23D01

Large-Area Coating of High functionality Oxide Thin Film through MOCVD Processing

MOCVD法による高機能被覆の大面積化

Yoshimitsu Hishinuma, Teruya Tanaka, Takuya Nagasaka, Akio Sagara and Takeo Muroga
菱沼 良光, 田中 照也, 長坂 琢也, 相良 明男, 室賀 健夫

National Institute for Fusion Science
322-6, Oroshi-cho, Toki, Gifu, 509-5292, Japan
核融合科学研究所 〒509-5292 岐阜県土岐市下石町322-6

The blanket system is one of the important components in order to realize the fusion power plant. In the liquid Lithium breeding blanket, reducing of the Magneto Hydrodynamic (MHD) pressure drop is key issue to operate stably in the magnetic confinement fusion reactor. The electrical insulating coating on the blanket components such as ducts and large walls is an attractive concept to reduce MHD. We have constructed the Metal Organic Chemical Vapor Deposition (MOCVD) apparatus for the large area and complicatedly shaped erbium oxide (Er_2O_3) insulator coating. Furthermore, we also succeeded to demonstrate the Er_2O_3 coating into the interior surface of the stainless steel (SUS) pipe stably through the MOCVD process.

1. Introduction

The MHD pressure drop is a critical issue for liquid lithium fusion reactor blankets [1]. An electrically insulating coating with oxide ceramics is one of the attractive methods for reducing the MHD pressure drop. A ceramic coating would also be necessary to suppress the hydrogen permeation in a molten salt type blanket systems using Flibe or Flinak as the breeding and cooling fluid [2]. Some ceramic materials such as CaO, Y_2O_3, $CaZrO_3$, AlN and Er_2O_3 have been studied as candidates for the insulating coating [3,4]. Based on these studies, Er_2O_3 was selected as one of the candidate materials for MHD insulator coating because of high compatibility with liquid Li and high electrical resistivity [4]. In the previous studies, Er_2O_3 coatings were developed by Physical Vapor Deposition (PVD) methods. However, the PVD methods have limited capability in coating on complex surfaces expected in the blanket components. It is important to develop new methods of large area Er_2O_3 coating on the inner and outer surface of the complex shaped duct tubing for the advanced liquid metal breeder blanket application.

We investigated the MOCVD process as a new technology for large area coating on broad and complicated shaped components. MOCVD process is a concise procedure to form homogeneous large area coating layer which is synthesized via vapor phase from a metal organic complex. It has the possibility to form homogeneous coating layer into the interior surface of the metal tube using vapor flowing control.

2. Construction of large area MOCVD coating apparatus

We constructed MOCVD apparatus to form large area oxide coating in NIFS. Large area MOCVD apparatus constructed in NIFS is shown in fig.1. The MOCVD apparatus consists of three main components; the metal organic complex supplying line with a vaporizer, a gold furnace type quartz

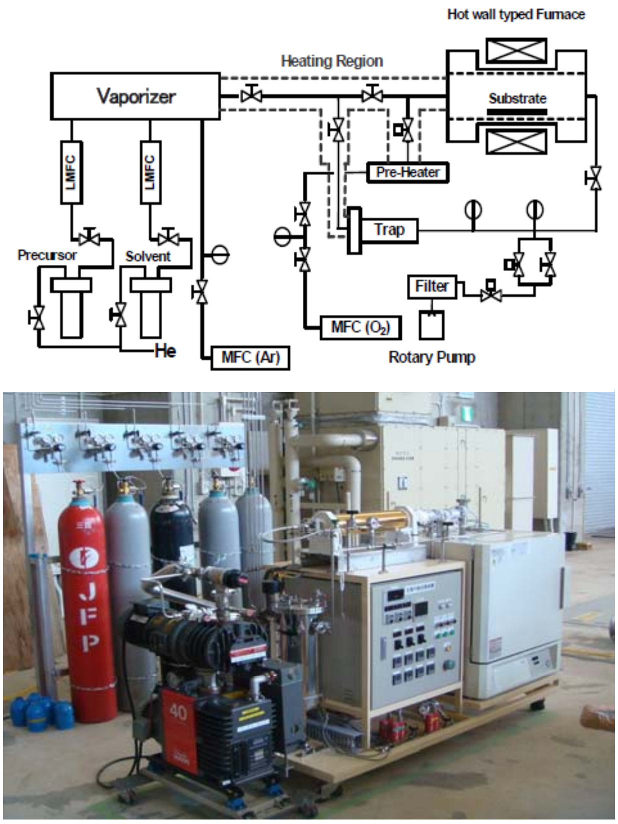

Fig.1. Large area MOCVD apparatus in NIFS

tube reactor having long plateau temperature and an exhaust system [5]. The metal organic complex was vaporized at 150℃in the vaporizer and introduced into the reactor by the argon carrier gas. All supplying lines were heated at 250℃ by the ribbon heater to prevent the metal organic complex solidification. The vaporized complex reacted with oxygen gas via the other supplying line and the oxide coating layer was grown on the various substrates. In this study, we used the Er(IBPM)$_3$ (isobutyrylpivaloylmethane) complex made in Toshima MFG Co.,Ltd as the Er source material [5,6].

