Applications
of HTS coatings

Thin HTS coatings on sigle crystal wafers or flexible metal tapes are beneficial for a variety of technical applications. The following compilation gives an overview of mainstream applications.

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Communication

Cellular communication

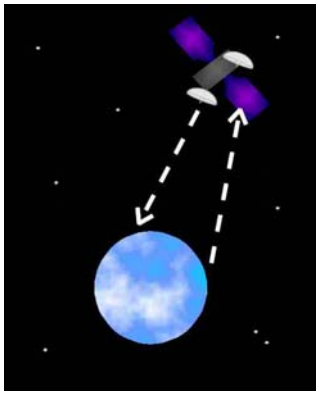
Superconducting filters in cellular base stations are the most advanced application of HTS films and various companies have placed commercial units on the market. Several thousand high frequency signal filters have been installed in the base-stations of cellular networks to improve their performance.

Due to the low RF – resistance these filters offer the advantage of a lower noise level combined with sharp filter skirts which translates in higher selectivity and suppression of interference from other sources.

The immediate benefits for network operators range from extended coverage to enhanced traffic and capacity per cell site. Consequently, the individual mobile phone user experiences better voice quality and fewer dropped calls.

The extension of range can play an important role in rural areas or where GSM networks are upgraded to UMTS (3G filters) because these new networks usually require smaller cell size. The implementation of superconducting receiver front ends in mobile phone networks leads to a considerable reduction in the number of expensive base stations and consequent cost savings. As a matter of fact the installation of new antennas in urban areas is also getting increasingly problematic because of inhabitants' resentments.

Satellite communication



Communication satellites are giant relay stations receiving weak signals from a station on earth and bouncing them back after amplification. The major part of the payload of such a satellite consists of RF - filters to select signals (calls, TV - programs) from a broadband transmission. After amplification signals are multiplexed and returned to a receiver on earth.

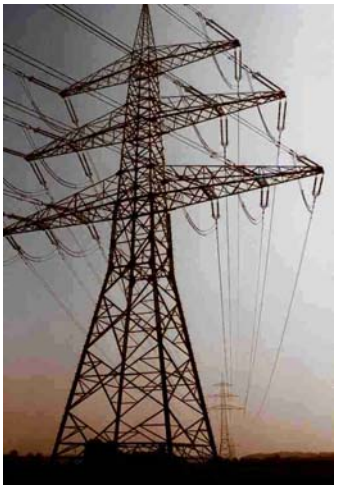
Even in combination with cryogenics (to keep the filter at 60 – 80 K) superconducting filters offer the same performance as conventional filters at considerably smaller size and weight. This translates in cost saving rated at 50,000 USD per kilogram payload.

The picture compares an Intelsat VI multiplexer built in conventional technology and one of its copper cavity filters to the (gold plated) superconducting filter (Source: Tesat). These filters are operated in the C-band around 4 GHz.

By courtesy of Tesat GmbH

Electric power technology

Fault current limiters (FCL)



Fault current limiters are protective units in the electric power grid. In case of short circuits, lightning strokes or whenever sudden excessive current bursts are threatening components of the grid a fuse has to protect these components by switching off the network. Conventional circuit breakers are relatively slow and consequently the grid capacity has to be vastly oversized to withstand excess currents. Since conventional circuit breakers have to be serviced and reset manually, such faults result in long term blackouts.

Superconducting fault current limiters are based on the principle, that high temperature superconductors turn into a highly resistive state when a certain critical current is exceeded. This switching occurs within milliseconds and throttles down the excess current to the rated value. Hence, the grid is very effectively protected, existing capacities can be used better (smaller safety margins), and transformers can be saved when connecting grids. After the fault the FCL recovers within seconds and power outages can be avoided or are less severe.

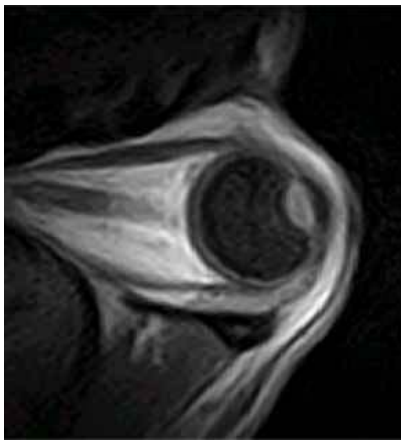
Electric power cables

Transmission of electric power without losses is certainly the first idea when thinking about superconductivity. However, cables have to be flexible and the use of high temperature superconductors which are ceramics is tricky. For some of the Bi-based HTS a technology which produces HTS filaments imbedded in a silver matrix is mature enough to produce kilometers of superconducting wire. It has been used to fabricate liquid nitrogen cooled cables which have been installed and successfully tested in many sites all over the world.

The development of a new generation of so called 2G wire or coated conductors engaging YBCO is very much advanced and at the threshold of commercialization. YBCO offers better performance, reduced AC losses and the perspective of lower costs due to the lack of silver. However, the technical difficulties are immense since a high quality YBCO film on a metal tape requires more or less single crystalline (highly oriented) growth over hundreds of meters or even kilometers. A variety of manufacturing techniques has been developed and result in coatings on flexible metal tape with extremely high current carrying capability.

