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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 mm^2 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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