AT THE TECHNOLOGY FRONTIER

Among other things, these Chinese researchers are BRINGING US SMALLER DEVICES and are poised at the cutting-edge of semiconductor and quantum technology research.

Semiconductor technologies are the bedrock of the information industry and support economic development and national defence in today's information age. In 1988, against a backdrop of booming semiconductor technologies, the State Key Laboratory of Superlattices and Microstructures (SKLSM) was founded based on the proposal of the late semiconductor physicist, Huang Kun, a pioneer in solid state physics. It is one of two state key laboratories at the Institute of Semiconductors of the Chinese Academy of Sciences (CAS), China's key base for semiconductor technology and research, and the country's only state key laboratory focused on fundamental semiconductor physics.

Geared towards cutting-edge research, SKLSM has been committed to studying low-dimensional semiconductor structures—the sometimes one-atom thick material graphene is a famous example—and quantum structures to explore new physical phenomena and novel device applications. The laboratory's research ranges from looking at basic theory, the basic physical properties and the functions of micronano devices, to studying material growth and the applications of semiconductor optoelectronic devices. It aims to boost China's semiconductor research and enhance technological innovation in electronic, optoelectronic and optic information technologies.

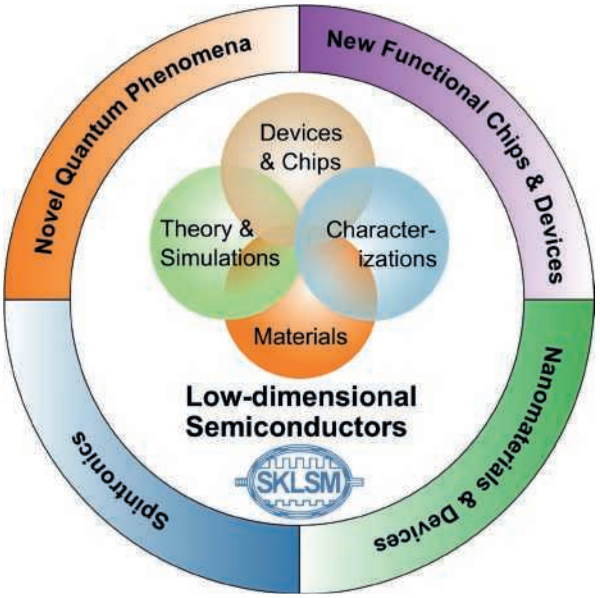
Remarkable research achievements

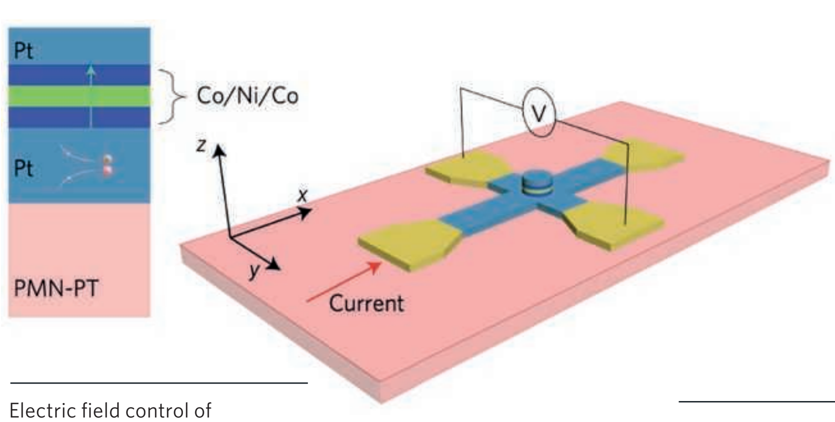
The efforts of generations of researchers mean SKLSM has achieved a series of globally recognized results in semiconductor physics and devices, and has won multiple national natural-science awards. Specifically, these achievements are concentrated in its four major research areas: novel quantum phenomena in semiconductors; spintronics; nanomaterials and devices; and, semiconductor devices and chips with new functionalities.

As early as the 1980s, SKLSM researchers started exploring spintronics, including the properties of electron spin and devices exploiting these spin properties for information processing. They now focus on two-dimensional electron gas systems, common in transistor-like semiconductor structures, to study the quantum Hall effect. Working on (Ga,Mn)As—a magnetic semiconductor that also exhibits ferromagnetic characteristics—the team found a way to enhance its Curie temperature, solving a problem that has puzzled many scientists in spintronics. Their approach combines heavy Mn-doping with micronano processing. It has increased the Curie temperature to 200 K, a world record, and made the application of this popular spintronic material possible. More recently, the team gave evidence, for the first time, of the presence of a robust orbital two-channel Kondo effect in an electron system with significant spin polarization and they realized electric field control of deterministic current-induced ferromagnetization switching at room temperature without external magnetic field.

