ED6-1-INV

High Sensitivity Nuclear Magnetic Resonance Spectroscopy Using HTS Resonators

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Nuclear magnetic resonance (NMR) is a powerful and widespread method for the detection of molecules and the determination of molecular structure. However, it has a relatively poor sensitivity compared to other techniques such as mass spectrometry. The very narrowband NMR signals are typically observed by Faraday induction in a resonant detector which is noise matched to a low noise preamplifier. In today's laboratory magnets, the NMR resonance bands of interest may be anywhere between ~40 MHz to above 1 GHz. For the most commonly observed isotopes, ^{1}H, ^{13}C, and ^{15}N resonance frequencies are very close to 10:2.5:1 ratio. We have improved the sensitivity of several spectrometers by using high-Q HTS resonators [1]. Some of the opportunities and challenges involved in using these resonators as NMR detectors will be presented.
An example of a useful resonant structure is the counterwound spiral shown in fig. A. Spirals of opposite helicity are patterned on a double-side coated wafer to produce a low frequency resonator for nuclides such as ^{13}C or ^{15}N. The relative orientation of the spirals confines most of the electric field within the dielectric substrate, reducing the electric coupling to the sample. This is important because NMR samples can be electrically lossy and are typically near room temperature. However, the high Q factor of the resonator limits both the reception and excitation bandwidth, requiring the use of techniques such as overcoupling and Q switching [2].
The HTS resonators are mounted to a cold head on either side of a liquid sample as shown in fig. B. In probes such as described in [1] there may be two or more sets of nested resonator pairs tuned to different frequencies, and interactions between the resonators must be taken into account. Problems also occur if the higher modes of ^{13}C transmission line resonators such as shown in fig. A are close to the ^{1}H resonance. Fortunately, modifications to the design of the transmission line resonator can be used to adjust its dispersion and move the modes away from other frequencies of interest [3].

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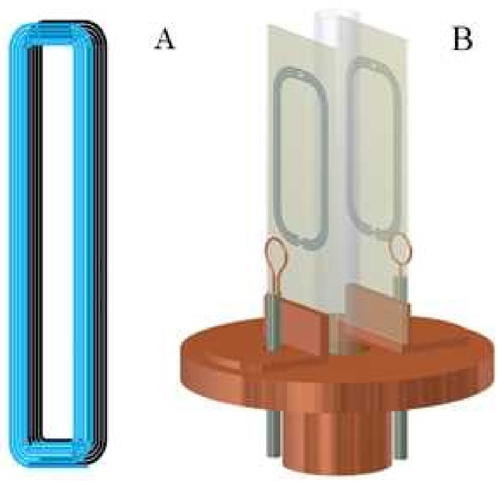

Fig. A. Counterwound spiral resonator; B. HTS resonators on both sides of the sample.

Keywords: Nuclear magnetic resonance, High-temperature superconductors, Superconducting devices

ED6-2-INV

Compact and High Performance Microwave Superconducting Bandpass Filters Using Microstrip Multimode Resonators

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As the key passive component in the radio-frequency (RF) front-end, bandpass filter (BPF) with compact size and high performance are in great demand for enhancing system functionality. Meanwhile, high-temperature superconducting (HTS) materials are becoming more and more attractive in the context of designing microwave filters because of their lower losses and excellent performance.

In past few years, several types of high performance HTS BPFs have been designed for demonstration. For circuit size miniaturization, various microstrip multimode resonators have been proposed, such as the multi-stub-loaded resonators and square ring loaded resonator. At first, a series of the second-order multiband HTS filters have been presented based on the multi-stub-loaded resonators [1], [2]. The measured insertion losses are all extremely small, but the selectivity and stopband performance need to be improved because of the low-order design. Therefore, a newly dual-mode hairpin ring resonator is proposed and applied to constitute an eighth-order dual-band HTS BPF [3]. The configuration of the designed filter and the obtained frequency responses are respective shown in Fig. (a) and (b). As predicted, the band edge selectivity and the attenuation in stopband are highly enhanced.

In addition, the differential circuits have been received much attention recently due to their ability of lower electromagnetic noise and crosstalk. So, based on the HTS technology, a fourth-order differential dual-band HTS BPF has been designed using the proposed square ring loaded resonator [4]. The layout of the differential filter is depicted in Fig. (c) and the simulated results as well as the measured results are shown in Fig. (d). It is seen from Fig. (d) that a favorable common-mode (interference signal) suppression over a wide frequency range is obtained.

With the advantages of ultra-low in-band insertion losses and high selectivity, these proposed filters are attractive for potential applications in multiband communication systems requiring high-sensitivity and high anti-interference properties.

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ED6-3-INV

Development of High-Temperature Superconducting Pick-up Coils for Field-Swept Nuclear Magnetic Resonance

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Nuclear magnetic resonance (NMR) can obtain rich information concerning molecular properties including local molecular structures and dynamics. High-temperature superconducting (HTS) pick-up coils for NMR are useful for detecting very low level RF signals. Some research groups have studied and used these coils from 40 to 700 MHz [1-3]; however, systematic research on the quality factor of the coils and detection frequency has not been done.

In this paper, we investigated the frequency dependency of unloaded quality factors, Q_u, for Cu and HTS pick-up coils by using electromagnetic simulation from 40 to 700 MHz. From the results with one-turn coils, the Q_u values assuming Cu coils were proportional to 1⁄2 the frequency power, and those assuming HTS coils were inversely proportional to the frequency. These results could be explained by the definition of the quality factor and microwave losses in normal metal and HTS material. In comparison, the Q_u values of square-spiral Cu and HTS coils significantly increased as frequency decreased below 100 MHz. Additionally, the total length of these coils was less than that of the one-turn coils at the same resonant frequency. These results indicate that square-spiral coils with a low-resonant frequency have higher Q_u values and are advantageous as miniaturized coils.

