Positive in-plane magnetoresistance induced by nanodomain boundaries in graphene

Graphene supports long spin lifetimes and long diffusion lengths, making it promising for spintronics. However, rendering graphene magnetic remains a fundamental challenge. Among the different types of graphene, graphene with zig-zag edges and ripples are the most promising candidates, as zig-zag edges are predicted to host spin-polarized electronic states and ripples can induce spin–orbit coupling (SOC). We investigated the magnetoresistance (MR) of graphene grown on SiC/Si(001) wafers, in which inherent nanodomain boundaries (NBs) sandwich zig-zag structures between adjacent ripples of large curvature (Fig 1b). Localized states at the NBs result in an unprecedented positive in-plane MR (Fig 1c). Our work may offer an exciting way to add the spin degree of freedom to graphene.

Figure 1d shows the calculated charge density distribution under various bias voltages. An obvious charge density accumulation occurs at the NB, and when the bias is increased to a value of 0.5 V, the charge density begins to spread across to the NB. The charge density is greater along the NB than in the pristine graphene, clearly demonstrating the 1D transport properties of the NBs at low bias voltages. Furthermore, the large curvature at the ripples of the graphene can result in SOC. To investigate the spin-dependent transport across the NBs with weak SOC, we calculated the spin density distribution under a bias voltage of 0.4 V in Fig. 1e. Clearly, only electrons with a particular spin can cross the NBs under a bias voltage of 0.4 V, indicating that NBs with ripples can work as spin filters and that the SOC at ripples causes spin-dependent energy splitting. Moreover, when an in-plane magnetic field is applied perpendicular to the NBs, fewer electrons can cross the NBs, implying a positive MR, which is consistent with the MR calculation. We also investigated the length variation in the NB, disorder within a single NB, and orientation of the magnetic field. The relative strengths of the spin filter and confinement effects are shown to be only marginally influenced, and the fundamental phenomenon is still observed.

The NBs with ripples are shown to have the potential to work as a spin filter and can result in a positive MR at low temperature. Moreover, our work suggests that graphene with NBs has localized states and large spin-orbit interaction at the ripples. The confinement of electrons of a particular spin direction from 2D to 1D NBs by the Zeeman effect is responsible for the positive MR observed at high temperatures.

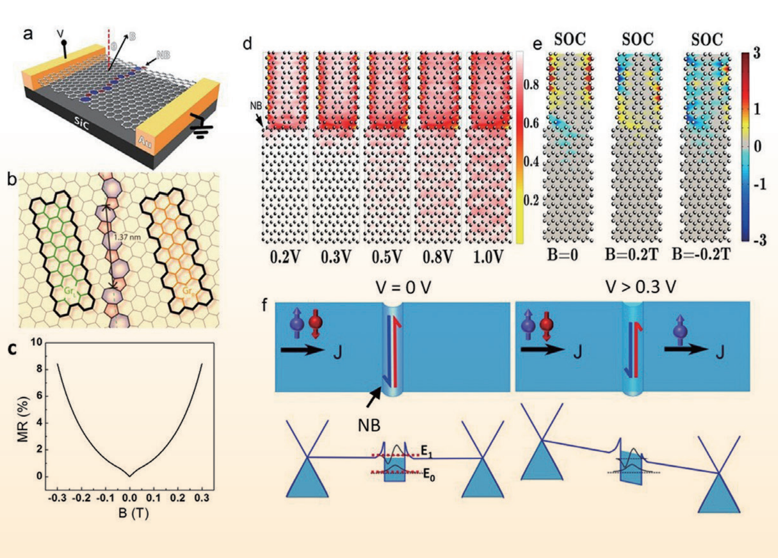

Figure 1. MR and spin filtering effect of graphene containing a single NB. (a) Schematic drawing of the model used. (b) Schematic drawing of the structure of an NB. (c) MR of graphene containing a single NB calculated with an in-plane magnetic field. (d) Calculated charge distribution at different bias voltages. (e) Calculated spin density distribution perpendicular to graphene plane under a bias voltage of 0.4 V to demonstrate the spin-filtering effect due to the localized state of an NB and SOC of 0.1 meV at ripples. The sign indicates the orientation of the spins. (f) Schematic electrical transport and spin-filtering effect due to localized state of NBs and SOC at ripples.

Reference
Han-Chun Wu, Alexander N. Chaika, Ming-Chien Hsu, Tsung-Wei Huang, Mourad Abid, Mohamed Abid, Victor Yu. Aristov, Olga V. Molodtsova, Sergey V. Babenkov, Yuran Niu, Barry E. Murphy, Sergey A. Krasnikov, Olaf Lübben, Huajun Liu, Byong Sun Chun, Yahya T. Janabi, Sergei N. Molotkov, Igor V. Shvets, Alexander I. Lichtenstein, Mikhail I. Katsnelson & Ching-Ray Chang (2017). Large positive in-plane magnetoresistance induced by localized states at nanodomain boundaries in graphene. *Nature Communications, 8*, 14453. DOI:10.1038/ncomms14453.

Professor Ching-Ray Chang
Department of Physics
crchang@phys.ntu.edu.tw

Evidence-based international recommendations for difficult biliary access

A must-read for endoscopists

Endoscopic retrograde cholangiopancreatography (ERCP) is the preferred treatment for bile duct stones and plays an important role in the management of various diseases of the bile duct and pancreas. The first step in ERCP is advancement of the endoscope to the bile duct opening in the duodenum followed by entry into the bile duct; further endoscopic therapy is then administered. Difficulty achieving biliary access is a commonly encountered challenge, with an estimated incidence of 11% in patients with normal anatomy. In patients with altered anatomy of the gastrointestinal tract due to previous surgeries, the incidence of difficult biliary access is even higher, and special instruments and techniques are often needed. Various approaches are currently used to manage difficult biliary access, including advanced endoscopic techniques and methods involving specialized endoscopic equipment. However, there is little consensus regarding the optimal approach for each condition that leads to difficult biliary access.

To provide endoscopists with evidence-based recommendations for managing difficult biliary access, researchers from the Department of Internal Medicine of National Taiwan University Hospital organized a panel of leading experts from different countries to review available evidence from existing research and generate consensus recommendations using the modified Delphi method. A total of 13 statements were generated and presented along with corresponding supporting evidence as well as grades for this evidence and the recommendations.

This consensus provides a standardized definition of difficult biliary access as the inability to achieve access via standard ERCP techniques within 10 minutes or up to 5 attempts or failure to access the bile duct opening. An increased risk of post-ERCP pancreatitis with difficult biliary access and the need to implement measures to reduce the risk of pancreatitis are highlighted. For patients with normal anatomy, available salvage techniques and the experts' preferences in various clinical scenarios are discussed in detail, with consideration of success and complication rates. For patients with surgically altered anatomy, the utility of device-assisted enteroscopy and the emerging technique of endoscopic ultrasound-guided biliary access are discussed and compared.