ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-TUPTB018

MgB_2 COATING PARAMETER OPTIMIZATION USING A 1.3-GHz 1-CELL CAVITY

T. Tajima†, T. P. Grumstrup, J. D. Thompson
Los Alamos National Laboratory, Los Alamos, NM, USA
H. Sakai, H. Ito, E. Kako, T. Okada, K. Umemori, KEK, Tsukuba, Japan

Abstract

We started performing the tests to react B-coated samples with Mg vapor using a full-size 1.3-GHz elliptical cavity with coupon holes. So far, we have tested 7 times and we started to see superconductivity on samples from the 4th test. The highest transition temperature (T_c) has been ~32 K so far. Comparing to the results with small furnace, new samples show wide superconducting transitions suggesting some contaminations. This paper describes the tests and their results. The B coating system has been under construction in parallel with this effort.

INTRODUCTION

MgB_2 has been studied for applications to SRF cavities due to its favorable properties such as significantly higher T_c of ~40 K compared to other promising superconductors for SRF cavities such as Nb_3Sn whose T_c is ~18 K [1]. We are constructing a system to coat a full-size cavity with MgB_2 at LANL [2]. Figure 1 shows a schematic of the new system. Elliptical cavities of ~1 GHz or higher can fit in the new furnace pipe. The method we chose for the MgB_2 coating is a 2-step technique, i.e., coat B layer with CVD using B_2H_6 gas in the first step and react it with Mg vapor in the 2nd step [3]. We were able to obtain samples with a T_c of >35 K with experiments using a small tube heater [3, 4]. Our effort has been to re-create the same conditions with the newly built large system. This paper presents the results of the reaction tests using existing flat B-coated samples (6 mm x 6 mm, on Nb or sapphire) attached at the coupon holes on beam pipes and cell on a 1.3-GHz 1-cell Nb elliptical cavity.

TEST PROCEDURE

The B-coated substrates being used were obtained during a project that ended in 2015 [5]. In that project we were able to coat B layer on the surface of a 1.3-GHz cavity but were unsuccessful in producing MgB_2. Nearly the end of that project, we tested this 2-step technique using a small tube heater and successfully obtained MgB_2 with a T_c of >35 K as shown in Fig. 2. After further studies of the parameters, we purchased a large furnace to apply this technique to full-size cavities. We started to follow the same process as we took with the small tube heater, i.e., (1) bake out the furnace at 50-100 °C higher than the B-Mg reaction temperature without including Mg pellets under vacuum using a 70-L/s turbo pump, (2) cool it down naturally and let up the furnace with nitrogen gas, (3) remove all the parts out of the furnace, (4) install samples at the 3 locations (inlet and outlet beam pipes and cell equator as show in Fig. 3) and Mg pellets in the Nb tray in the Mo boat located in the smaller diameter pipe, (5) re-install all the parts back into the furnace, (6) make a gap between the cavity and Mg section and pump down the furnace including the cavity, (7) raise the temperature to ~150 °C and hold it for ~12 hours to degas the surfaces, (8) let up the furnace including the cavity with Ultra High Purity (UHP) Ar gas to slightly higher than 1 atm using a 1/3 psi check valve, (9) close the gap between the beam pipe and Mg section and raise the temperature to the planned temperature and hold it for ~6 hours, (10) cool down the furnace with slowly flowing UHP Ar gas to prevent the pressure from negative to avoid oxidation of the cavity in case of air leak during this cool down and (11) remove the parts out of the furnace at <~50 °C and retrieve samples and Mg pellets.

RESULTS

So far, we have performed 7 tests. First 3 tests did not produce any superconductor probably because the temperature was too low at the MgB_2 section as shown in Fig. 4. We started to see superconducting transitions from the 4th test. Figures 5 through 8 show the temperature profiles and magnetometer test results of the samples taken from inlet beam pipe (BP), cell and outlet BP for each test from the 4th to 7th tests. The T_c's were measured by the Quantum Design Model MPMS3.

