A Study on the Formation of Uranium Carbide in an Induction Furnace

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1. Introduction

Uranium is a typical carbide-forming element. Three carbides, UC, U_2C_3 and UC_2, are formed in the uranium-carbon system. The most important of these as fuel is uranium monocarbide UC.

It is well known that Uranium carbides can be obtained by three basic methods:
1) by reaction of uranium metal with carbon;
2) by reaction of uranium metal powder with gaseous hydrocarbons;
3) by reaction of uranium oxides with carbon [1].

The use of uranium monocarbide, or materials based on it, has great prospects as fuel for nuclear reactors [2,3]. It is quite possible that uranium dicarbide UC_2 may also acquire great importance as a fuel, particularly in dispersion fuel elements with graphite matrix [3].

In the present study, uranium carbides are obtained by direct reaction of uranium metal with graphite in a high frequency induction furnace.

2. Experiments and Results

2.1 Casting methods and results

Depleted uranium lumps (99.9 % pure) were directly charged in a graphite crucible without any coating. It was melted under a vacuum atmosphere (4 x 10^{-2} torr) using a high frequency induction furnace. The temperature rise ratio was 27℃ per minute and the holding time was 10 minute for direct diffusion reaction above 2700℃.

Figure 1 shows the schematic drawing of graphite crucible. The graphite crucible was designed sufficient thickness to prevent from leaking out the melt due to severe interaction between uranium and graphite.

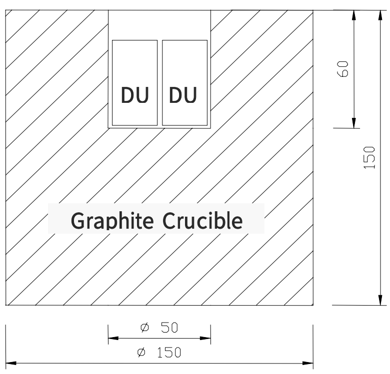

Figure 1. Schematic drawing of graphite crucible (unit : mm)

Figure 2 shows cross-section of uranium carbide casting product. It shows that there are interactions between uranium and graphite crucible. The uranium carbide object eroded graphite crucible by about 5 mm and the middle of the crucible was more severely interacted due to higher temperature. The casting product was brittle, so it was considered to form the inter-metallic uranium carbide compounds.

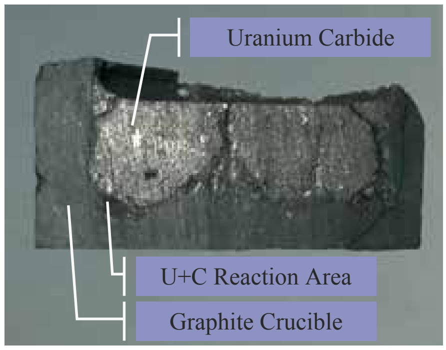

Figure 2. Cross-section of uranium carbide casting product

2.2 The phase analysis and results

A specimen for observation of microstructures and analysis was mounted and polished. The microstructures of a specimen were observed using SEM(Scanning Electron Microscopy and EDS(Energy Dispersive Spectroscopy). The X-ray diffraction peak of a specimen was measured for the structure analysis by XRD using a Cu-Kα target. The step scanning method was used (counting time=4 sec., step width=0.02°). A specimen for the X-ray diffraction was mounted and polished. Chemical composition of a specimen was measured using ICP-AES and density was measured using Archimedean method.

The density of the product is measured at 10.56 g/cm^3. It is lower than the theoretical density 11.68 g/cm^3 of uranium dicarbide UC_2[4]. So it is considered the product includes some pores and another types of uranium carbide metallic compound. The result of the XRD pattern of uranium carbide is shown in Figure 3. It shows that the measured peak is confirmed as that of uranium dicarbide UC_2. The chemical composition result of uranium carbide using ICP-AES consists of 89.75 wt.% of uranium and 10.25 wt.% of carbon. The UC_2 has theoretically 9.2 wt% of carbon. The microstructure of uranium carbide is shown Figure 4 and 5. The results of the microstructure show that an amount of carbons are precipitated throughout the uranium carbide matrix. The EDX results show the matrix is U-5.03 wt% C.

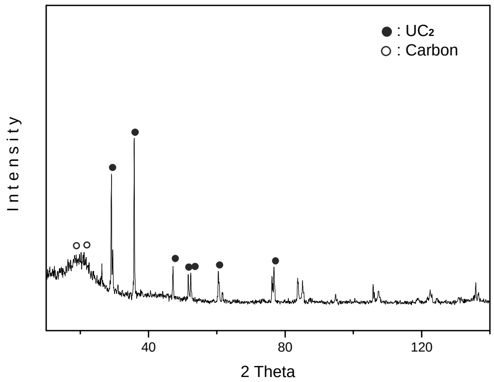

Figure 3. X-ray diffraction pattern of Uranium Carbide

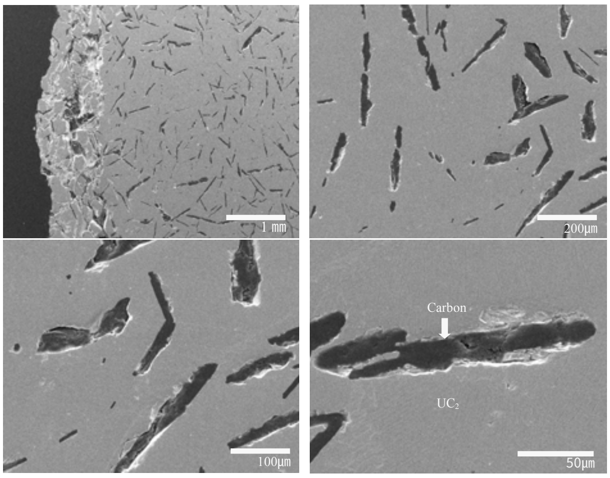

Figure 4. Microstructures of uranium carbide specimen using SEM

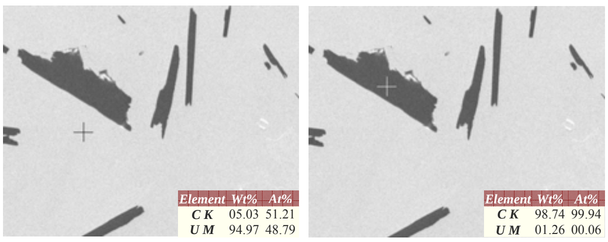

Figure 5. Microstructures analysis using EDS for qualitative and quantitative analysis

3. Conclusion

The metallic compound of uranium carbide may have a great importance as a fuel, particularly in dispersion fuel elements with graphite matrix, so we tried to make it using induction furnace by direct reaction methods between uranium and graphite .

The uranium dicarbide UC_2 was produced with an amount of carbon precipitates in the UC_2 matrix.

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