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<th>HIGH TEMPERATURE SUPERCONDUCTING (HTS) TAPE COIL WITH ENHANCED PROTECTION AND METHOD FOR MAKING SAME</th>
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The invention provides an improved method of manufacturing an HTS tape coil for an MRI device with enhanced protection. The method comprising attaching high-Q capacitors at each end of an HTS wire, removing substantially all electrically conductive sheathing material on an inner side of the HTS wire, while retaining substantially all electrically conductive sheathing material on an outer side of the HTS wire. The invention also provides an HTS wire made in accordance with the foregoing method.

110 Attach capacitors to an HTS wire
120 Place coil in an etching device
130 Etch only inner side of coil
140 Wash and dry coil
Figure 1

110: Attach capacitors to an HTS wire
120: Place coil in an etching device
130: Etch only inner side of coil
140: Wash and dry coil
HIGH TEMPERATURE SUPERCONDUCTING (HTS) TAPE COIL WITH ENHANCED PROTECTION AND METHOD FOR MAKING SAME

FIELD OF THE INVENTION

This invention relates to superconducting receiver tape coils for magnetic resonance imaging (MRI) having enhanced protection from bending strain, and to methods for making the same. All publications and patents referred to below are incorporated by references herein.

BACKGROUND OF THE INVENTION

Receivers coils using High-Temperature Superconducting (HTS) materials are able to achieve higher quality factor (Q-factor) than conventional copper coils, thus higher signal-to-noise ratio (SNR) or shorter imaging time. Ma, “RF Applications of High Temperature Superconductors in MHz Range,” IEEE Trans. on Applied Supercon., 9, 3565-3568 (1999), describes the use of expensive HTS thin film receiver coil for substantial SNR improvements.

HTS wire or tape is later used to fabricate receiver coil. Cheng et al., “HTS Tape RF Coil for Low Field MRI,” Proc. Intl. Soc. Magn. Reson. Med., (2003), demonstrates a 5-inch HTS tape receiver coil, which possesses the advantages of lower cost, enhanced filling factor and flexible coil design over traditional HTS thin films, while significant SNR improvement can still be achieved.

Black et al., “A High-Temperature Superconducting Receiver for Nuclear Magnetic Resonance Microscopy,” Science 159, 793-795 (1993), implies that it is most beneficial to use HTS coil for small-size sample or low-field system. Such applications include mouse imaging, which is important for basic research and clinical investigations. However, removal of all the electrically conductive materials results in very brittle HTS tape coils. Relatively large recoil force experienced by small-size tape coils makes their fabrication even more difficult.

It is, therefore, an object of the invention to provide a method to protect the small-size HTS tape coils such that their fabrication is made easier and thus enjoys the advantages of having a HTS tape coil over conventional copper coils.

SUMMARY OF THE INVENTION

The present invention provides a method of manufacturing an HTS tape coil for an MRI device such that protection for the coil is enhanced. The method comprises attaching high-quality capacitors at each end of an HTS wire; removing only the electrically conductive materials covering the inner side such that the electrically conductive material on its outer side can act as a protective layer to resist bending strain for tape coil.

The invention also provides a method of manufacturing an HTS tape coil for an MRI device using an etching device, wherein the etching device comprises an HTS wire attached with high-Q capacitors at each end, a strong but flexible strip that tightly confines the HTS wire and minimizes contact of etching solution on the outer side of the HTS wire, and a support that maintains the strip in a smooth circular shape.

The invention further provides an HTS tape coil made by one of the foregoing methods.

BRIEF DESCRIPTION OF THE FIGURES

Further features and advantages of the invention may be understood with reference to the drawings in conjunction with the drawings in which:

Fig. 1 is a process flow diagram illustrating one embodiment of the present invention;

Fig. 2 is an illustration of one embodiment of the present invention;

Fig. 3 presents an MRI scan of a phantom using the HTS tape coil of the present invention;

Fig. 4a presents an MRI scan of a phantom using copper coil as a control;

Fig. 5a presents an MRI scan of human fingers in an MRI apparatus including the HTS tape coil of the present invention;

Fig. 5b presents an MRI scan of a human palm in an MRI apparatus including the HTS tape coil of the present invention;

Fig. 5c presents an MRI scan of a human wrist in an MRI apparatus including the HTS tape coil of the present invention; and

Fig. 5d presents an MRI scan of a human wrist in an MRI apparatus including the HTS tape coil of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

High temperature superconducting (HTS) material is used for building HTS tape receiver coil. In a preferred embodiment, HTS wire composed of Bi-2223 compound is adopted. The commercially available HTS wire, however, cannot be directly used for RF application due to screening of RF signal from superconducting core by coatings of electrically conductive materials. U.S. Patent No. 6,943,550 (Cheng), incorporated herein by reference, discloses a method of manufacturing HTS tape receiver coil for Magnetic Resonance Imaging (MRI).