Medicine technology

Magnetic resonance imaging (MRI)



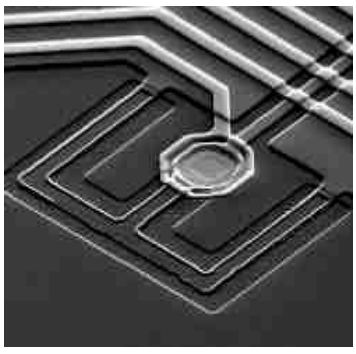
Magnetic resonance imaging (MRI) is a non – invasive medical diagnosis technique to detect e.g. fractures of bones or sinews or for cancer prevention. Unlike X-raying it does not expose the body to high energy radiation and reduces the risk of damages. It does not depend on the absorption of X-ray radiation, yields a completely different contrast and offers the advantage to investigate soft tissue structures as well.

The quality of MRI images can be greatly enhanced by using superconducting RF - receiver coils. The receiving unit is realized in planar technology from thin films and can integrate coils and interdigital capacitors to build an oscillating circuit tuned at the magnetic resonance frequency of the atomic nuclei which should contribute to the contrast of the image. Due to the compact geometry it is even possible to integrate several receiver units tuned to different frequencies to take images from various element distributions (e.g. H, Na) simultaneously.

The main advantage of the superconductor, however, lies in its low RF - losses (1000 times lower than copper). The high quality factor of the oscillator increases the receiver sensitivity and results in an enhanced signal to noise ratio by at least one order of magnitude. As a consequence the sampling time to take a high resolution MRI image is greatly reduced.

Superconducting receivers are essential for low field MRI. This gives the chance to build small and cheap open MRI systems affordable not only for large clinics but for single doctors (e.g. orthopedists, vets etc.) and in developing countries.

SQUIDS



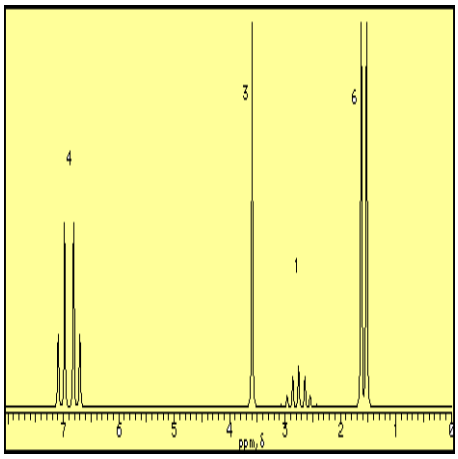
Squids, i.e. superconducting quantum interference devices are extremely sensitive magnetic field sensors which have no parallel in conventional electronics and are based on the quantum effects which are responsible for superconductivity (Josephson effects). They are the most sensitive sensors available to date.

Since every electrical current produces a magnetic field they can be used to monitor tiniest current levels, generated e.g. in the human brain or wherever nerves are transmitting signals through a body. Consequently, Squid – sensors can be used in medicine for remote recording of magnetocardiograms (MKG) or magnetoencephalograms (MEG) with high spatial resolution.

But also in other fields like material science and quality control non - destructive evaluation (NDE) methods for metal pieces (e.g. airplane components, tires, fuselage) to detect hidden flaws or fatigue cracks have been successfully demonstrated.

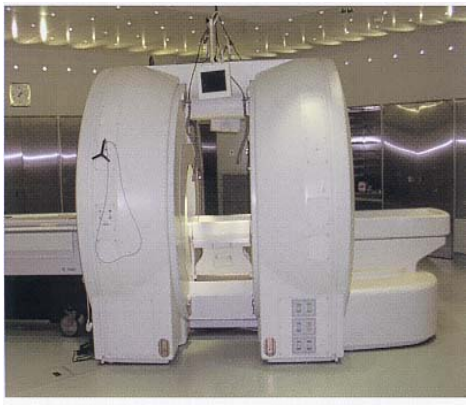
Science and research

Nuclear magnetic resonance (NMR)



Nuclear magnetic resonance (NMR) is an analytical tool to determine the chemical composition and structure of complex chemical compounds like proteins etc. In order to get good resolution superconducting magnets are employed to produce the necessary high magnetic fields for the magnetic spitting of the RF signal. However, sensitivity and sampling time also depend on the noise of the RF receiver system. Superconducting antennas can considerably improve the signal to noise ratio by more than an order of magnitude. Consequently, the sampling time is greatly reduced and even very faint signals can be detected.

Magnets



Superconductors are the only reasonable way to produce high magnetic fields necessary for research, in particle accelerators, and in medical and analytical tools like magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) systems. Nowadays, such magnets employ conventional metallic superconductors like niobium, NiTi, or Nb_3Sn operated at liquid helium temperature (4.2 K above absolute zero) and at the limit of the material performance. HTS wire offers the chance to operate such magnets at higher temperatures and to produce higher fields.

YBCO coated conductors exhibit extremely good performance even in strong magnetic fields. Insert coils in high field magnets can boost the fields to unprecedented levels .