Laser melting study of nanograined uranium carbides

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Introduction

UC_{2-y}/C composites are world reference materials for ISOL spallation targets [1]. Recently, an increase of the radioactive ion beam intensities was observed on nanomaterials [2], but their basic properties are largely unknown. Here, we present a study of the high-temperature transitions of nanograined UC_{2-y} with C and UO_2 impurities, using laser heating.

Experimental

UC_{2-y} samples prepared by electrospinning using solutions of cellulose acetate and uranyl salts on acetic acid and 2,4-pentanedione. Good precursors were obtained from uranyl acetate solutions with 15% wt. cellulose acetate.

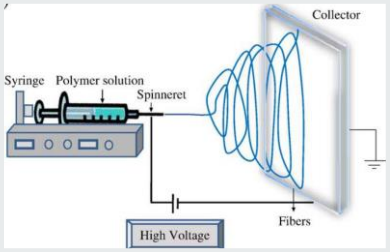

Fig. 1. Set up of an electrospinning system [1].

Precursors were decomposed by heating until 823K under Ar, and carboreduced under vacuum at 2073K for 2 h. The final material contains UC_{2-y} as the major phase, and unreacted UO_{2+x} and C.

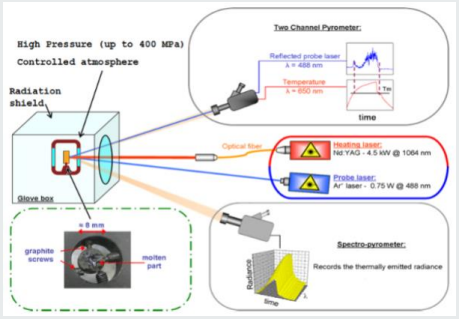

Fig. 2. Laser-heating and radiance spectro-pyrometry set-up [2].

UC_{2-y} samples were laser-heated under Ar up to >3000K and their behavior was studied by radiance spectroscopy. The materials were characterized by XRD, SEM/EDS and Raman spectroscopy.

Results

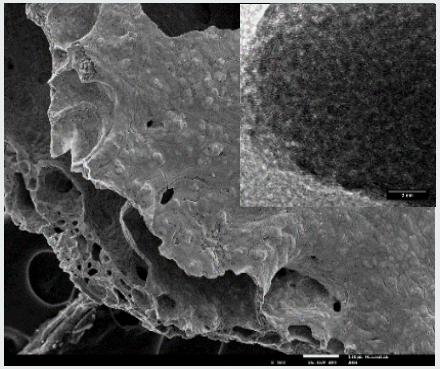

Fig. 3. SEM image of UC_{2-y} materials before laser heating (insert: TEM image).

The post-laser heated sample consists of UC_{2-y}, UO_2 and C, but an increase of the UC_{2-y} peaks is seen, indicating that this phase is favored under the fast laser heating conditions.

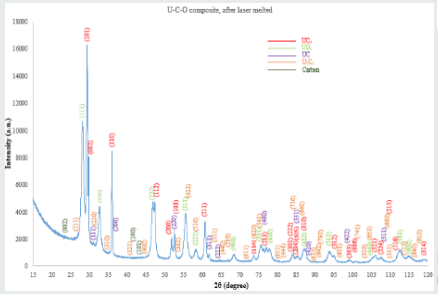

Fig. 5. X-ray diffractogram of UC_{2-y} materials after laser heating.

The pre-laser heated sample observation points to a partial melting during decomposition. EDS indicates the presence of U, O, and C, showing that the carbothermal reaction, $UO_2 + 4C \rightarrow UC_{2-y} + 2CO$, was not completed. TEM images show 4 to 10 nm gran sizes.

XRD measurements confirm EDS results, showing that UC_{2-y}, UO_2 and C constitute the pre-laser heated material.

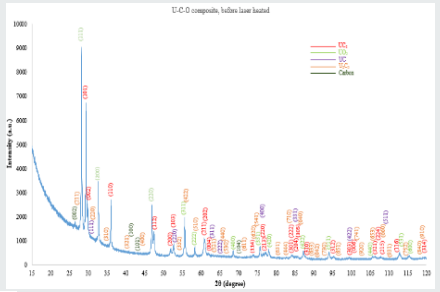

Fig. 4. X-ray diffractogram of UC_{2-y} materials before laser heating.

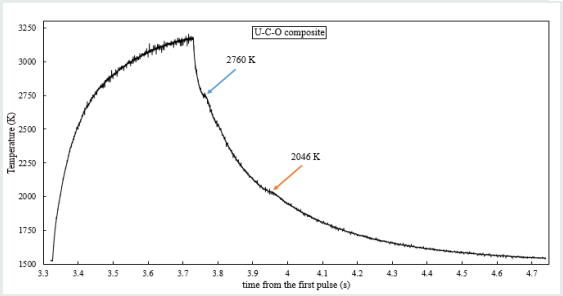

Fig. 7. Thermogram of UC_{2-y} materials for a 585 W laser heating shot.

Laser shots increased temperature up to ~3100 K. On cool-down, anomalies at ~2760 K and ~2046 K occurred. The first corresponds to UC_{2-y} liquid to solid transition, while the second is attributed to the structural UC_{2-y} transition.

Post-laser heated sample has holes of 10 - 100 µm diameter. EDS analysis confirms U, O and C. TEM shows grain sizes of 10 - 20 nm, pointing that C prevents the growth.

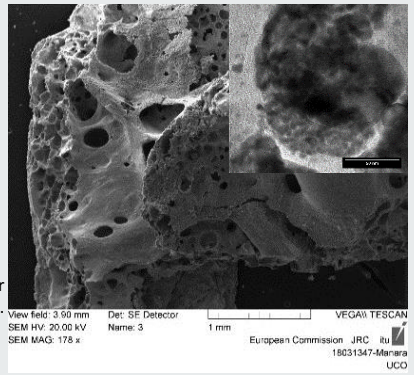

Fig. 6. SEM image of UC_{2-y} after laser heating (insert: TEM image).

Conclusions

UC_{2-y} materials consisting of UC_{2-y} as major phase, plus UO_{2+x} and C, with nanometric grain sizes, show a melting temperature of 2760 K, close to the previously reported data, pointing to a small effect of the grain size on it. Observations of post-laser heated samples revealed grain sizes slightly larger than the pre-laser heated ones, indicating excess carbon as an inhibitor of the grains growth.

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References: [1] N. Bhardwaj, et al. Electrospinning. Biotechn. Adv. Vol. 28(3), p. 325-347, 2010. [2] D. Manara, et al. Laser-heating and radiance spectrometry for the study of nuclear materials in conditions simulating a nuclear power plant accident. J. Vis. Exp. (130), e54807, 2017.