thin material with high mobility and high current carrying capability. By adding a graphene layer on top of an artificial terraced substrate, the research team led by Prof Ariando from the Department of Physics, NUS has developed a 2-D magnetic sensor with an electrical resistance that can increase its original value 50-fold at room temperature. This is ten folds higher than that reported on previous single-layer graphene devices at the same conditions.

The detection of nanoscale magnetic domains is a fundamental challenge. As magnetic domains become smaller (nanoscale), the dimensions of the sensor need to be reduced accordingly to maintain the high spatial resolution and signal-to-noise ratio. However, for traditional 3-D material-based sensors, the reduction in size will lead to thermal magnetic noise and spin-torque instability. The recent discovery by the team paves the way for the development of 2-D magnetic field sensors that can operate at room temperature for the detection of nanoscale magnetic domains. This can improve the performance of scanning probe magnetometry, biosensing, and magnetic storage applications.

Mr Junxiong Hu, a Ph.D. student on the research team, said, "The core part of the 2-D magnetic sensor is the terraced graphene formed by stacking graphene on an atomically terraced substrate. The process is similar to placing a carpet on a staircase."

Due to its flexibility, the graphene will also replicate the staircase morphology. During this process, topographic corrugations and charge puddles will be induced in the terraced graphene. In the presence of a magnetic field, the current in the terraced graphene will not travel in a straight line but is strongly distorted by the discontinuities at the boundary of the puddles, causing a significant change of its resistance.

Prof Ariando said, "This technology has the potential for developing the next generation of highly sensitive sensors for the detection of the nanoscale magnetic domains. The single-layer graphene films used for the sensor can be manufactured by batch production for scalability."

The research team has filed a patent for the invention. Following this proof-of-concept study, the researchers plan to optimize the terraced geometry further and adapt it for large-scale production techniques. This will then scale up their experimental outcomes leading to the manufacture of industry-size wafers for commercial use.

More information: Junxiong Hu et al. Room-Temperature Colossal Magnetoresistance in Terraced Single-Layer Graphene, *Advanced Materials* (2020). DOI: 10.1002/adma.202002201

Provided by National University of Singapore