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Mechanical and microstructural characterization of different oxides for oxide-dispersion-strengthened (ODS) steels

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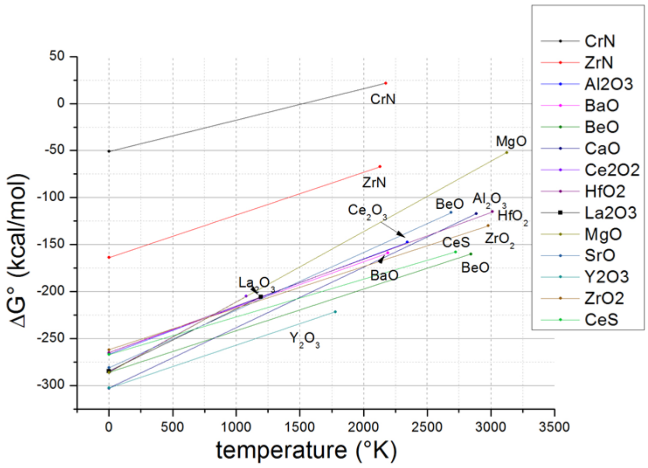
Introduction

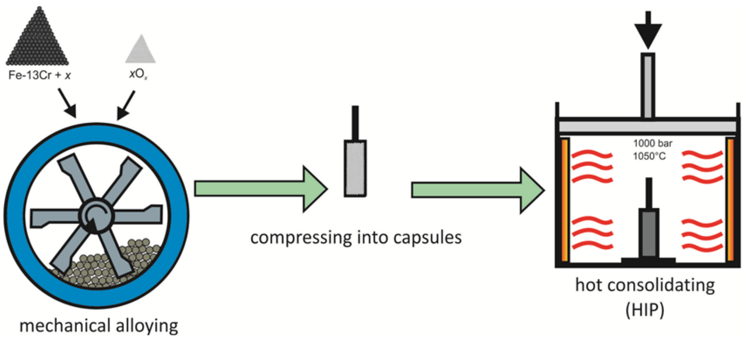
Compared to present reactors, modern nuclear power plant concepts are based on materials which can be operated at higher temperatures and up to higher neutron doses. Oxide dispersion strengthened (ODS) steels – produced by mechanical alloying – with chromium contents of 9 and 14 wt. % (or even more) are typical candidate materials.
Y_2O_3 has proven to be an excellent oxide for strengthening steels in order to improve several mechanical properties. Since Y_2O_3 is one of the most stable oxides, it has superior properties for nano-oxide-particle formation and stability. The aim of the work presented here, is to look for alternative oxides for ODS steel. These alternatives may provide better mechanical properties when combined with Y_2O_3, and added to the ferritic ODS alloy.

Methods and Materials

Several different oxides were selected by looking at their Gibbs-Free-Enthalpy and thermal stability for the desired operating temperatures. **Lanthana (La_2O_3), Zirconia (ZrO_2), Ceria (Ce_2O_3)** and **Magnesia (MgO)** were chosen for the experiments according to these requirements.



Production

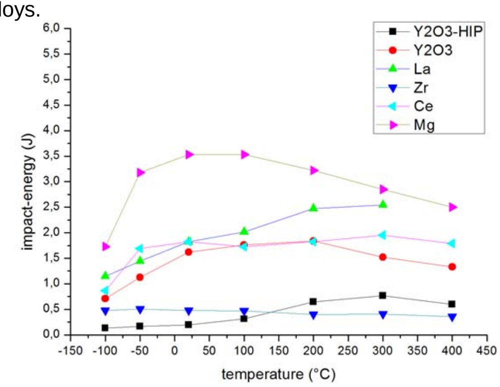


Pre-alloyed gas-atomized steel powder (Fe13Cr1W0.3Ti) was mixed with the different oxides and milled in an Attritor ball-mill for 80 hours. Than the material was put into steel cans and HIPped for 2 hours at 1423K and 100 MPa. After the consolidation, hot-rolling was performed at 1373K. Material was rolled from 45 mm cans to 6 mm plates in 5 passes with reheating after each pass.

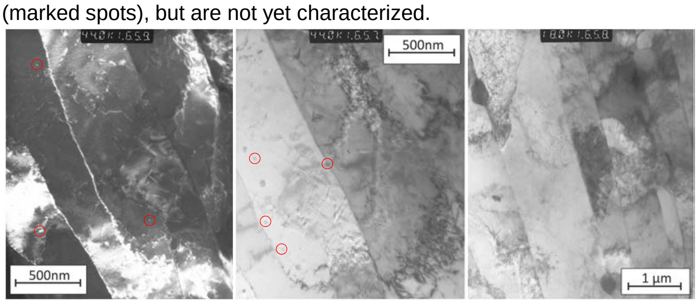
The production process was completed with a final heat treatment at 1073K for 2 hours.

Results

The different alloys show major differences in the charpy-impact-energy. Brittle behavior of ODS alloys strongly depends on the morphology of the nano-sized oxide particles. Micro-meter sized particles at the grain boundaries may produce the brittle behavior of some alloys (e.g. ZrO_2).
Also, it is clearly visible when comparing Y_2O_3-alloys in as-hipped and as-rolled condition, that thermo-mechanical treatment is essential for ODS alloys.



First TEM bright- and dark-field images show the micro-structure with elongated grains in rolling direction after the thermo-mechanical treatment.
Particles were found inside the grains and on the grain boundaries (marked spots), but are not yet characterized.



TEM images (dark-field and bright-field) of Fe13Cr1W + 0.3 La_2O_3

Outlook

First results show, that the selected oxides have a strengthening effect on ferritic-steels. Some oxides (MgO, Ce_2O_3) perform even better than Y_2O_3 in terms of charpy-impact-tests. Although the different behavior of the oxides needs detailed examination.
TEM investigation of all alloys are performed at the moment to determine size and distribution of the oxide-particles. Further mechanical testing (tensile-tests) and microstructure analysis is also done.

Acknowledgements

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