Collage of Basic Education
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FOURTH STAGE

Chapter four application of superconductors

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Applications of Superconductivity

Superconducting materials find applications in the area of medical magnetic-imaging devices, magnetic energy-storage systems, motors, generators, transformers, computer parts, and very sensitive devices for measuring magnetic fields SQUID (superconducting quantum interference device) , voltages, or currents. The main advantages of devices made from superconductors are low power dissipation, high-speed operation and high sensitivity.

Current Commercial Applications

- Magnetic Resonance Imaging (MRI)
- Nuclear Magnetic Resonance (NMR)
- High-energy physics accelerators
- Plasma fusion reactors
- Industrial magnetic separation of kaolin clay

The major commercial applications of superconductivity in the medical diagnostic, science and industrial processing fields listed above all involve LTS materials and relatively high field magnets. Indeed, without superconducting technology most of these applications would not be viable.

Emerging Applications

Electric Power

Computers

Maglev

magnetic levitation

Maglev (derived from magnetic levitation), is a system of train transportation that uses two sets of electromagnets: one set to repel and push the train up off the track, and another set to move the elevated train ahead, taking advantage of the lack of friction.

The main advantages of Maglev transportation systems are freedom from friction, maximum ride comfort, maximum safety, high cruising speeds, low noise pollution, no formation of particulate matter, no pollutant emissions, low maintenance costs.

Concept

With Maglev technology, there are no moving parts. The train travels along a guideway of magnets which control the train's stability and speed. Maglev vehicles have set several speed records and Maglev train systems can accelerate and decelerate much faster than conventional trains; the only practical limitation is the comfort of the passengers and increasing energy consumption at higher speeds.

Design

There are two types of Maglev systems for high speed passenger transport. High speed Maglev such as the Trans rapid and the JR Chuo Shinkansen have travel speeds of up to 600 km/h. By contrast, urban and regional Maglevs are designed for speeds of up to 200 km/h.

Comfort

Along medium range routes (up to 1000 miles) Maglev can compete favorably with airplanes. Maglev Systems are also quieter and smoother than conventional trains, and have the potential for much higher speeds.

Cost

While high-speed maglev infrastructure is relatively expensive to build, maglevs are much less expensive to operate and maintain than traditional high-speed trains or airplanes.

A computer chip is a tiny wafer of semiconducting material with an embedded electronic circuit. It contains millions of microscopic electronic components called *transistors* that transmit data signals.

Communications

Over the past decade, HTS filters have come into widespread use in cellular communications systems. As the world moves from analog to all digital communications, LTS chips offer dramatic performance improvements in many commercial and military applications.

Applications in the Electronics and Communications Sectors

Application	Impact of superconductivity
Digital circuits:	
A-D converters, shift registers, memories, etc.	Demonstrated with LTS; possible for HTS.
Computers	LTS JJs may be suitable for logic and cache memory, but high-density memory still a problem. HTS/semiconductor hybrid systems are possible.
Analog circuits:	
SQUIDS	Successful application of LTS; significant for HTS if noise problems can be overcome.
Signal processing:	
Amplifiers, oscillators, etc.	LTS performance already impressive. Moderate for HTS, if high-quality tunnel junctions can be fabricated, and if high-frequency losses can be reduced further.

Applications in the Electronics and Communications Sectors

Application	Impact of superconductivity
Passive devices:	
Computer wiring, interconnects	Silicon-based machines do not operate at LTS temperatures. Moderate for HTS at chip and board level at 77 K.
Antennae, filters, delay lines, etc.	Demonstrated with LTS; promising for HTS.
Communications	LTS circuits already demonstrated at microwave frequencies (1 to 30 GHz); could open up new regions of the electromagnetic spectrum at even higher frequencies. HTS could extend this up to the TH_z range.
New *devices*	If new phenomena are responsible for HTS, then new devices may be possible.

Industry

Large motors rated at 1000 HP and above consume 25% of all electricity generated in the US. They offer a prime target for the use of HTS in substantially reducing electrical losses. Powerful magnets forwater remediation, materials purification, and industrial processing are also in the demonstration stages.

Applications in the Industrial Sector

Application	Impact of superconductivity
Sensors: Processing Quality control	Minor for LTS, significant for HTS.
Magnetic separation	Significant for LTS, potentially promising for HTS.
Materials processing and shaping	Moderate for LTS, minor for HTS.
Compact accelerators	Moderate for LTS, minor for HTS.
Motors	Minor for LTS, possible for HTS.

Applications in the Transportation Sector

The rapid and efficient movement of people and goods, by land, sea, and air poses important logistical, a new generation of transport technologies including ship propulsion systems, magnetically levitated trains, railway.

Magnetic-levitation is an application where superconductors perform extremely well. Transport vehicles such as trains can be made to “float” on strong superconducting magnets, virtually eliminating friction between the train and its tracks. Recently, in 2015 April, Japan’s maglev train broke the world speed record with 603 km/h in a test run.

Application	Impact of superconductivity
Maglev systems	Technical feasibility demonstrated with LTS, minor with HTS.
Automobiles	Negligible unless room-temperature superconductors are discovered.
Ships:	
Electric drive	Technical feasibility demonstrated with LTS, possible with HTS.
Electromagnetic thrust	Possible with LTS, unlikely for HTS.

Applications in the Medical Sector

Advances in HTS promise more compact and less costly Magnetic Resonance Imaging (MRI) systems, Magneto encephalography (MEG), Magnetic Source Imaging (MSI) and (MCG) .

i. An area where superconductors can perform a life-saving function is in the field of biomagnetism. Doctors need a non-invasive means of determining what is going on inside the human body. By impinging a strong superconductor-derived magnetic field into the body, hydrogen atoms that exist in the body's water and fat molecules are forced to accept energy from the magnetic field. They then release this energy at a frequency that can be detected and displayed graphically by a computer .