However, relatively large recoil force is experienced by small-size HTS tape coil. The removal of the entire electrically conductive coatings (the silver sheath), as suggested by above method, will largely reduce its ability to resist the large bending strain encountered in use, making fabrication of small-size HTS tape coil very difficult. Using the present method, protection for HTS tape coil will be enhanced, in particular for those of small-size. At the same time, substantial signal-to-noise ratio improvements can be achieved over conventional copper coil.

Fig. 1 is a process flow diagram illustrating one embodiment of the present invention. In step 110, an HTS wire is attached with capacitors at its two ends. Preferably, a portion of HTS wire is cut to a length slightly shorter than the desired circumference of coil, and carefully wound onto a smooth cylinder to assume its shape without bending. The
For further evaluation, we compared our coil to the 5-inch HTS tape coil discussed in Cheng, "HTS Tape RF Coil for Low Field MRI," Proc. Intl. Soc. Magn. Reson. Med. (2003). Lee et al., “Performance of Large-Size Superconducting Coil in 0.21T MRI System," IEEE Trans. on Biom. Eng., 51, 2024-2030 (2004), states that the SNR images obtained by a coil are inversely proportional to the square root of coil resistance and sample resistance. Results show that the coil resistance for the two coils is approximately the same (20 mΩ), while the sample resistances are in the order of one milliOhm. Since the sample loss is reduced for the 6 cm coil, the SNR of the images obtained by the coil is higher.

Thus, the present method can effectively enhance the protection for HTS tape coil in particular for those of small size. The inner side of silver sheath is removed to avoid shearing of the superconducting phase from RF signal, while the outer side is retained to increase the ability of the tape to resist against bending strain. This implies that small-size HTS tape coils for imaging of small nonmetal parts and animals can be much more easily realized. Potential applications include mice imaging in high field MRI system. It also makes a solenoid coil of small radius feasible.

Having thus described illustrative embodiments of the invention, various modifications and improvements will readily occur to those skilled in the art and are intended to be within the scope of the invention. Accordingly, the foregoing description is by way of example only and is not intended as limiting. The invention is limited only as defined in the following claims and the equivalents thereto.

What is claimed:

1. A method of manufacturing an HTS tape coil for an MRI device with enhanced protection, the method comprising:
   - attaching high-Q capacitor at each end of an HTS wire;
   - removing substantially all electrically conductive sheathing material on an inner side of the HTS wire while retaining substantially all electrically conductive sheathing material on an outer side of the HTS wire.

2. The method of claim 1, wherein the electrically conductive sheathing material is a silver alloy.

3. The method of claim 2, where the electrically conductive sheathing material is removed by contacting the sheathing material with an etching solution.

4. The method of claim 3, wherein the etching solution is an aqueous solution of ammonium hydroxide and hydrogen peroxide.

5. The method of claim 3, wherein the etching solution contains 40% ammonium hydroxide.

6. The method of claim 3, wherein the etching solution contains 20% hydrogen peroxide.

7. The method of claim 1, further comprises the use of an etching device comprising:
   - a HTS wire attached with high-Q capacitors at two ends;
   - a strong and flexible strip that tightly confines the HTS wire to minimize the contact of etching solution to the outer side of HTS wire; and
   - a support that maintains the strip in a circular shape.

8. The method of claim 7, wherein the strip is contacted with a high-density sponge.
9. The method of claim 7 wherein the support is a circular plastic dish.

10. An HTS tape coil having enhanced protection against bending strain for an MRI device, comprising: an HTS wire with a high-Q capacitor at each end, the wire having substantially all silver alloy sheathing removed from an inner side of the wire, while retaining substantially all silver alloy sheathing from an outer side of the HTS wire.

11. An HTS tape coil having enhanced protection against bending strain made in accordance with the method of claim 1.

12. An HTS tape coil having enhanced protection against bending strain made in accordance with the method of claim 7.