

REDUCTION OF OUTGASSING FROM THE FERRITE CORES IN THE KICKER MAGNET OF J-PARC RCS

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Abstract

Kicker magnets are used to kick out the accelerated beam to the transport lines in the RCS of the J-PARC. A high voltage is applied to kickers for a short period, so they must be installed in a vacuum to prevent discharge. Therefore, it is important to reduce the outgassing of water vapour from the ferrite cores. This time, we have decided to construct the reserve magnets with very low outgassing at high-voltage discharge. First of all, the thermal desorption behaviour of the ferrite was investigated. Water vapour has two peaks: at 150°C and 300°C. Carbon dioxide is rather largely emitted with the peak around 275°C and then decreases with the temperature. From these results, the ferrite cores were vacuum-fired at 450°C for 48 h. Then the good properties for the magnetic cores were confirmed. And now the assembling of the kicker magnet is undertaken.

INTRODUCTION

Kicker magnets have been used to extract a 3 GeV proton beam and inject it into a downstream beam transport line [1]. They are fast pulse magnets whose current rise time and flat top length is about 80 ns and 1 μ s, respectively. The whole magnet is placed in a vacuum because its excitation voltage is quite large. Being completely in a vacuum, it is important for kickers to prevent electrical breakdown. In addition, suppression of the outgassing is needed since outgas interacts with the beam and causes beam loss. Figure 1 shows the outline structure of a kicker magnet.

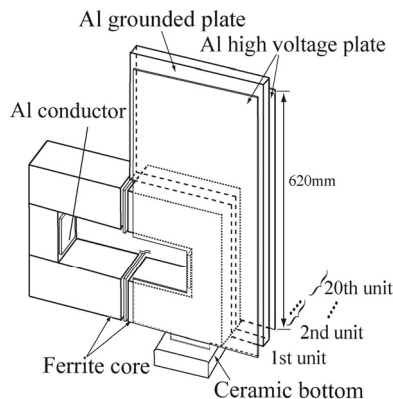


Figure 1: Outline structure of a kicker magnet.

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Table 1: Main Components and Their Outgassing Rate for the Working Kicker Magnet

Material	Outgassing Rate (Pam/s)
Ferrite	$\sim 10^{-7}$ (200°C 300h bake)
Al alloy (A5052)	$< 10^{-10}$ (Pit-free electrical polishing +150°C 25h bake)
SUS304	$< 10^{-10}$ (450°C 48h bake)

The main materials of the magnet, which are listed in Table 1, are ferrite, aluminium alloy (A5052) and stainless steel SUS304. The ferrite has the nominal composition of $AF_e_2O_4$ ($A=Ni$ and Zn) and good high-frequency properties, so it is used as the magnetic core. Aluminium alloy is used for all the electrodes and conductors for exciting current. The stainless steel is used for the mechanical support.

PREVIOUS TREATMENTS TO REDUCE THE OUTGASSING FROM THE COMPONENTS

Aluminium Alloy

According to the reference [2], the surface of Al alloy, which is treated by the pit-free electrical polishing method and successively baked out at 150°C for 25 h, has a good vacuum property. The outgassing rate is reported to be less than 10^{-10} Pam/s after bake-out. So, all the Al alloy surfaces in the working kickers were treated by the above treatment. The same treatment is also employed for the Al alloy in the reserve magnets.

Stainless Steel SUS304

As well known, the surface treatment and the heat treatment for the stainless steel SUS304 have been widely investigated. We adopted the combination of electrical polishing and the vacuum-firing at 450°C for 30 h. The low outgassing rate less than 10^{-10} Pam/s was reported [3].

Ferrite Core

The ferrite PE14 produced by TDK was used in the working kicker magnets. The outgassing rate of the ferrite has been found to be $\sim 10^{-5}$ Pam/s[4]. As the rate was too large to enable us to use in a vacuum of RCS, the ferrite cores were baked out in a vacuum at 200°C for 300 h. Finally the rate of $\sim 10^{-7}$ Pam/s was obtained [5].

NEW TREATMENT FOR REDUCTION OF OUTGASSING FROM THE FERRITE CORES

Thermal Desorption Measurements

As shown in Table 1, the outgassing rate from the ferrite is 100 times larger than the other main materials. The vacuum properties might be greatly improved when the ferrite were well de-gassed. Thus, we investigated the ferrite through the thermal desorption spectroscopy (TDS) method for the construction of the reserve kicker magnets.

