UMo processing by DC-magnetron sputtering

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The research reactor "Forschungsneutronenquelle Heinz Maier-Leibnitz" (FRM II) currently uses U_3Si_2 nuclear fuel based on high enriched uranium (or: HEU), that means fuel with an ^{235}U isotope content of $> 85at\%$. In connection with international efforts on proliferation control, a program was initiated to convert all HEU-using research reactors worldwide to fuels with low ^{235}U enrichment. In case of FRM II this conversion is only possible if the fuel is changed from the low density U_3Si_2 to an alternative high density fuel [1].
Monolithic UMo is a promising candidate in this context due to its high uranium density of up to $16gU/cm^3$ [1]. Unfortunately the processing of UMo alloys by classical processing techniques like rolling or welding is very extensive and error-prone, due to the metallurgical properties of these alloys [2,3]. The production processes of foils from UMo and the cladding of these foils are therefore very inefficient and only work on laboratory scale up to now.
An approach to overcome this situation is the application of DC-magnetron sputtering as a processing technique [4]. The sputtering process can in principle be used to produce complete and full-sized UMo fuel plates within just two steps: first by sputtering a monolithic UMo foil, which is the final and full-sized fuel meat. Second by deposition of cladding material onto the surface of this fuel meat foil, which clads it and creates a finished fuel plate [5].

Fig. 1: Production of DU8Mo foils at RCM.

As a proof of principle for this two-step process a small DC-magnetron sputtering device has been built (Fig. 1a) and operated at the TUM Institute for Radiochemistry (RCM). In first experiments with this setup we could reach a deposition rate for DU8Mo (depleted uranium with $8wt\%$ molybdenum content) of $5\mu m/h$ and fabricate foils of excellent quality with a size of 60mm x 25mm and $10\mu m$ thickness (Fig. 1b). Further experiments showed, that foils of 120mm x 50mm in size and $150\mu m$ thickness can be reached without any problem.
A phase analysis of the deposited layer showed the DU8Mo is in the tetragonal γ-phase after the sputtering process, which is an irradiation-stable and therefore favoured phase for monolithic UMo fuel.
Besides the small sputtering device a DC-magnetron sputtering plant has been built and operated at the Maier-Leibnitz Laboratorium (MLL). It was designed for the production of foils with a size of 700 mm x 65 mm and $300\mu m$ thickness, which corresponds to the fuel meat layer of a full-sized fuel plate of the FRM II. We could show already in 2007, that in this plant we can successfully produce foils of surrogate meat materials in the desired geometry and clad them in a second step with aluminum [5].
In 2008 the plant has been reconstructed for the handling of UMo under inert atmosphere (Fig. 2). The reconstruction works are finished now and currently the plants installation in the radioisotope laboratory K8 of the LMU Sektion Physik is prepared.

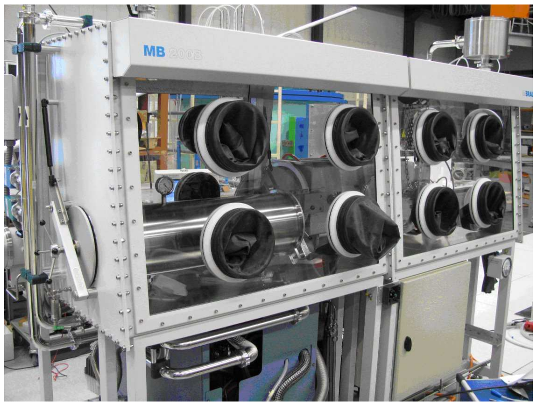

Fig. 2: The DC-magnetron sputtering plant for production and cladding of full-sized DU8Mo foils was built at MLL.

For the next months we plan to do further experiments in RCM to determine optimal processing parameters for DU8Mo foil production and foil cladding. As soon as the DC-magnetron sputtering plant is installed and ready for operation we intend to fabricate full-sized DU8Mo foils.

References

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