Our goal was to create the same conditions as the tests with small tube heater, but the temperature control has been the most challenging issue with the large system. First, we found actual temperatures on the cavity was ~50 °C lower than those shown on the furnace controller. We installed thermocouples at the locations where the samples are located, on the Mg section pipe and on the end flanges, and controlled the temperatures based on these actual temperatures.

We have not been able to do detailed systematic studies, but the following summarizes the facts we found so far.

- The cell temperature tends to be higher than beam pipes.
- Mg pellets temperature seem to be lower that the pipe temperature since they did not melt much at 700 °C at the pipe. (Mg melting temperature is 650 °C.)
- The reaction at ~750 °C seems to be best so far.
- It is difficult to keep Mg temperature higher than the cell temperature without independent heater.
- The main reason for lower-than-expected T_c seems to be insufficient Mg vapor pressure.

† tajima@lanl.gov

21th Int. Conf. RF Supercond. SRF2023, Grand Rapids, MI, USA JACoW Publishing
ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-TUPTB018

- Since the highest T_c is still ~32 K with broad transition, there is still room to improve with further parameter optimizations.

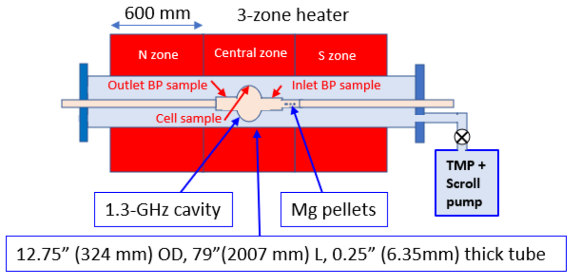

Figure 1: A schematic showing relative locations of components.

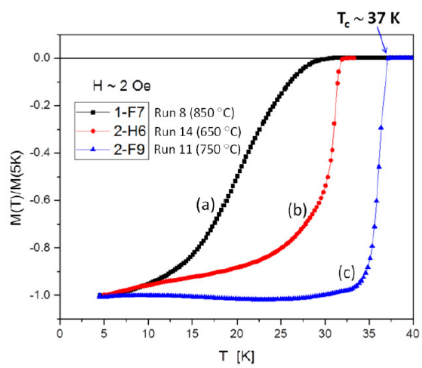

Figure 2: Magnetometer measurement results of the B-Mg reaction test using small tube furnace [3].

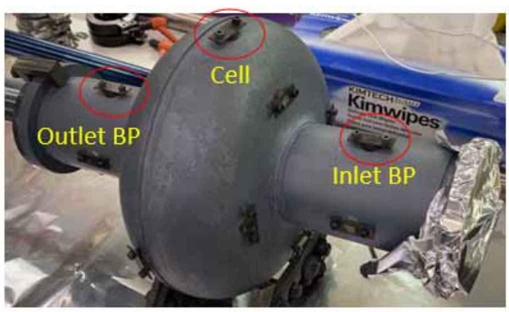

Figure 3: A 1.3-GHz Nb cavity with coupon holes. The cell diameter is 8.3 inches (211 mm).

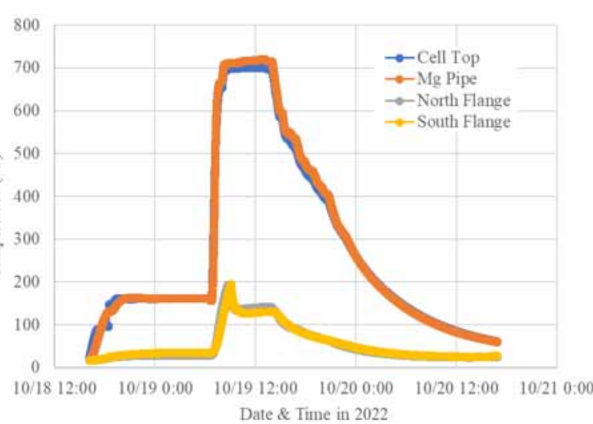

Figure 4: The 3rd B-Mg reaction test temperature profile. No superconducting transition was detected.

