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Isolation of UC_2 fuel kernels from coated particles

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Isolation of UC_2 fuel kernels from coated particles

Executive summary

Three types of UC_2-based coated particles were identified, one from "HOBEG" the other two from pilot series of HTR fuel production. Intact UC_2 kernels could by isolated from the series labelled with "UC2 uf15" whereas the fuel kernels from the two other particle types broke during the isolation procedure.
A milling machine was used for cracking the coatings. The fuel kernels were separated from the broken coating by swivelling in water due to the levitation behaviour of the kernels. The remaining pyrocarbon buffer material was removed by an ultrasonic treatment. Approximately 60% of the fuel kernels could by isolated by this procedure without producing broken kernels.
The isolated UC_2 kernels were characterised by optical and electronic microscopy and x-ray diffraction.

Revisions

Rev.	Date	Short description	Author	WP Leader	SP Leader	Coordinator
01	24/11/2005	Draft	J. Fachinger FZJ	J. Fachinger FZJ		
02	09/12/2005	2. Draft	J. Fachinger FZJ	J. Fachinger FZJ	W. von Lensa FZJ	
03	16/01/2006	Final	J. Fachinger FZJ	J. Fachinger FZJ	W. von Lensa FZJ	E.Bogusch, ANP

1 Raw materials

For the present work coated particles from HOBEG was used as source for UC_2 fuel kernels. The container with the coated particles was labelled “UC2 uf15”. The other UC_2-based coated particles could not be used, because the kernels were broken during the isolation procedure.
The coated particles are spherical particles with a diameter of approximately 0.8 mm. For an investigation of their inner structure, the particles were fixed in epoxy resin and thereafter grinded and polished. Photographs of the coated particles sections are presented in Figure 1.

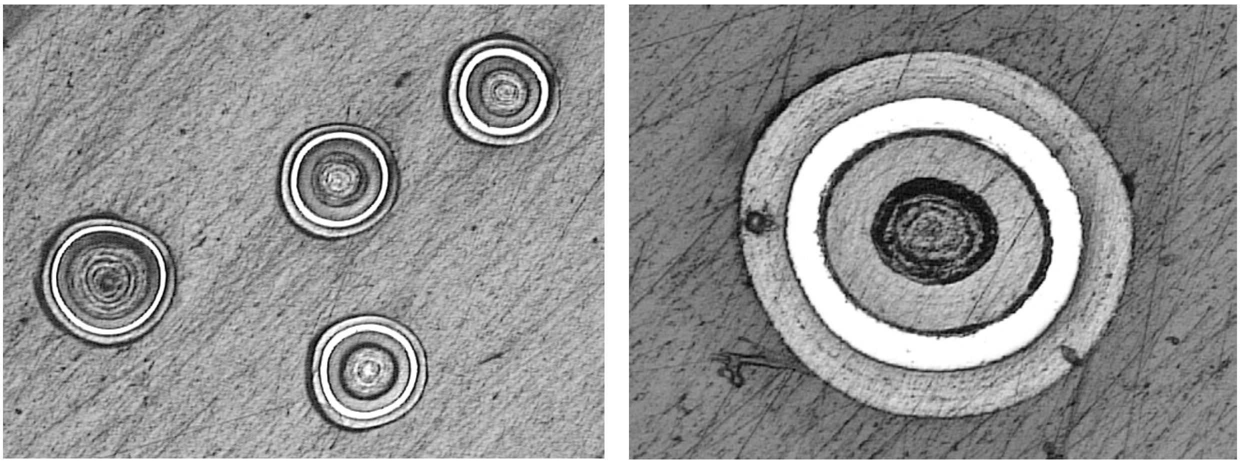

Figure 1: Sections of UC_2 coated particles.

The structure of the coated particle sections allows classifying them as TRISO particles, with a dense silicone carbide layer located between layers of pyrocarbon. At the places of the kernels, only hollows are visible on the sections presented due to the of low strength of the bonding between fuel kernel and porous pyrocarbon buffer layer, which led to a detachment of kernels during the polishing procedure.
The diameter of the kernels is very important for a successful isolation procedure. Therefore, several coated particles were cracked by point loading in a micrometer. The UC_2 fuel kernel diameter could be estimated with approximately 0.18 mm.

