A new method of fabricating HTS tape coil

Y. W. Wong[1], E. S. Yang[1]
[1]The Jockey Club MRI Centre, The University of Hong Kong, Pokfulam, Hong Kong

Introduction

High-Temperature Superconducting (HTS) materials can introduce substantial improvement in signal-to-noise ratio (SNR) of images for small-size sample or low-field MRI system (<1T) [1]. Expensive HTS thin film is typically used for making receiver surface coils for substantial SNR improvements [2]. A 5-inch HTS tape coil using silver-alloy sheathed Bi-2223 tape was first developed [3], which allows easier fabrication, frequency adjustment and lower cost than thin films. Imaging using small-size HTS tape coil has been shown to yield significant SNR improvement at 3T [4], but its fabrication is limited by relatively large recoil force experienced by etched HTS tape, which leads to bending and even cracking of filaments, thus degrades its performance. In our work, a new method of fabricating HTS tape coil is demonstrated.

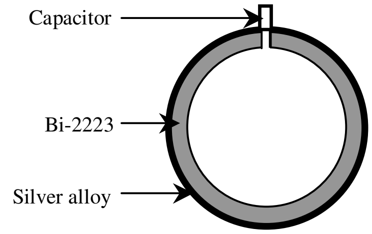


Fig 1: HTS coil by our method

Materials and Methods

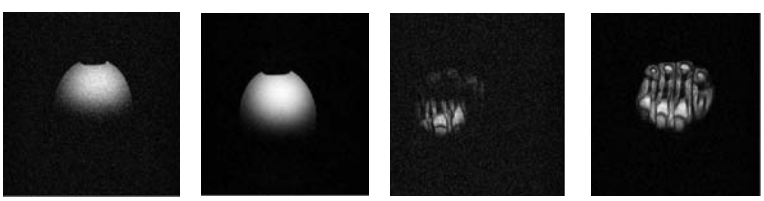
A silver sheathed Bi-2223 HTS tape is adopted to build our receiver coil. It is fabricated with high quality capacitors from American Technical Ceramics (ATC) to achieve the required resonant frequency (8.92MHz at 0.21T MRI system). Previously, silver sheath on both sides of HTS tape is removed for RF application, but its ability to resist bending strain is also significantly reduced. In our method, only the inner side of the tape is removed such that the external silver coating can act as a protective layer against large recoil force without complete screening of superconducting core from RF signal (figure 1). To examine the performance of our developed coil, it is compared with that by previous method. Consider that SNR of images can be expressed as follows [5]:

$$SNR \propto \frac{B_1}{\sqrt{R_c T_c + R_s T_s}} \qquad (1)$$

where B_1 is the B-field from sample, R_c is the coil resistance, R_s is the sample resistance, T_c is the coil temperature (77K) and T_s is the sample temperature (300K). R_c can be calculated by $R_c = \omega L / Q_{unloaded}$ [5], where ω is the resonant frequency of coil, L is the inductance, and $Q_{unloaded}$ is the unloaded quality factor (Q-factor). Inductance of coil can be obtained using $\omega = 1/\sqrt{LC}$, where C is the capacitance of the tank circuit. The unloaded Q-factor is measured with a Hewlett Packard-8753ES Network Analyzer at the iso-center of 0.21T magnet. Phantom and human images are captured in our home-built 0.21T MRI system at 77K, and its performance is compared with that of an equivalent copper coil at room temperature. Conventional spin-echo (SE) pulse sequence is used for capturing images.

Results

To evaluate our method, a 6 cm single turn HTS tape coil is fabricated, and its performance is compared with that of the 5-inch HTS tape coil fabricated in [3]. Results show that the coil resistances for the two coils are approximately the same (20mΩ) while the sample resistances are in the order of milliohm. This implies that the sample noise is comparable to the coil noise. The relationship, $SNR \propto \sqrt{Q/T}$ [1] (where T is the absolute temperature), which is a good approximation when coil noise dominates, cannot be applied in our case. Since the sample loss is reduced for the 6 cm coil, according to equation (1), the SNR of the images obtained by our coil is higher, despite a lower Q-factor. Images including phantom and human hand are captured with our new tape coil at 77K (figure 2). Phantom studies show that SNR improvement of 3.5 times is achieved over an equivalent copper coil at room temperature, which is better than the SNR improvement (3 times) introduced by the 5-inch HTS tape coil. There is indeed an enhancement of SNR for smaller coil.



Copper (300K) HTS (77K) Copper (300K) HTS (77K)

Fig 2: Comparisons of phantom and human images using copper and HTS coils

Conclusions

It is shown that our 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 screening of 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 human parts and animals can be much more easily realized. Solenoid coil of small radius has also become feasible. Potential applications include mice imaging in high field MRI system.

References

[1] R. D. Black et al., “A High-Temperature Superconducting Receiver for Nuclear Magnetic Resonance Microscopy”, Science 159, 793-795 (1993)
[2] Q. Y. Ma, “RF Applications of High Temperature Superconductors in MHz Range”, IEEE Trans. on Applied Supercon., 9, 3565-3568 (1999)
[3] M. C. Cheng et al., “HTS tape RF coil for low field MRI”, Proc. Intl. Soc. Magn. Reson. Med. (2003)
[4] H. L. Lee et al., “High-Temperature Superconducting RF Coils for 3T MRI”, Proc. Intl. Soc. Magn. Reson. Med (2005)
[5] K. H. Lee et al, “Performance of Large-Size Superconducting Coil in 0.21T MRI System”, IEEE Trans. on Biom. Eng., 51, 2024-2030 (2004)