Development of High Performance Materials for Nuclear Fusion Power Plants

Tungsten and tungsten alloys are currently considered as candidate materials for various divertor applications in future fusion reactors as well as for shielding the first wall. This is mainly due to their high temperature strength, good thermal conductivity, and comparably low activation under neutron irradiation. The main components where these materials could be applied are (1) plasma facing shields, (2) high temperature cooling structures, and (3) high temperature backbone/support structures. For the shields, tungsten is used as armour material (also due to its high sputter resistance) to protect the subjacent cooling structure. Depending on the plasma operation conditions in tokamaks the shielding surface temperatures might, on the one hand, well exceed 1800 °C, and on the other hand, drop down to the maximum operation temperature of the cooling structure, which is limitied for most tungsten materials to about 1200 °C due to recrystallization and loss of strength.
The most important, and necessary, properties of the armour materials are therefore related to crack resistance under thermal shock load and resistance to irradiation damage in general. Obviously, the backbone/support structures should be made of steel which restricts its operation temperature to about 550 °C for conventional steels and to 700 °C or possibly above for ODS steels. Therefore, the cooling structures are expected to work within the temperature interval of about 450-1200 °C. In that temperature range the most critical requirements for possible structural tungsten materials are ductility, the creep strength, and resistance to recrystallization – all under severe neutron irradiation.
The long-term objective of the European W and W alloys programme is to develop structural as well as armour materials in combination with the necessary production and fabrication technologies for future divertor concepts. The programmatic roadmap is structured into four engineering research parts which are (1) fabrication process development, (2) structural material development, (3) armour material optimisation, and (4) irradiation performance testing, which are complemented by a fundamental research programme.
This paper presents the current research status of the work on the experimental and testing programme for divertor applications carried out in Europe under EFDA, and gives an overview on the mopst important results on tungsten alloys, mass fabrication, joining, plasticity and fracture mechanics.

Dr. Michael Rieth,

born in 1963, works as senior research scientist at the Institute of Applied Materials (IAM) at KIT, the Karlsruhe Institute of Technology, Germany, since 2002. He is the head of a consulting company (AIFT) since 1987. He worked as a researcher at the Institute of Materials Research II, Forschungszentrum Karlsruhe, from 1995 to 1999 and at the Engineering Science Department of the University of Patras, Greece, from 1999 to 2000. He was product manager at AMA Systems, Pforzheim, Germany, from 2000 to 2001. He received his Master of Science degree in electrical engineering from the University of Karlsruhe in 1991 and his doctoral degree in physics from the University of Patras in 2001. Dr. Rieth was the editor-in-chief of the *Journal of Computational and Theoretical Nanoscience* from 2004 to 2005. He is the author of *Nano-Engineering in Science and Technology* (World Scientific, Singapore, 2003) and he is editor of the *Handbook of Theoretical and Computational Nanotechnology* (American Scientific Publishers, Stevenson Ranch, 2006). He further published several patents and book chapters. His main scientific interests are in materials development for advanced fusion reactor applications as well as modeling of metallic materials and nanosystems. Since 2008 he is co-chairing (together with Sergei Dudarev) the EFDA Topical Group on Fusion Materials. He also gives lectures in materials science at the University of Karlsruhe, at the Baden-Wuerttemberg Cooperative State University, and at summer schools.