2 Isolation technique

The kernels were isolated from the coatings by mechanical cracking using a Retsch milling machine (Figure 2). Before isolation, the mill was calibrated and the distance between the work faces was adjusted to be slightly higher than the diameter of a UC_2 fuel kernel. Approximately 5 g of coated particles was treated at one run. All isolation steps were performed in argon-saturated deionised water in order to prevent dust formation and direct contact of the fuel kernels with air.
The mill was operated for approximately 15 minutes and then switched off. The content of the mill was rinsed by deionised water through a set of two subsequent sieves of 0.20 and 0.16 mm mesh size. The mesh size apertures were selected according to the kernels size of 0.18 mm. Thereafter, the content of the 0.16 mm sieve was placed in a Petri dish, and fuel kernels were separated from broken coatings by swivelling in water due to the floating behaviour of the kernels and coatings.

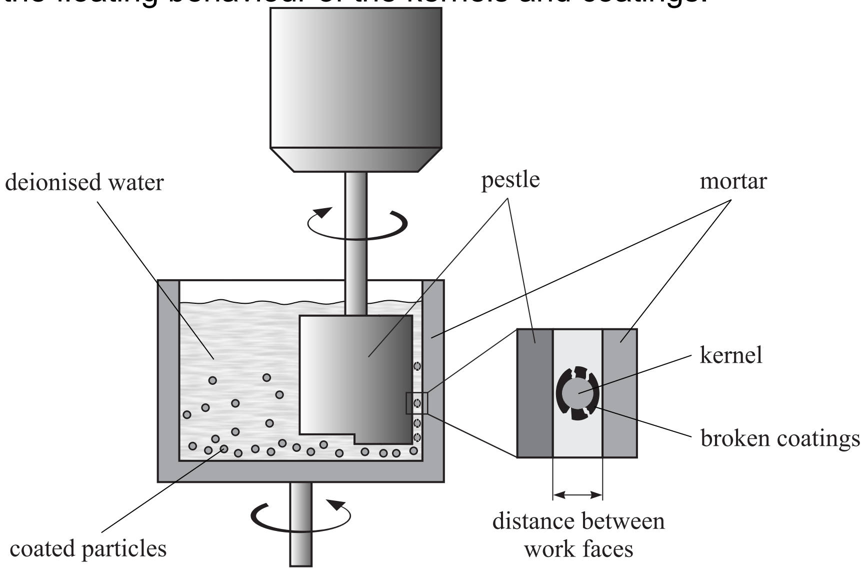

Figure 2: Isolation of fuel kernels from coated particles by means of a Retsch milling machine.

After drying a test sample of kernels was investigated be means of a scanning electron microscope (SEM). As can be seen in Figure 3, after isolation the kernels still bear a rest of their pyrocarbon buffer layer. To remove this surface contamination, the kernels were thoroughly cleaned in an ultrasonic bath for 90 minutes.

After ultrasonic cleaning the kernels were dried for 48 hours in a desiccator in vacuum and finally stored in argon atmosphere.

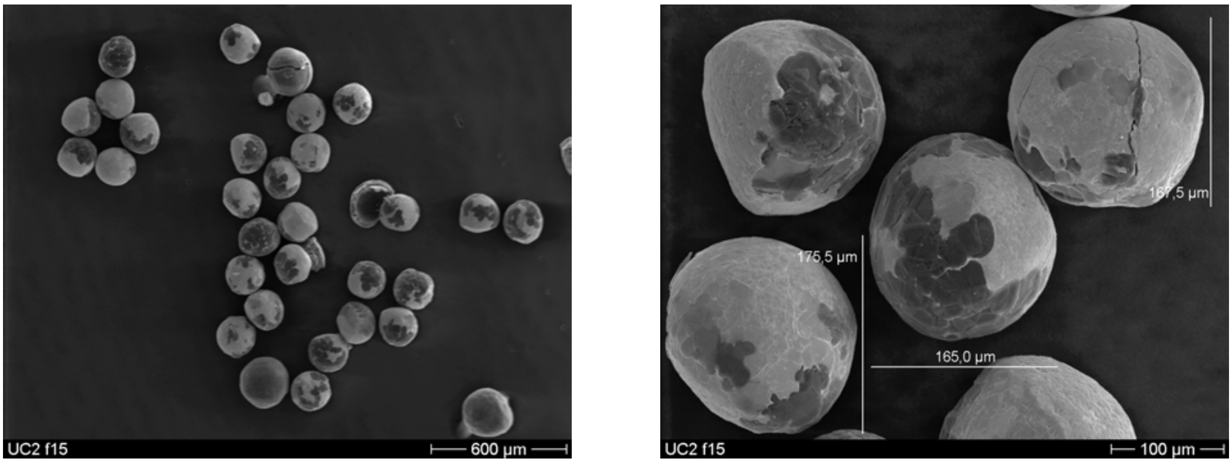

Figure 3: UC_2 kernels after isolation in a milling machine.

