

Fig. 1 (color online) The differential cross section for J/ψ production from the semi-coherent two-photon interaction in proton- proton collisions at RHIC, LHC, and FCC.



Fig. 2 (color online) The differential cross section for J/ψ production from the semi-coherent two-photon interaction in nucleus- nucleus collisions at RHIC, LHC, and FCC.

References

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2 - 29 Preparation of Uranium Monocarbide Powder by Carbothermic Reduction

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Uranium dioxide (UO_2) has become the basic fuel material for power reactor industry. It has many excellences such as high melting point, dimensional stability under irradiation and good mechanical property. Compared with UO_2 , uranium monocarbide (UC) also has high fissionable material density and thermal conductivity, which can generate more power per kilogram. Therefore, uranium monocarbide (UC) is considered as a potential nuclear fuel in the fourth generation nuclear reactors, especially in accelerated driven systems.

UC can be synthesized by at least five different methods as shown below:

(a) Reaction of carbon with uranium metal or uranium hydride;

(b) Reaction of hydrocarbons with uranium metal or uranium hydride;

- (c) Precipitation of uranium carbide from metal melts;
- (d) Reduction of uranium halides;

(e) Carbothermal reduction of uranium oxide under vacuum or in an inert atmosphere.

The method chosen for this study is carbothermic reduction of uranium dioxide with graphite. In general, the carbothermic reduction of UO_2 may be represented by the following equation:

$$UO_2(s) + 3C(s) \rightarrow UC(s) + 2CO(g).$$

The reaction rate between solid reactants are, among other factors, determined by particle size and how well the reactants are mixed. In addition, the partial pressure of gaseous product CO also affects the rate. The composition of the final product depends on the initial ratio UO_2/C , the reduction temperature and the effective CO pressure.

The starting materials were uranium dioxide powder and graphite powder, which were mixed manually with an agate mortar in glove box for approximately five minutes. After that, the powder was pressed into a pellet with

5 ton·cm⁻² pressure, and then the pellet was put in a tantalum capsule. Finally the reduction was carried out at 1 600 $^{\circ}$ C in flowing argon in a sintering furnace.

The product was analyzed by XRD, SEM, and Raman measurements. Fig. 1 shows the X-ray diffraction result for the UC synthesized by carbothermic reduction in the study. It is clear that the product consists of 98% UC and slight UO₂. As shown in Fig. 2, the product UC was porous.



Fig. 1 (color online) XRD pattern of the product.



Fig. 2 (color online) SEM of the product.

2 - 30 Manufacturing of Uranium Microspheres Using Improved Internal Gelation Process

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Preparation of UO_2 microspheres is the basic work for ceramic fuel. Many workers had paid attention on it. In 1970s and 1980s, United States Department of Energy had conducted numerous studies on the fabrication of nuclear fuels particles with the internal gelation process ^[1]. Manufacture nuclear kernels with internal gelation process is the mature method in wet chemical. Internal gelation process has the advantages of high uniform and spherical microspheres can be prepared. In the fabrication process, there are many factors, such as subsequent ageing, HMTA/uranium mole ratio, gelation forming temperature, washing step, heating rate of the calcined and sinter steps, that affect the quality of the microsphere. The solution is stable at low temperature in the traditional internal gelation process, the speed of gelation was controlled by changing the temperature. However, in present work, the gelation was controlled by selecting the suitable mole ratio of HMTA/uranium at room temperature. The equipment used for cooling the UO₂ spheres was not needed which simplify the equipment of the process. By using high performance liquid pump to mix the solution at room temperature, the gel reaction was under control. The basic research work for preparing UO₂ microspheres with the improved internal gelation process was carried out.

The used uranium solution was concentration of 1.0 mol/L, $\text{HNO}_3 / \text{UO}_2^{2+} = 1.6$; The temperature of Silicone oil is 70 °C. Preparation of the uranium microsphere involved several steps. First, the fabrication of the uranium stock solutions (with and without dispersed carbon black) and HMTA-urea^[2,3]. The solution with dispersed carbon black were obtained by dispersing 100 g carbon black under mechanical stirring for 1 h and ultrasonic dispersing 2 h^[4,5]. Secondly, the feed solution was droplet dispersed into silicone oil at 70 °C to cause the occurrence of gelation. The rate of the flow was ADUN=1.2 ml/min and HMEA=1.2 ml/L. In this step, the gelation reaction occurred immediately when the two solution were meet, which was originally two hours in the traditional ceramic process with chilled mixing solution. The gelled microspheres were aged for 20 min in the hot silicone oil. Finally, the microspheres were collected and successively washed with carbon tetrachloride (three times) and carbon tetrachloride for at least 30 min to remove the silicone oil ^[6]. The other impurities in the microspheres were removed by washing the microspheres with NH₄OH and deionized water. To obtain the uranium microsphere with good quality, many detailed works need to be done in the future to optimize the improved internal gelation process.