The block of ferrite PE14 was cut into test pieces. The size of the piece is 10mmx10mmx1mm¹. We made three kinds of sample from these pieces. First of all, all the pieces were ultrasonically rinsed in C₂H₅OH for 15 min and then dried quickly. Some of the pieces were used as the samples "as-received". Then the others were vacuum-fired at 450°C for 48 h. Some of these vacuum-fired samples are used as the samples "450°C-48h". The rest pieces were additionally rinsed in distilled water for 15 min (as "450°C-48h+water" ones).

Main gas species from the sample "as-received" are H₂O and CO₂. The water vapor has the peaks at 150°C and 300°C as shown in Fig. 2. The two peaks have rather sharp distributions. The water molecules from the peak at 150°C have the binding energy about 0.44 eV. This low binding energy implies that this peak is ascribed to the absorbed water molecules. On the other hand, the peak at 300°C is supposed to be originated from the hydrate, because the binding energy is rather high (~1.7 eV). The carbon dioxide has the broad peak at 275°C.

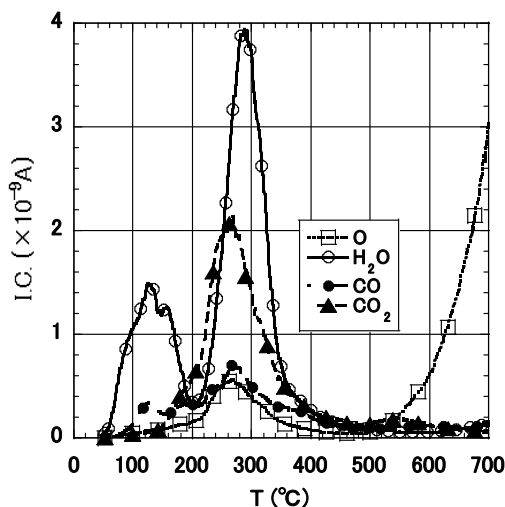


Figure 2: TDS spectra from the sample "as-received".

Figure 3 shows the TDS spectra for the sample which was degassed by preheating at 450°C (sample "450°C-48h"). It is found that most of the H₂O and CO₂ are removed from the ferrite sample.

Figure 4 shows the TDS spectra from the sample "450°C-48h+water". There is a large amount of H₂O with the peak at 150°C, although the peak at 300°C is maintained to be low. These observations strengthen the interpretation that the H₂O peak at 150°C is ascribed to the absorbed molecules on the surface and that the peak at 300°C is supposed to originate from the hydrate in the ferrite.

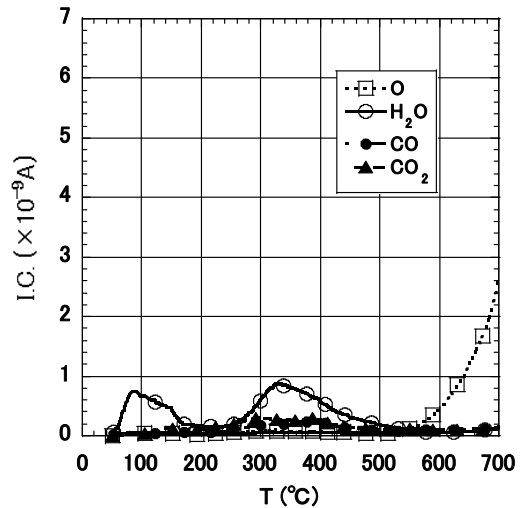


Figure 3: TDS spectra from the sample "450°C-48h".

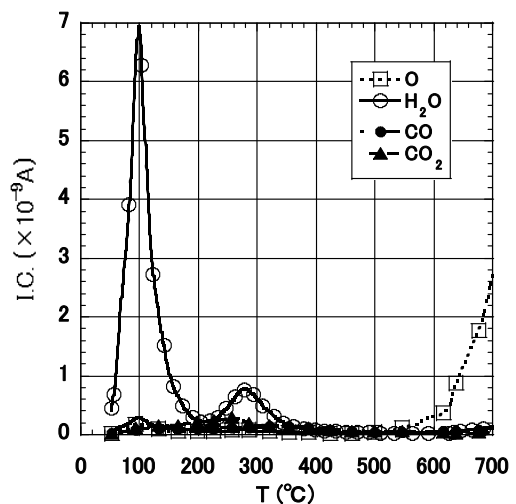


Figure 4: TDS spectra from the sample "450°C-48h+water".