3 Overview of isolated UC_2 kernels

SEM investigations (Figure 4) show that isolated kernels have regular clean surfaces and are intact. A detailed photograph of a typical UC_2 fuel kernel surface is presented in Figure 5. The surface is facetted with a facet size of about 25 μm. This facet size is more likely connected with the fabrication procedure, rather than represents the grain size of the material. The kernel seems to have approximately reached its theoretical density.

XRD investigations (Figure 6) show that the fuel kernels consist of only one crystal phase, i.e. tetragonal body-centred UC_2 with lattice parameters of a=0.352±0.001 and c=0.599±0.001 nm. The theoretical density is calculated with 11.75 g/cm^3.

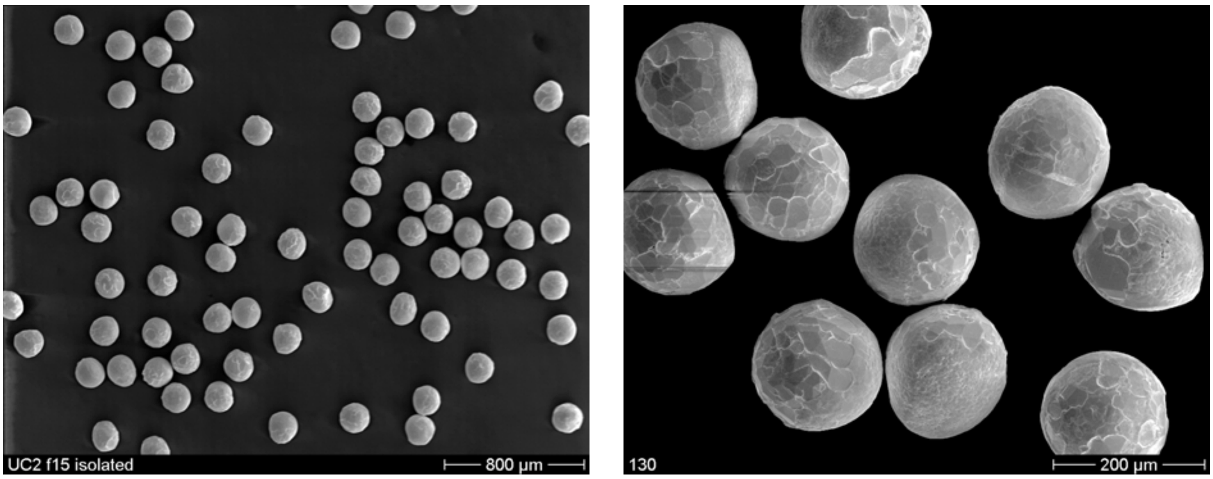

Figure 4: Isolated UC_2 kernels of final quality.