Next, we designed and fabricated HTS pick-up coils at around 40 MHz for a field-swept solid-state NMR. A square-spiral shape with a 100-μm line and 100-μm spacing was used for the coils and put on a 25 × 25 mm² dielectric substrate. We analyzed the S_{11} reflection, quality factors, and electromagnetic field and found that the simulated resonant frequency was around 40 MHz and the Q_u values of the coils exceeded 3×10^4. We then fabricated coils with 250-nm-thick YBCO thin films deposited on CeO_2-buffered r-sapphire substrates. The coils were patterned with laser lithography and dry-etching techniques. The S_{11} reflections of the coils were measured with a loop antenna, vector network analyzer, and cryostat. A resonant frequency of 38.525 MHz and Q_u of more than 1.6×10^4 were obtained at 9 K in a magnetic field of 3.6 T. Details will be presented at the conference.

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Keywords: NMR, Pick-up coil, YBCO thin film

ED6-4

Required Characteristics of YBCO Thin Films to Fabricate High-Q NMR Pickup Coils

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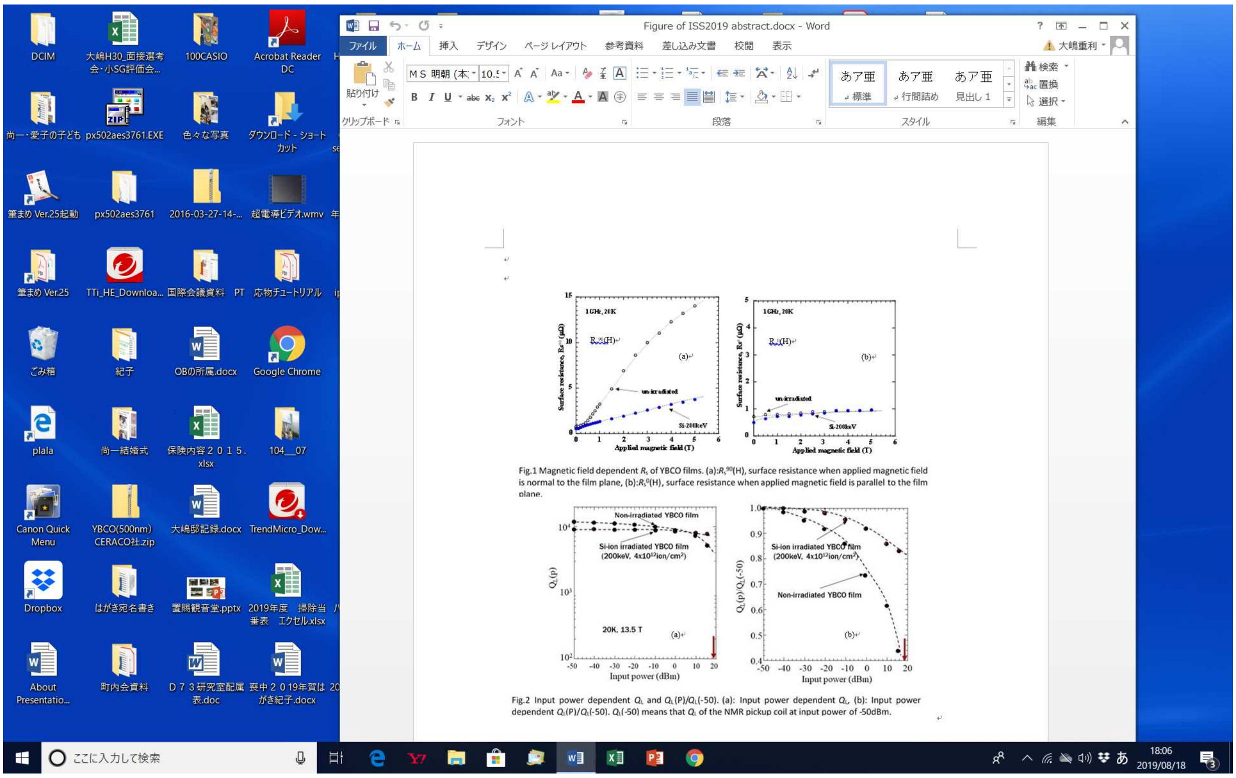
The enhancement sensitivity of the NMR system is roughly classified into the following two methods. One is the development of a high frequency NMR system. Recently, a 1.3 GHz NMR development project has been carried out. The other is to increase the loaded quality factor (Q_L) of the NMR pickup coil. In order to increase the Q_L, it is necessary to reduce the surface resistance (R_s) of the pickup coil materials used under a high magnetic field, and superconducting films are useful for NMR pickup coil materials. We examined the R_s of the Si-ion irradiated YBCO films, and found that the YBCO films irradiated with Si ions have a small $R_s{}^{90}$, and Rs^0 in a high magnetic field (Fig.1). We fabricated the NMR pickup coils using the YBCO films with Si-ion irradiation and without Si-ion irradiation, and found that the NMR pickup coils made with Si ion irradiated YBCO films had large Q_L in high input power region (Fig.2).



Keywords: NMR pickup coil, surface resistance, Si-ion irradiation, YBCO film