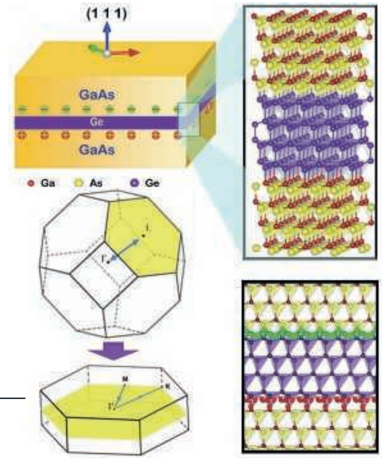
SKLSM researchers' exploration of novel quantum phenomena is primarily focused on theoretical and experimental research on the physical properties of low-dimensional quantum structures. It has led to original results in the control of energy bands, the band gaps in semiconductors, and the optical mechanisms of two-dimensional materials.

For the first of these, SKLSM researchers theoretically demonstrated that the band gap of semiconductor quantum wells can be modulated using an extremely strong local electric field. The work enables large-range modulation of the band gaps of semiconductor





Electric field control of deterministic current-induced magnetization switching in a hybrid ferromagnetic/ ferroelectric structure



Interface-induced topological insulator transition in GaAs/Ge/ GaAs quantum wells

materials, including indium nitride, silicon and germanium. This can be applied to fabricating novel wide-spectrum semiconductor devices. SKLSM researchers also developed new methods to simulate ultra-fast processes in semiconductors and million-atom scale devices.

Nanoscale semiconductor materials, with their unique physical properties and improved functions, have wide application potentials in information technology, biomedicine, energy and environmental protection. SKLSM researchers have systematically studied the physical properties and functions of low-dimensional semiconductor materials using high-powered computation, and devised experimental techniques to study two-dimensional layered materials. Their exploration of the latter has led to the fabrication of a GaS infrared photodetector with optimised electronic, optical and mechanical properties. They also found that novel very thin two-dimensional metal sulphides can be used in high-efficiency nanosensors, photodetectors, field-effect transistors and other micro-nano photoelectric devices.

Applying molecular beam epitaxy technology, a technique for making crystals, SKLSM researchers have also grown high-quality semiconductor nanowires. The InAs nanowires grown on Si substrates have great potential for application in nano devices with low power dissipation.

Aiming at finding applications in smart wearable devices, SKLSM researchers have developed a series of low-dimensional and organic semiconductor materials that are flexible. These include: flexible photodetectors based on one-dimensional inorganic semiconductors and organic-inorganic hybrid semiconductors; flexible energy storage devices, such as a flexible supercapacitor; and, various micro-nano systems that integrate energy storage and photodetection. Their results have earned the laboratory an international reputation.

The research team on semiconductor devices and chips have also developed a series of novel devices. With a focus on infrared optical devices, their inventions include InGaAsSb quantum well lasers, InAs/GaSb supperlattice detectors and InAs/GaAs quantum dot light-emitting sources. In generating a quantum dot single-photon source in 0.85-1.31 µm wave band, they observed single-photon coherent scattering of quantum dots and achieved two-photon interference without the need to independently adjust quantum systems.

Harnessing future technologies

With the advancement of semiconductor information technologies, solid devices are becoming smaller and increasingly use low-dimensional materials. The large power dissipation caused by quantum mechanical effects has become a bottleneck issue for the development of modern information technology. As a result, harnessing quantum information technologies to explore new approaches to computation, coding and information transmission is essential.

Studying the quantum physics processes of low-dimensional semiconductors is at the cutting-edge of solid state physics research and is also the basis for quantum information technology. Harnessing quantum modulation of low-dimensional semiconductor structures, for example, will not only bring about significant breakthroughs in solid state physics, but also help develop quantum information technologies to meet China's strategic needs.

Embracing technological advances, SKLSM has optimized its research planning and resource allocation to continuously improve the research environment for junior researchers and upgrade research platforms. It is expecting to expand its four research areas by attracting more talented young scientists and strengthening international cooperation. With its existing achievement track record and the continuing efforts of its more than 40 talented researchers—including three CAS members, nine recipients of the National Science Fund for Distinguished Young Scholars, numerous winners of various talent plans, and its other staff and postgraduates—SKLSM is undoubtedly a world-class laboratory in semiconductor physics. ■

SKLSM

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