3. Er_2O_3 coating through MOCVD process

We confirmed clearly that Er_2O_3 coating layer can be formed on various metal disk substrates such as V, SUS and Ni, macroscopically. Transmission Electron Microscope (TEM) and selected area diffraction (SAD) images of the Er_2O_3 coating layer is shown in fig.2. As dark field image and SAD pattern are figs. a) and b). We found that Er_2O_3 coating layer with about 800 nm thickness was formed stably. In the boundary of Er_2O3 and SUS substrate, no macro defect such as crack and adhesion was also observed. In the SAD patterns, it was clear that Er_2O_3 coating layer was crystallized uniformly because the diffraction fleck arranged like a ring shaped.

4. Large inner surface coating of metal tube pipe

We found that Er_2O_3 coating was able to form on the metal substrates using MOCVD process. So, we tried to form the Er_2O_3 insulator coating on the large interior surface area of a commercial SUS 316 pipe. Typical photograph images of the interior surface of a part of the SUS pipe before and after MOCVD process is shown in fig. 3. We confirmed that the green-colored homogeneous thin coating was formed stably on the interior surface of the SUS pipe. In addition, Er_2O_3 coating was not removed from the interior surface at all. This was caused by the reduced surface roughness. It was suggested that the surface conditions such as roughness and undulation were important factors to form coating layer into interior surface of the metal pipe via MOCVD process.

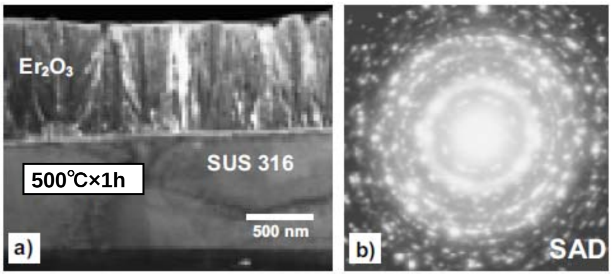

Fig.2. TEM and SAD images of Er_2O_3 coating layer via MOCVD process

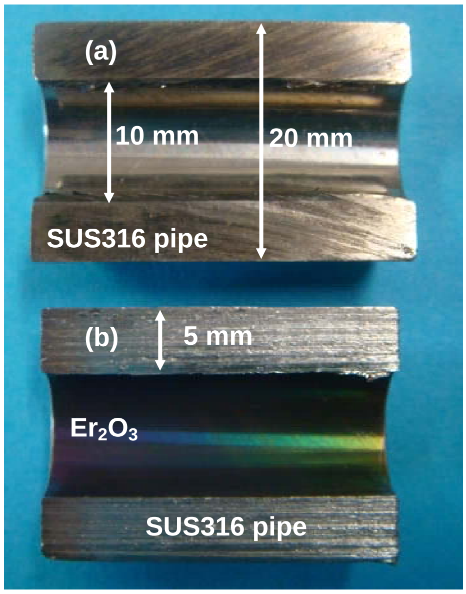

Fig.3. Typical photograph of the interior surface of the SUS pipe before and after MOCVD Er_2O_3 coating. (a) Before MOCVD coating, (b) After MOCVD coating

Acknowledgments

This work was mainly supported by the NIFS Program Budget (NIFS11UFFF026) and Collaboration Research Program with Toshima MFG Co.,Ltd: NIFS10PLFF401), in part by the Grant-in-Aid for Scientific Research (A) 21246141 (2009-2012).. In addition, we would like to thank to Prof. K. Matsuda, University of Toyama, for providing us with the microstructure analysis using TEM observation.

References

[1] S. Malang, H.U. Borgstedt, E.H. Farnum, K. Natesan and I.V. Vitkovski, Fusion Eng. Des. **27** (1995) 570.
[2] T. Muroga, T. Tanaka and A. Sagara, Fusion Eng. Des. **81** (2006) 1203.
[3] D.L. Smith, J. Konys, T. Muroga and V. Evtikhin, J. Nucl. Mater. **307–311** (2002) 1314.
[4] B.A. Pint, P.F. Tortorelli, A. Jankowski, J. Hayes, T. Muroga, A. Suzuki, O.I. Yeliseyeva and V.M. Chernov, J. Nucl. Mater. **329–333** (2004) 119.
[5] Y. Hishinuma, T. Tanaka, T. Tanaka, T. Nagasaka, S. Yoshizawa, Y. Tasaki and T. Muroga, J. Nucl. Mater. **417** (2011) 1214.
[6] Y. Hishinuma, T. Tanaka, T. Tanaka, T. Nagasaka, Y. Tasaki, A. Sagara and T. Muroga, Fusion Eng. Des. **86** (2011) 2536.