Applications in the Medical Sector

Application	Impact of superconductivity
MRI magnets	Successful application of LTS; minor for HTS.
Biomagnetics:	
SQUIDS	Demonstrated for LTS; possible for HTS, especially in applications not requiring the highest sensitivity.
Pickup coils for MEG	Demonstrated for LTS; promising for HTS.
Room shielding	Not feasible for LTS: minor for HTS.
Research magnets	Successful application of LTS; minor for HTS.

Applications in the Electric Power Sector

Several applications of superconductivity in the electric power sector have undergone extensive evaluation generators, superconducting magnetic energy storage (SMES), and AC transmission lines. these applications is provided in table .

Applications in the Electric Power Sector

Application	Impact of superconductivity
Fusion magnets	Technical feasibility demonstrated with LTS, unlikely with HTS.
Magnetohydrodynamics (MHD) magnets	Technical feasibility demonstrated for LTS, unlikely for HTS.
Generators	Technical feasibility of rotors demonstrated with LTS, possible with HTS.
Superconducting Magnetic Energy Storage (SMES)	Technical feasibility demonstrated with LTS, possible with HTS.
Transmission lines	Technical feasibility demonstrated with LTS, potentially attractive with HTS.
Auxiliary equipment: Current limiters Switches Fuses Power leads	Minor with LTS, promising for HTS.

Military

i. Superconductors have also found widespread applications in the military. SQUID (superconducting quantum interference device are being used to detect mines and submarines. Significantly, smaller motors are being built for ships using superconducting wire and tape. 5000 horse power motor has been made with superconducting wire.

ii. The military is also looking at using superconductive tape as a means of reducing the length of very low frequency antennas employed on submarines. Normally, the lower the frequency, the longer an antenna must be. However, inserting a coil of wire ahead of the antenna will make it function as if it were much longer. However, this loading coil will increase the resistance in the coil. Using superconductive materials can significantly reduce losses in this coil. The construction of superconducting microwave antenna has already been successful. The superconducting carbon nanotubes might be an ideal nano-antenna for high-gigahertz and terahertz frequencies applications.

iii. The most ignominious military use of superconductors may come with the deployment of "E-bombs". These are devices that make use of strong, superconductor-derived magnetic fields to create a fast, high-intensity electro-magnetic pulse to disable an enemy's electronic equipment. Such a device saw its first use in wartime, in March 2003, when US Forces attacked an Iraqi broadcast centre.

Application in the Defense and space sectors

Application	Impact of superconductivity
Defense:	
Sensors	Possible with LTS; promising for HTS.
Submarine detection	
Infrared detectors	
Mine detection	
Electronics	Significant for LTS; potentially significant for HTS.
Pulse power	Demonstrated for LTS; possible for HTS.
Kinetic energy weapons	Possible for LTS, minor for HTS.
Free electron lasers	Possible for LTS; minor for HTS.
Ship propulsion	Electric drive demonstrated for LTS, minor for HTS

Application	Impact of superconductivity
Space:	
Sensors	Demonstrated with LTS; HTS could offer greater sensitivity.
Satellite electronics	HTS could enable greater flexibility of design and greater mission capabilities.
Radiation shield	Possible for HTS.
Electromagnetic launch	Possible for LTS, doubtful for HTS.
Magnetic bearings	Possible for HTS.

Space research

i. Superconductors may even play a role in Internet communications soon. Superconductivity can be used to develop a superconducting digital router for high-speed data communications. Since Internet traffic is increasing exponentially, superconductor technology is being called upon to meet this super need.

Pollution control

i. Another impetus to the wider use of superconductors is in pollution control. The reduction of green-house gas can be accomplished by the use of superconducting devices in different manufacturing units. The heavy reduction of carbon dioxide emissions in power plants can be accomplished by the use of high-temperature superconductors.

Maglev Systems

Airports and highways are becoming more and more congested, resulting not only in costly time delays, but in serious smog problems in heavily traveled corridors. Community resistance to new roads and airports compounds the difficulties of expanding these to fill travel demand. Transportation petroleum consumption alone exceeds domestic oil production, and oil supplies will continue to diminish as travel demand increases. 37 High-speed maglev vehicle systems offer one solution to these problems.

There are two principal levitation concepts for maglev vehicles: attractive-force and repulsiveforce, Attractive maglev uses non superconducting electromagnets mounted on the vehicle that are attracted to the underside of steel rails.

Repulsive-force maglev, also called “electrodynamics, ’ uses vehicles levitated by superconducting magnets that induce repulsive currents in a guideway containing aluminum sheets or coils. Vehicles are levitated 6 to 10 inches above the guideway. This concept, invented in the United States, was developed into scale models in the early 1970

Potential applications of superconductivity in vital areas

Field	*Applications*
• Magnets	• High field Magnets • Magnetic Levitation • Magnetic Shielding • NMR (Magnetic diagnostics and spectroscopy) • Large Machines (colliders, Magnetic fusion confinement, r.f. cavities) • Ore refining
• Energy or Power-related	• Electric power storage and transmission • Magnetic energy storage • Power production by magnetic fusion and magnetohydrodynamics (MHD)
• Transportation	• High speed maglev trains • ship-drive system
• Electronic and other small devices	• SQUIDs • Bolometer • Electromagnetic shielding • Josephson devices (square-law detector, parameteric amplifier, mixer)
Computer and information processing	• Optoelectronics • Voltage standard • Active superconducting elements (FETs) • Malched filters • Semiconductor-superconductor hybrids (A-D converters)