FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

Synthesis of nanometric MoNbW alloy using self-propagating high-temperature synthesis

Considering applications for plasma facing materials (PFM) in tokamak, the French laboratory LSPM has developed a new methodology for nanometric refractory tungsten alloys manufacruting with high homogeneity in composition. The originality of the invention consists in providing to the nanopowders interesting properties' such as a low brittle-to-ductile transition temperature in order to be machinable, and a good resistance to oxidation. The synthesis of nanometric tungsten alloy powder into submicron platelets offers an increase of ductility of up to 30% and make them suitable for fusion application. This methodology could be applied to other binary, ternary and quaternary alloys as well as High Entropy Alloys (HEA) and find therefore potential applications in non-fusion domains.

Description of the technology

Recent studies show that low grain sizes help improving ductility and machinability in tungsten, as well as the resistance to ablation and spallation if this material is to be used in thermonuclear fusion environment. Considering applications for plasma facing material (PFM) in tokamak, the French laboratory LSPM has developed a new methodology of nanostructured tungsten alloys (Mo-Nb-W) production based on powder metallurgy, including the powder synthesis by the reduction of tungsten trioxide by magnesium using the Self-propagating High-temperature Synthesis. Results show that full tungsten densification may be obtained by SPS at a temperature lower than 1800°C and that the resulting morphology, keeping a partial nanostructure inherited from the synthesized powders, seems indeed favorable to the use of these materials in fusion environments.

WO3, Mg, and NaCl, acting, respectively, as oxidizer, reducer, and reaction moderator are first thoroughly mixed, set in a closed reactor and heated. For the reaction to be complete, Mg amounts are increased from the stoichiometric proportions by 50%, and NaCl is added in order to decrease the overall products final temperature to 1800°C. Resulting products are then lixiviated then filtered, rinsed, and dried.

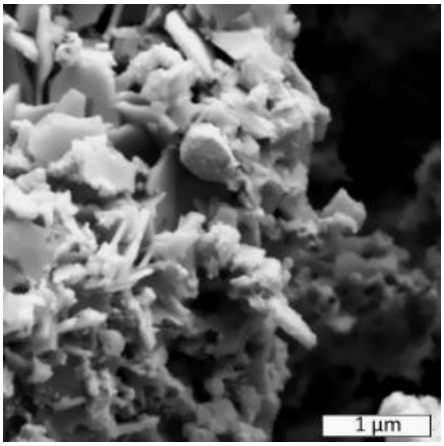

Fig.1 : SEM observation of the SHS produced submicrometric powders

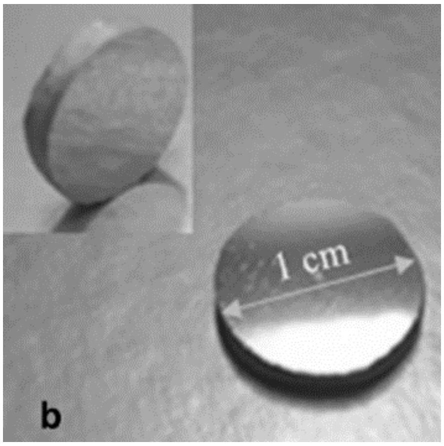

Fig.2 : Photograph of a sintered sample after polishing

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Innovation and advantages of the offer

- Production of high purity nanostructured products in the 20–800 nm range, with an average equivalent diameter, from specific surface measurements, of 66 nm
- Relative ease for scaling-up and possible extension of the protocol to other tungsten alloys (different alloying elements, different concentrations)
- Full tungsten densification may be obtained by SPS at a temperature lower than 1800°C
- This nanometric substructure also resulted in an improved hardness of the material up to 25% increase from the theoretical hardness of bulk tungsten
- Improved resistance to ablation and spallation

Non-fusion Applications

This methodology could be applied to other binary, ternary and quaternary alloys as well as High Entropy Alloys (HEA) and find therefore potential applications in non-fusion domains, especially where high operational temperatures are encountered and low brittle-to-ductile transition temperature/high oxidation resistance are requested (Energy, Oil and Gas, Aerospace, Defence).

EUROfusion Heritage

Due to its high melting point, good thermal conductivity, high temperature resistance, low plasma sputtering, and low neutronic irradiation activation, tungsten is considered as one of the main candidates for plasma facing material (PFM) in tokamak. However, tungsten brittleness is a strong drawback for its use for classical structural applications, and, partially, including its use as a PFM as crack generation due to thermal fatigue is therefore observed. Several routes are currently being investigated in order to improve tungsten ductility. Among them, the use of alloying elements is a natural choice in metallurgy. However, only Re is known to induce ductility in W, and unfortunately this choice is not relevant for large-scale alloys.

Moreover, in fusion specific operational conditions Re increases neutron irradiation induced embrittlement, reduces thermal conductivity and is highly activated under neutron irradiation, being transmuted into radioactive Os, thus inducing safety and waste management issues. In the same way, Nb and Mo additions should also be avoided, as they also transmute under neutron irradiation, into radioactive elements with very long half-lives. This methodology for Tungsten alloy nanopowders production has been developed in collaboration with the IRFM Institute (CEA Cadarache) for fusion application.

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