Mechanical Strength and Magnetic Properties after Heat Treatments

The change in mechanical strength, as shown in Table 2, is quite small even after heat treatment at 850°C for 10h.

As shown in Figure 5, there are no changes in magnetic properties after heat treatments with the temperatures less than 650°C. However, the magnetic

Table 2: Change in Mechanical Strength of the Ferrite after Heat Treatments.

Sample	as-received	450°C-48h	650°C-48h	850°C-10h
flexural strength (MPa)	69±10	69±10	66±10	69±11

permeability decreases by ~ 20% after heat treatment at 850°C. This behavior is probably related to the explosive emission of oxygen above ~ 700°C in the TDS spectra.

- After bake out, the magnet should be kept in the vacuum or in the pure Ar.

- Facility to bake out the magnet installed in the ring should be prepared. The temperature should be 150-200°C.

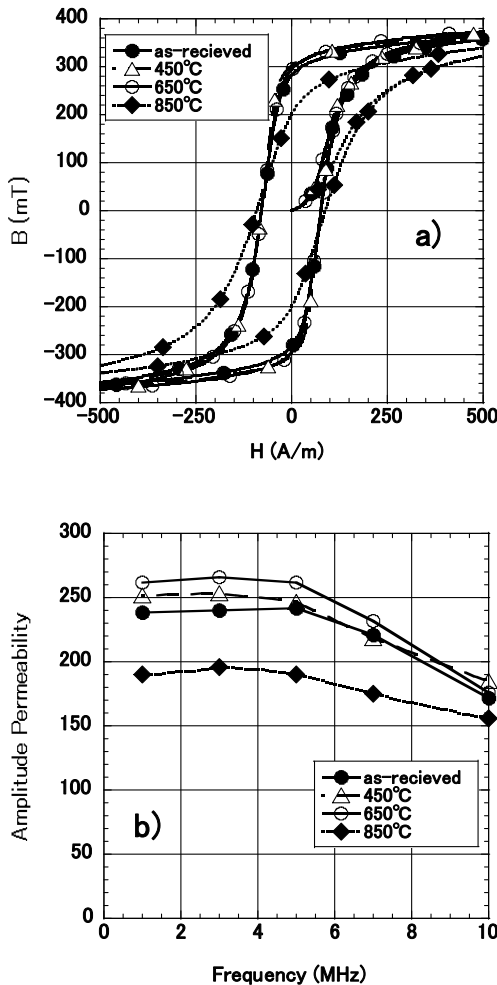


Figure 5: Changes in magnetic properties of the ferrite after heat treatments. a); B-H curves, b); amplitude permeability as a function of frequency.

Effective Treatments for Reduction of Outgassing from the Ferrite

Based on the above measurements, the following procedures were adopted:

- The ferrite cores are vacuum-fired at 450°C for 48 h to remove the water (including hydrate).

- After completion, the whole magnet should be baked out at 200°C for 48 h to remove the water vapor absorbed during air exposure.

SUMMARY

We are now constructing the reserve kicker magnets with very low outgassing at high-voltage discharge. To reduce the outgassing from the ferrite completely, we investigated the outgassing behavior of the ferrite through the thermal desorption spectroscopy (TDS), paying attention to the changes in mechanical strength and magnetic properties after heat treatments. The followings were obtained:

1) Main gas species from the as-received sample are H₂O and CO₂. The water vapor has the peaks at 150°C and 300°C. The H₂O peak at 150°C is ascribed to the absorbed one on the surface. And the peak at 300°C is supposed to be originated from the hydrate. The carbon dioxide has the broad peak at 275°C.

2) The change in mechanical strength is quite small even after heat treatment at 850°C for 10 h.

There are no changes in magnetic properties after heat treatments with the temperatures less than 650°C.

Based on the above measurements, the ferrite cores were arranged to be vacuum-fired at 450°C for 48 h to remove the water (including hydrate) before assembling. Then, after completion, the whole magnet should be baked out at 200°C for 48 h to remove the water vapor absorbed during air exposure. Finally, the reserve magnet should be kept in the vacuum or in the pure Ar.

REFERENCES

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