EFFECT OF METALLIC ELEMENT ADDITION ON THERMAL CONDUCTIVITY OF CARBON/COPPER COMPOSITE MATERIALS

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Introduction

Recently, nuclear grade graphite materials and high thermal conductivity carbon-carbon composite materials have extensively been used for plasma facing compo-nents of fusion devices. However, in the engineering phase of fusion reactors, such as ITER, there are some problems, such as erosion due to high heat flux from fusion plasma and difficulty of control of tritium inventory due to chemical interaction of carbon wall with plasma. One of the reason for this is that the thermal conductivity of carbons deceases with increasing temperature. The thermal conductivity of metals does not indicate so large decrease with increasing tempera-ture. In this way, effects of copper and silver on the thermal conductivity of carbon materials have been examined so far[1]. The compounds including silver should be excluded from the standpoint of radioactivity for applications to fusion reactors. In the case of copper addition to carbon materials, thermal conductivity of composite materials was lower than that of carbon materials only over a certain range of lower tempera-tures. The reason for this is considered that carbon does not react with copper over a range of temperature measured here and cohesion of carbon with copper is very poor[2]. Then, the third elements which are reactive with carbon and copper, and have lower formation energy of reaction compounds have been investigated. There were some elements[3], such as titanium, zirconium and others, which satisfy the conditions stated above.

Experimental

Materials tested here are shown in Table 1. IG-430U is a graphite for fission and fusion reactor grade material made by Toyo Tanso Co. Ltd. CX-2002U is a felt type C/C composite for plasma facing components of fusion devices. Besides these materials, carbon composite materials with copper - titanium or copper - zirconium were used as base materials. These composite materials, that is carbon alloy, were manufactured to give high thermal conductivity as a trial. IG-430U is a high strength graphite which has fine-grained ($\sim 10\mu$m) cokes with highly purification and used for JT-60U, a fusion plasma device at JAERI. CX-2002U is a two dimensional woven C/C composite with fiber diameter of $\sim 10\mu$m and has been used for JT-60U, too.

Thermal conductivity measurements were performed 293 to 1200K using a pulse laser type thermal property measurement apparatus (MJ-800HW made by Rigaku Ltd.) The specimen size was ϕ 10x(2-4) mm.

The observation of interface between carbon and copper was conducted by using a transmission electron microscopy (JEM-4000).

Results and Discussion

Temperature dependence of thermal conductivity for IG-430U is shown in Figure 1. The thermal conductivity of carbon composite material containing Cu-Zr was higher than that of the material containing Cu-Ti at room temperature and was rarely changed at high temperatures. Temperature dependence of thermal conductivity for CX-2002U is indicated in Figure 2. The thermal conductivity of CX-2002U with Cu-Zr was higher than both of the original and the Cu-Ti containing materials at room temperature. However, the thermal conductivity of Cu-Zr containing material changed with little at high temperatures. The effect of zirconium on the thermal conductivity of the carbon composite material with copper was seen to be particularly large at room temperature and to be almost the same at high temperatures as compared to that of titanium.

The observation of the interfaces between carbon and copper by TEM showed that there exist the compounds of CuZr and ZrC on the interface between carbon and copper. The formation of CuZr and ZrC was considered to increase cohesive force of the interface and to work to thermal conduction effectively.

Conclusion

In order to improve the thermal conductivity of carbon copper composite materials at high temperatures, it turned out that it is effective to add a certain metallic element which has lower values of formation energy of compounds with carbon and copper to the original composite materials.

Acknowledgments

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References

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Table 1 Materials tested.

Base Materials	Tested Materials	wt.%	vol.%	Bulk Density (g/cm^3)	Electrical Resistivity ($\mu\Omega \cdot m$)
Graphite	IG-430U	-	-	1.82	9.0
	IG-430U+Cu	33.1(Cu)	9.2(Cu)	2.74	2.9
	IG-430U+Cu/Ti	36.0(Cu) 0.8(Ti)	11.1(Cu) 0.5(Ti)	2.84	-
	IG-430U+Cu/Zr	34.7(Cu) 1.2(Zr)	11.0(Cu) 0.5(Zr)	2.84	-
C/C Composite	CX-2002U (XX,YY,ZZ)	-	-	1.67	1.7 (XX) 3.4(YY) 5.1(ZZ)
	CX-2002U+Cu	44.3(Cu)	13.1(Cu)	2.83	1.4(XX)
	CX-2002U+Cu/Ti	48.1(Cu) 1.1(Ti)	18.1(Cu) 0.3(Ti)	3.29	-
	CX-2002U+Cu/Zr	50.1(Cu) 1.7(Zr)	19.5(Cu) 0.9(Zr)	3.45	-

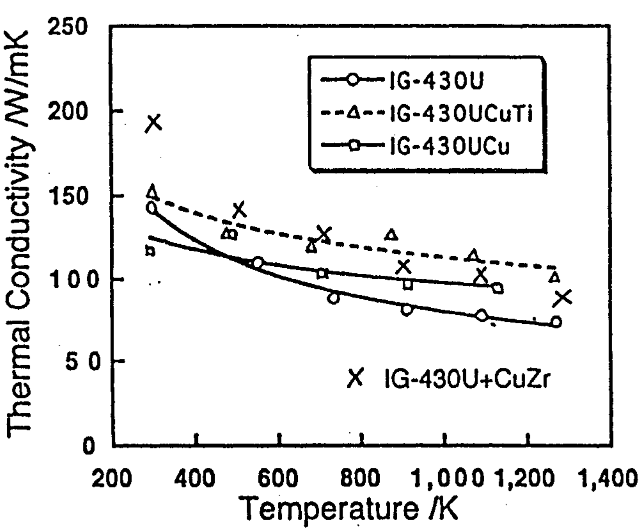

Figure 1 Temperature dependence of thermal conductivity for IG-430U, IG-430U+Cu, IG-430U+CuTi and IG-430U+CuZr.

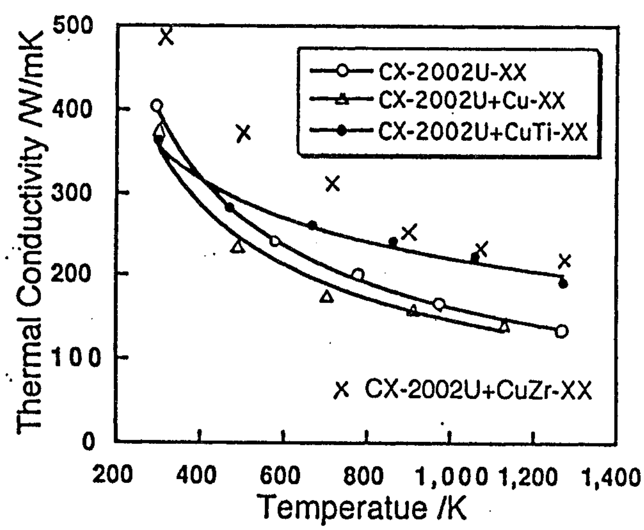

Figure 2 Temperature dependence of thermal conductivity for CX-2002U, CX-2002U+Cu, CX-2002U+CuTi and CX-2002U+CuZr.