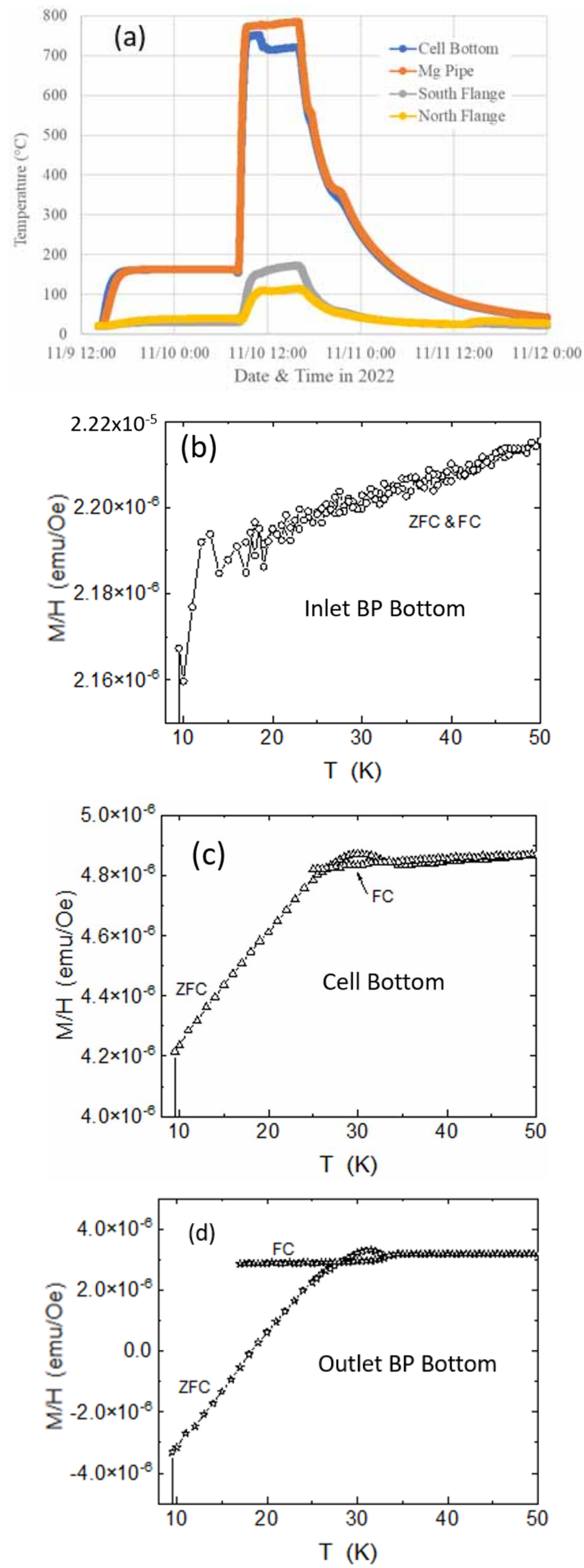

Figure 5: The 4th B-Mg reaction test temperature profile (a), magnetometer measurement results of the samples from input beam pipe (BP) (b), cell (c) and output beam pipe (d). FC stands for Field Cooling and ZFC stands for Zero Field Cooling. Nb transition at ~9 K is also seen.

ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-TUPTB018

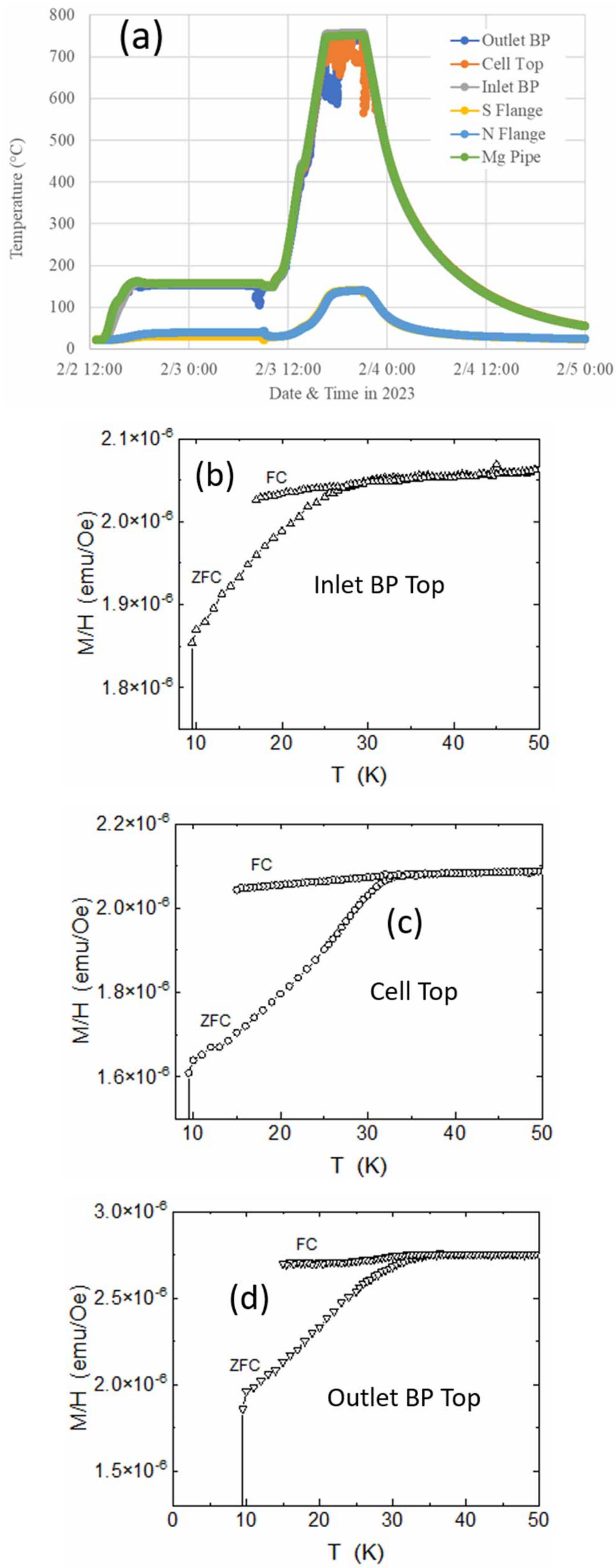

Figure 6: The 5th B-Mg reaction test temperature profile (a), magnetometer measurement results of the samples from input beam pipe (BP) (b), cell (c) and output beam pipe (d). Some temperature measurements had some issue at the feedthrough on the south flange. Nb transition at ~9 K is also seen.

