2020 Helmholtz – OCPC – Program
for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project: Influence of microstructure and interfaces on the hydrogen permeation and retention in tungsten coated steel for fusion applications

Helmholtz Centre and institute: Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research, Plasma Physics (IEK-4)

Project leader: Dr. Anne Houben

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Description of the project:
In future fusion reactors, the hydrogen isotopes deuterium and tritium will be used as fuel for the nuclear fusion process in order to generate electricity. For safety, operational and economic reasons, the hydrogen isotope retention and diffusion through reactor wall materials must be well controlled. Tungsten is intended as first wall and divertor material, mainly due to the high melting point and the low erosion by a hydrogen plasma. Furthermore, bulk tungsten has a relatively small hydrogen retention compared to other materials, however the diffusion of hydrogen through tungsten is high at fusion reactor wall temperatures of around 600°C. For future fusion reactors, tungsten coated steel components are one option for the first wall. Coatings exhibit other characteristics than bulk materials, since hydrogen retention and permeation are strongly dependent on the microstructure, defects and interfaces.
Previous studies show a much higher hydrogen retention and permeation of hydrogen isotopes in tungsten coatings compared to bulk tungsten, but a detailed investigation of the influences of the different coating characteristics on these properties is still missing. Furthermore, due to the very different thermal expansion coefficients of tungsten and steel, tungsten thin films coated by magnetron sputter deposition tend to crack during thermal treatment. These cracks can act as shortcuts for hydrogen to the substrate and the permeation flux can be increased by several orders of magnitude compared to a non-cracked coating. The aim of this project is therefore to find deposition parameters for the tungsten coatings which avoid crack formation under thermal treatment. After annealing of the coated steel substrates, the samples will be pre-characterized by x-ray diffraction (crystal structure) and scanning electron microscopy (microstructure, cracks). Deuterium gas permeation measurements will then be performed in the temperature range between 300°C and 550°C and the deuterium permeability, diffusion and solubility of the layer will be obtained by these measurements. A post-characterisation will be performed after the permeation measurements in order to determine the changes of the sample due to heat treatment in a deuterium atmosphere. In order to investigate the influence of the microstructure and interfaces, a variation of layer thickness (influence of interfaces) and microstructure is required. For prediction of the hydrogen permeation flux through fusion reactor components, the knowledge of the influence of the interfaces is requested. Furthermore, the influence of deuterium plasma exposure on the permeation will be studied on samples, by exposure to a deuterium plasma before permeation measurements. The deuterium

retention in coated substrates will be determined by thermal desorption (total inventory) and nuclear reaction analysis (depth resolved).
The goals of this work are the deposition of stable tungsten layers on steel substrates by magnetron sputtering, the pre- and post-characterization regarding the crystal and microstructure and the detailed investigation of the deuterium permeation and retention in tungsten coated steel. With this study a holistic overview of the hydrogen isotope behaviour in tungsten coated steel components will be obtained, which is crucial for the prediction of the component behaviour in future fusion devices.

Description of existing or sought Chinese collaboration partner institute:
The School of Materials Science and Engineering at the Hefei University of Technology (HFUT) has a large infrastructure and knowledge of sample preparation and characterization. Magnetron sputtering deposition devices have been used to prepare tungsten coatings on candidate reduced activation ferritic/martensitic steel CLAM (China low activation martensitic steel) for fusion applications. Sample characterization facilities such as x-ray diffraction, scanning electron microscopy, transmission electron microscopy, and x-ray photoelectron spectroscopy etc. are available. In addition, a linear plasma device has been constructed recently to study the plasma-material interaction (PMI) processes. The device can produce versatile low-energy and high-flux plasmas in laboratory experiments and is highly cost-effective to replicate the fusion-relevant plasma environment. Various plasma species such as hydrogen, deuterium, helium, and argon can be produced for different targets. The device will provide an experimental platform to improve the understanding of PMI, validate computational simulation results, and build a database for fusion materials.
There are several successful collaborations so far between the IEK-4 and the HFUT at other research topics, such as research and development of tungsten fibre enhanced tungsten (W_f/W), tungsten multilayer composites, and self-passivating tungsten alloys, etc. The aim of this OCPC-postdoc is to deepen and extend this collaboration to this topic about hydrogen isotope permeation and retention in fusion materials.

Required qualification of the post-doc:

- PhD in Engineering.
- Experience with magnetron layer deposition, deuterium permeation and retention measurements. Expertise on fusion materials such as tungsten and steel.
- Additional skills: international experience of the candidate is very desirable

PART B

Documents to be provided by the post-doc, necessary for an application to OCPC via a postdoc-station in China, which is affiliated to a research institution like a university:

- Detailed description of the interest in joining the project (motivation letter)
- Curriculum vitae, copies of degrees
- List of publications
- 2 letters of recommendation
- Proof of command of English language

PART C

Additional requirements to be fulfilled by the post-doc:

- Max. age of 35 years
- PhD degree not older than 5 years
- Very good command of the English language
- Strong ability to work independently and in a team