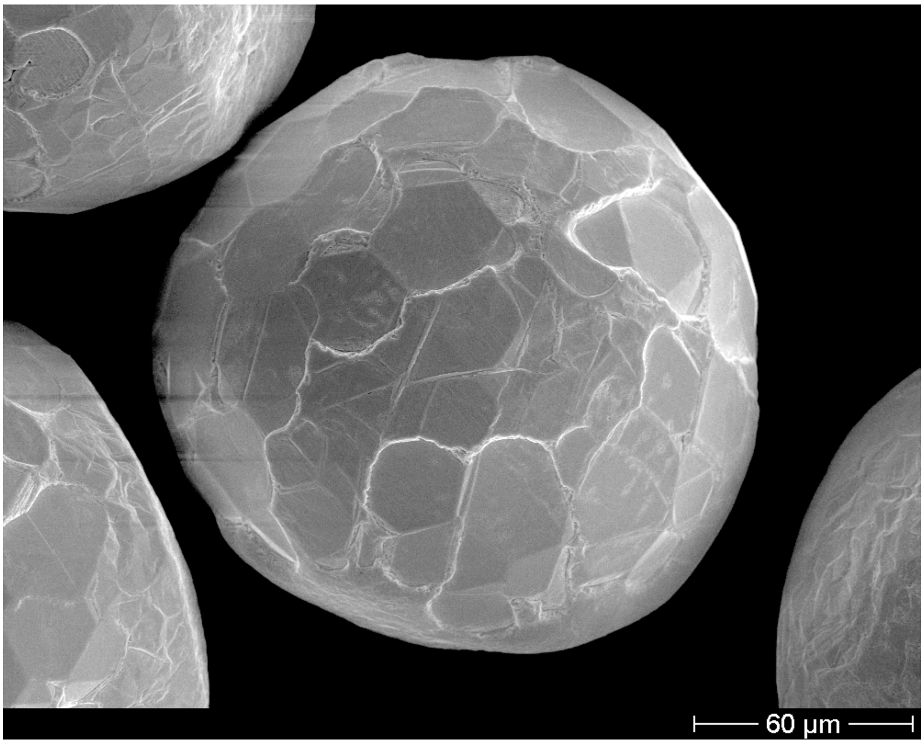

Figure 5: Surface of UC_2 fuel kernels.

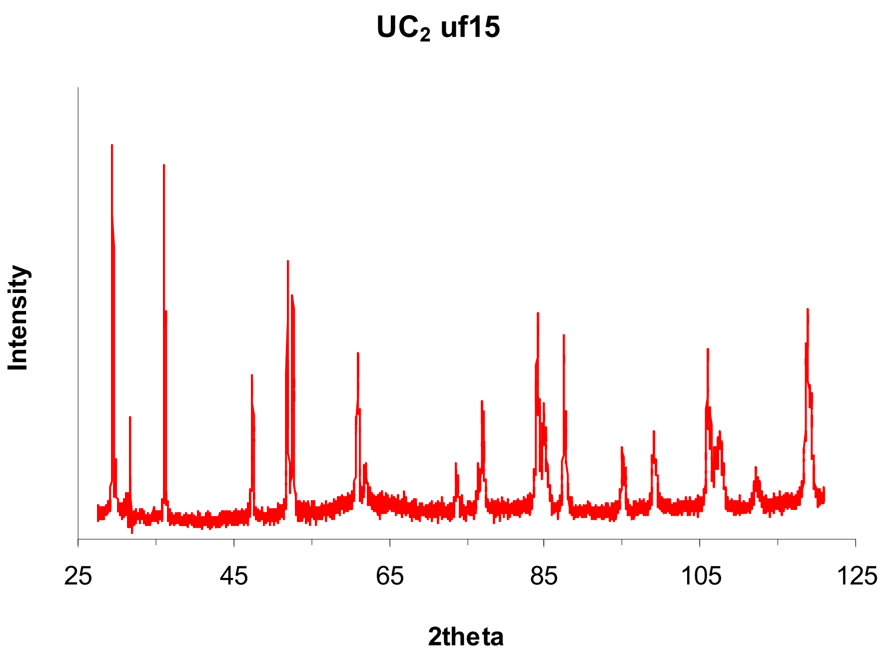

Figure 6: XRD spectra of a UC_2 fuel kernel.

4 Determination of recovery rate of isolation procedure

Before and after the isolation procedure the masses of initial coated particles and resulting kernels was determined. It could be derived, that from one gram of coated particles about 0.1 g of UC_2 fuel kernels can be obtained.

The second step was to determine the mass of single coated particles and fuel kernels. Since they are very small, approximately 500 particles and kernels were weighed on an analytical balance. The exact number of particles, taking part in the measurement, was then determined from macro-photographs. Based upon this procedure, the average weight was assessed to be 0.281 mg for a single coated particle and 0.044 mg for a UC_2 kernel, respectively. This means that the fuel kernel mass is only 15.7% from that mass of a coated particle.

Therefore, the recovery rate of the isolation procedure used can be estimated as 60%. It should be noted here, that the isolation procedure used was applied to obtain the best quality of the kernels, and no efforts were made to optimise the recovery rate of uranium.

5 Conclusions

UC_2 fuel kernels were successfully isolated from coatings by means of an automated procedure. The isolated kernels are intact, have no visible surface contaminations, and consist of only one crystal phase – tetragonal body-centered uranium dicarbide, at about maximum theoretical density.

The main kernel parameters are:

diameter:	0.18 mm
theoretical density:	11.75 g/cm^3
mass:	0.044 mg
specific geometrical surface:	23.1 cm^2/g