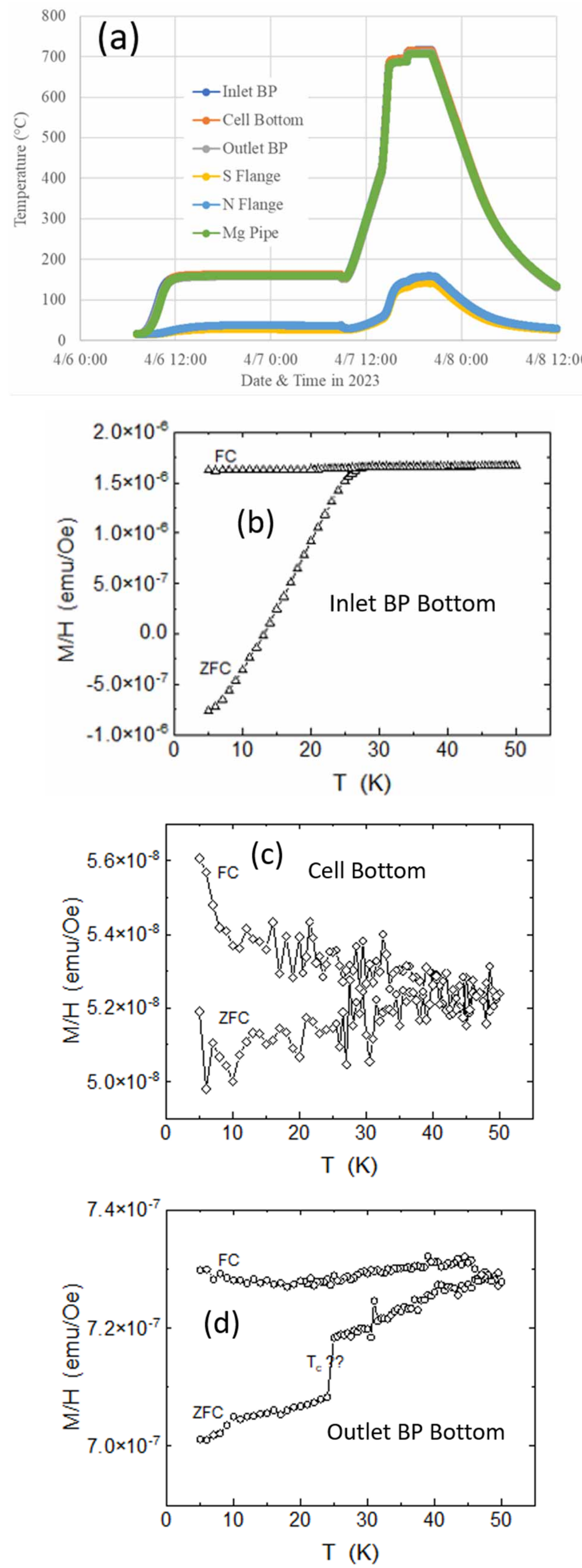

Figure 7: The 6th B-Mg reaction test temperature profile (a), magnetometer measurement results of the samples from input beam pipe (BP) (b), cell (c) and output beam pipe (d).

ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-TUPTB018

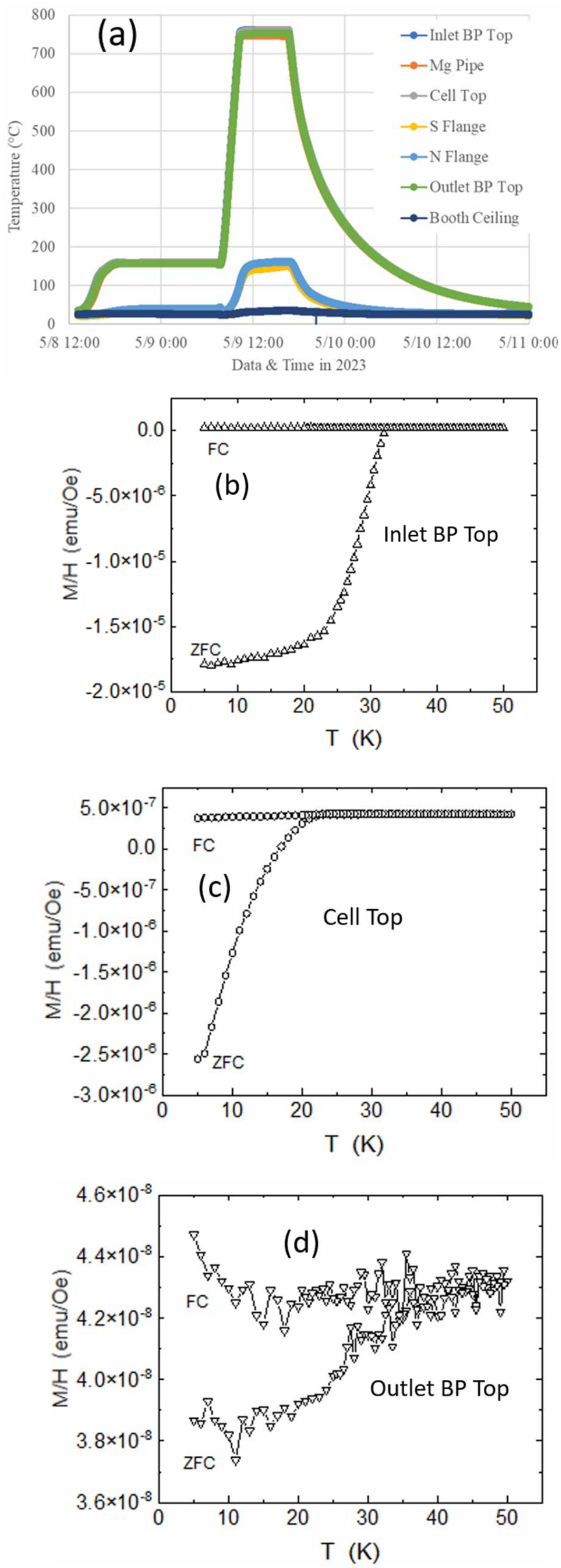

Figure 8: The 7th B-Mg reaction test temperature profile (a), magnetometer measurement results of the samples from input beam pipe (BP) (b), cell (c) and output beam pipe (d).

We plan to do the following to raise the T_c and make the transition width smaller.

- Install a heat radiation shield between the cell and the heater surface to lower the cell temperature relative to the beam pipes.
- Install an independent heater at the Mg pellet holder to be able to control its temperature independently and monitor the actual temperature of Mg Pellets.
- Add an Mg section to the north (N) side so that the Mg vapor pressure distribution will be more symmetrical if necessary.

CONCLUSION

We started commissioning a large new furnace system that is aimed at coating MgB_2 on the interior surface of full-size RF cavities. The first tests being performed are the reaction between small B-coated flat samples attached to the coupon holes on a 1.3-GHz elliptical cavity with Mg vapor since we had not performed this test using a full-size cavity although we have coated B on the inner surfaces of a similar cavity in the project that ended in 2015.

We started to see superconducting transitions starting up to ~32 K with broad transition width. We will continue searching for better parameters to obtain T_c >35 K with sharp transition as we had obtained with small tube heater experiments, while B coating system is being prepared.

ACKNOWLEDGEMENT

This work has been supported by the U.S.-Japan Science and Technology Cooperation Program in High Energy Physics [LAB 22-2607] within the Department of Energy (DOE) Office of High Energy Physics (HEP).

REFERENCES

[1] Tsuyoshi Tajima, "Application of MgB_2 to Superconducting Radio-Frequency Cavities", *TEION KOGAKU* (*J. Cryo. Super. Soc. Jpn.*), vol. 57, pp. 23-30, 2022. doi: 10.2221/jcsj.57.23

[2] T. Tajima *et al.*, "Construction of a New MgB_2 Coating System for 1.3-GHz Superconducting RF Cavities at LANL", *IEEE Trans. Appl. Supercond.*, vol. 33 p. 3500203, 2023. doi:10.1109/TASC.2023.3241261

[3] T. Tajima, L. Civale, and R. K. Schulze, "Research on MgB2 at LANL for the Application to SRF Structures", in *Proc. SRF'15*, Whistler, Canada, Sep. 2015, paper TUPB053, pp. 700-702.

[4] P. Pizzol *et al.*, "Progress of MgB2 Deposition Technique for SRF Cavities at LANL", in *Proc. SRF'21*, East Lansing, MI, USA, Jun.-Jul. 2021, pp. 482. doi:10.18429/JACoW-SRF2021-TUPTEV003

[5] T. Tajima, L. Civale, D. J. Devlin, G. C. Martinez, and R. K. Schulze, "Status of MgB2 Coating Studies for SRF Applications", in *Proc. SRF'13*, Paris, France, Sep. 2013, paper WEIOB01, pp. 777-781