Spintronics

Quantum information

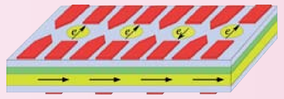
Quantum media conversion between spin and photon

Small-scale spin quantum computer (quantum dot, diamond NV center, magnetic molecule, …)

→ Quantum repeater
Quantum memory
Quantum processor

→ Quantum communication network

Large-scale spin quantum computer



Spin Photonics

High-frequency electronics

Spintronics

Optics / Photonics

→ Spin photodiode
Spin LED
Reconfigurable optoelectronics circuit

→ High-frequency spintronics

Spin - optical buffering memory

High frequency and thermo-spin devices

High output magnetoresistive high frequency device
(Oscillator, Detector, Mixer, Amplifier etc.)
Development in Spin caloritronics
(Spin Peltier effect, Spin Seebeck effect)

→ Spintronic monolithic microwave IC
Superhigh frequency device

→ Highly localized element cooling technique
Spin current generation by heat

Information transmission and processing by pure spin currents and spin waves

Storage

Areal bit-density（bit/in^2）	1 T	10 T	100 T
Bit size（nm x nm）	25 x 25	8 x 8	2.5 x 2.5
	TMR/CPP-GMR (by improvements)	→ CPP-GMR (with new materials and structures)	→ Molecular-/atomic-size sensors (using new principles)

Patterned media → Bit-patterned media (using self-assembly process) → Multi-level recording media

Memory·Logic

MRAM technology F

45nm	32nm	22nm
15F^2	10F^2	8F^2

MRAM write energy

～1.5pJ	～0.3pJ	～0.18pJ

Multi-bits, -layers circuits using magnetic domain control,
multi-bits, -layers circuits using multiferroics materials, ferromagnetic molecular memory

SRAM for mobile devices ⇒SRAM for PC ⇒nonvolatile logic ⇒reconfigurable hardwear, brain-computer type logic circuit
・in-vehicle memory ⇒substitution for DRAM ⇒nonvolatile・reconfigurable logic circuit

Materials·Physics

New materials fabrications with functionality

Dielectric, Transparent, Half-metal, Environmental harmonic, Spin-thermoelectric

Computational material design

Physics

Development of spin-current physics

→ Spin transistor

Devices using spin current and/or magnetic domain wall

Atomically-controlled crystal growth

Application using strongly-correlated electron systems

→ Self-handling materials
Permanent magnets without using rare-earth compounds
Magnetic superalloy with large magnetic moment

2015 — 2020 — 2025 — 2030 — 2035 — 2040 — year