2.2 Status of the European R&D on Beryllium as Multiplier Material for Breeder Blankets

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Within the international fusion community a variety of breeding blanket concepts are being considered, ranging from more conservative concepts to higher-risk concepts for fusion power reactors. In Europe, the Helium Cooled Pebble Bed (HCPB) blanket is one of the two reference concepts which will also be tested as Test Blanket Module (TBM) in ITER. In addition to the R&D for structural parts of the HCPB blanket, a considerable effort is devoted to the production and qualification of ceramic breeder and neutron multiplier (beryllium or beryllide) pebble beds. Since in the HCPB blanket pebbles made of lithium ceramics are foreseen, a high volume fraction of beryllium as a neutron multiplier to Li-based ceramic of about 4:1 is needed. The typical loading conditions for beryllium are, with a neutron wall load of ~12.5 MWa/m^2 and in ~5 years lifetime: T_{min} ~300°C, T_{max} ~600-900°C, displacement damage ~80 dpa, peak ^{4}He production ~26000 appm and peak ^{3}H production ~ 700 appm at the End-Of-Life. The behaviour of beryllium under irradiation is considered to be a key issue of the HCPB blanket, because of swelling due to helium bubbles and tritium retention.
A large R&D programme on beryllium has been implemented in Europe, aimed at characterising and predicting the material behaviour before and under irradiation. The programme includes:

I. The characterisation of non-irradiated Be-based material and pebble bed properties like thermal conductivity under compression tests (HECOP facility), impurity analysis and phase equilibria (X-ray microprobe, SEM), chemical reactivity of Be pebbles with air and steam;
II. A high dose irradiation of beryllium and beryllides up to 6000 appm ^{4}He production, the HIDOBE experiment in the High Flux Reactor in Petten, which will run from 2004 to 2007;
III. The development of models of helium and tritium diffusion, precipitation and release kinetics (the ANFIBE code) in connection with a specific programme of experimental characterisation (in particular TEM and X-ray microtomography analyses), aimed at validating models also from a microscopic point of view. The final aim is to enable a reliable extrapolation of models to EOL conditions of beryllium and, consequently, to optimise blanket design and material key characteristics in order to enhance gas release;
IV. The study of ^{4}He and ^{3}H release from highly irradiated beryllium from the disposed moderator of the Belgian Reactor 2 (about 20000 appm ^{4}He content) during a long-term out-of-pile annealing and measurement of thermal creep of the same material under compression load, also with the aim to enlarge the database for the validation of the ANFIBE code;
V. Accompanying activities like neutronics analysis (e.g. MCNP code, NJOY) to determine the entire spacial distribution of the nuclear response, molecular dynamics (MD) modelling of primary damage and helium kinetics and nuclear inventory calculations (e.g. FISPACT).

An overview on experimental and modelling activities performed during the past 2 years is given with typical results on non-irradiated and irradiated Beryllium materials and pebble beds and the relevance of major results on future beryllium R&D is addressed.