講座大師錢嘉陵專題演講－

Spin Electronics

Conventional electronics, which has propelled modern technologies including computers and cell phones, only manipulate the charge of the electrons. However, in addition to charge, electron also has spin 1/2, for which Pauli exclusion principle applies, and a magnetic moment due to its quantum angular momentum. In recent years, many new spin effects have been discovered leading to new devices, and indeed, multi-billion dollar industry, and also the new field of spin electronics (or spintronics, or magnetoelectronics). In this lecture, some of these spintronic effects, including giant magnetoresistance (GMR), magnetic tunnel junctions (MTJ), and the newly discovered spin-transfer torque, will be described. These effects can be combined and exploited for device applications including the ubiquitous spin-valve GMR read-heads, which are in virtually every computer hard drive, and non-volatile magnetic random access memory (MRAM), which is poised to become the universal memory of the future. Equally inspiring, many of these discoveries and advances were made by small research groups consisting of a few dedicated and aspiring researchers.

Manipulation of Nanoentities in Suspension

The exploration of nanoscience and the integration of nanoentities to other disciplines, especially biology, has the potential of revolutionizing many areas of science and technology. Small entities (e.g., nanoparticles and nanowires), after suitable functionalization, can selectively perform the intricate tasks of binding other chemical or biological entities. One of the most difficult challenges is the manipulation of small entities, such as nanowires. The manipulation of small objects with sizes less than 10 μm encounters several formidable obstacles. Small objects are usually suspended in a suitable liquid to avoid the strong van der Waals interactions that can immobilize the entities to a substrate. For biological entities, suspension in a suitable solution is imperative to their survival. However, once suspended, the motion of small entities in a liquid is in the realm of ultralow Reynolds numbers (defined as $R_e = Dv$ ~ , where, *D, v,* .. and are the size of particle, relative velocity, density of medium and viscous coefficient, respectively), where the drag force overwhelms the motion of the entities. For example, for a 10 μm long nanowire R_e is only 10^{-5}, whereas for a human swimmer $R_e \approx 10^4$. In this lecture we will describe a versatile method of using AC electric field applied to strategically patterned electrodes to manipulate as well as pattern nanowires and biological cells. We have also accomplished rotation of nanowires, for which the rotation chirality, rotation speed, and angle of rotation can be completely controlled. Despite very low Reynolds numbers, we have rotate nanowires to an extremely high rotation speed of 15,000 rpm. We have also demonstrated a small electrically controlled motor 5 μm in size, that has relevance to MEMS (Micro-Electro-Mechanical Systems) devices.