§32. Development of Steel-based Composite Materials with a High Thermal Conductivity

Hashimoto, N., Honma, H. (Hokkaido Univ.),
Muroga, T., Nagasaka, T.

Reduced activation ferritic/martensitic steels (RAFMs) have been employed as the structure material for fusion blanket due to its superior resistance to irradiation damage. The first wall of a blanket plays a role of heat-exchange and is subjected to 0.5 MW/m^2 of high heat from fusion plasma. While, the first wall is supposed to be composed of built-in cooling channels, therefore, this exquisite combination of RAFMs and first wall with built-in cooling channels should be extensively investigated. One of important issues would be low thermal conductivity of RAFMs as a heat-exchange component [1], so that development of high thermal conductive structure component is a big challenge. In this study, RAFM and related Fe-base materials were prepared. High thermal conductive materials, such as carbon nanotubes (CNT) and copper, were placed on bonding surface, and then, bonded by Vacuum Hot Press (VPS) and/or Spark Plasma Sintering (SPS) method, as shown in Fig.1, in order to improve a thermal conductivity of the materials.

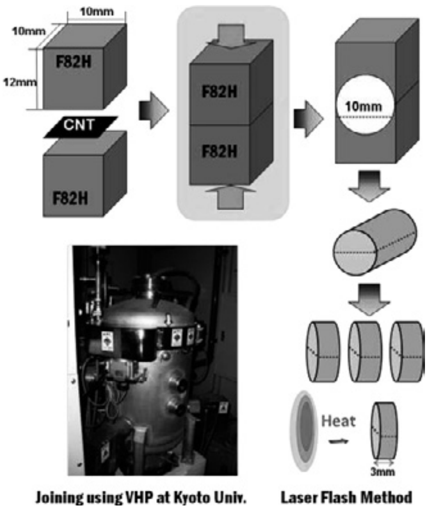

Fig.1 Schematic for the joining procedure of Fe-based composite materials with using VHP.

Joints of structure materials could be used as heat sinks between Plasma Facing Materials (PFM) and coolant during operation with using much higher thermal conductivity materials, such as CNT, Copper, and Tungsten etc. The thermal conductivity of composite would be estimated with a formula as follows.

$$\lambda_{com} = V_a\lambda_a + V_b\lambda_b$$

Here, λ: Thermal Conductivity of Composite (W/m・K), V_i : Volume Fraction of *i* (%), λ_i : Thermal Conductivity of *I* (W/m・K). In case *a*: CNT(6 mg) and *b*: F82H (10x10x12 mm block), the λ value of the composite would be estimated to be 69 (W/m・K), which is as twice as that of F82H.

Figure 2 shows the procedure of sample preparation for Fe-CNT composite and SEM images of joint surface. Fe block surface was ditched by sand papers and filled with multi-wall CNT (1 and 6 mg), and then joined with using VHP.

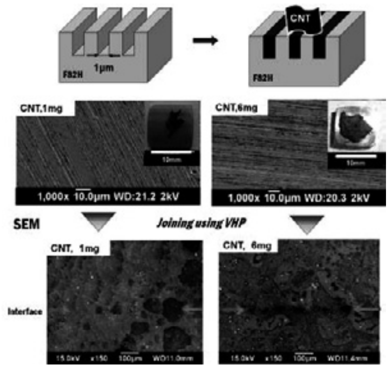

Fig. 2 Procedure of sample preparation for Fe-CNT composite and SEM images of joint surface.

Joining of Fe with MWCNT (1-6mg) between Fe (SCM440) blocks was succeeded by VHP. Joint area seemed to be smooth and tough according to microstructure observation by SEM. In addition, Cu plates (0.2 and 1.0 mm in thick) were also placed between Fe blocks and joined by VHP. According to the results from laser flash method, the thermal diffusivities of these samples appeared not to be increased, as shown in Figure 3.

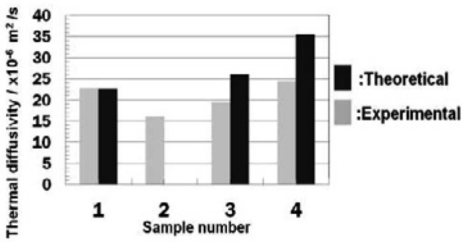

Fig. 3 Thermal diffusivities of samples 1: Fe (SCM440). 2: Fe w/ MWCNT-0.6mg, 3: Fe w/ Cu-0.2mm plate, and Fe w/ Cu-1mm plate.

Joining of Fe with MWCNT and Cu plates between Fe blocks with using VHP and SPS, respectively, was succeeded, and the joint area seemed to be smooth and tough. However, thermal diffusivities of the samples appeared not to be increased in this condition probably due to less amount and a poor arrangement of MWCNT. In addition, stability of MWCNT during joining and irradiation should be investigated at certain temperature. In case of Fe-Cu plate samples, porosity of joint surface could be a problem, so that improvement of joining process is needed.

[1] Suzuki, T.: J. Plasma Fusion Res. Vol.82, No.10 (2006) 699-706.