

### Background

Beryllium has been selected for the HCPB (Helium Cooled Pebble Bed blanket) in the European fusion technology long term program. Beryllium acts as a neutron multiplier that will allow tritium production in the lithium ceramic breeder. Before using the HCPB concept in a power reactor (e.g. DEMO) it has to be fully qualified and tested in experimental programs and in fusion reactor (e.g. ITER). Tritium production and retention is a potential safety and waste issue. Another important issue is the dimensional stability of the HCPB. Indeed, due to helium produced by irradiation and migration into bubble, swelling will occur. It will induce large compressive stresses in the pebble bed, undesirable loads on structural components and will modify heat transfer coefficient. Thermal creep can play an important role to reduce and redistribute stresses in the pebble bed.

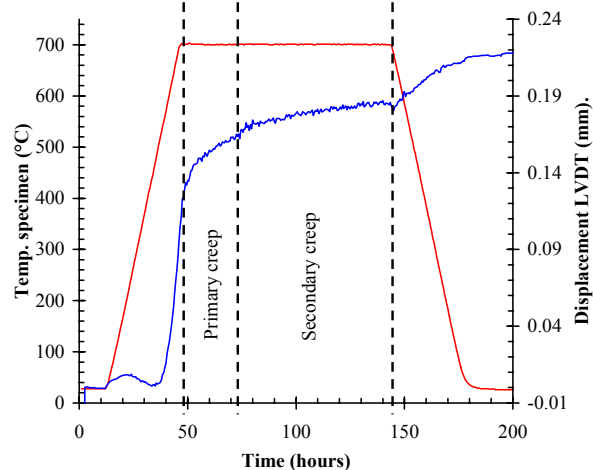
### Objectives

The objective of this task is to complement the beryllium database on radiation effects, with lacking data on helium build-up and release, the associated microstructure evolution, and the macroscopic swelling and creep phenomena. All these parameters are to be evaluated at conditions relevant to the end of life of a fusion power reactor: i.e. helium concentrations up to 30,000 appm and temperature up to 800 °C. The ultimate goal is to extend the validity of the ANFIBE code, developed at FZK in the context of the Helium Cooled Pebble Bed blanket design.

### Principal results

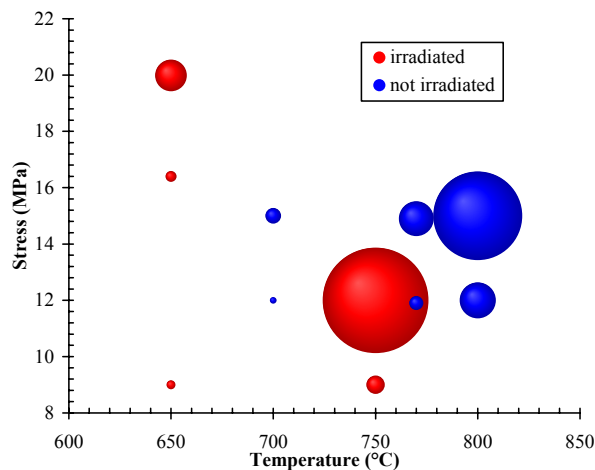
#### Creep

The experiment is performed on a home-designed creep machine housed in an alpha tight box on a dedicated machine that has been designed and qualified in 2004 [3]. It is a dead weight machine allowing loading a cross section of 16 mm<sup>2</sup> in compression from 2 MPa to 20 MPa. Specimen can be heated in a controlled manner up to 900 °C. Tests are performed on non irradiated and irradiated annealed condition. An example of test is given in the figure below where temperature and specimen length reduction is monitored as a function of time. A primary and secondary creep region can easily be identified.



Example of a creep test performed at 700°C

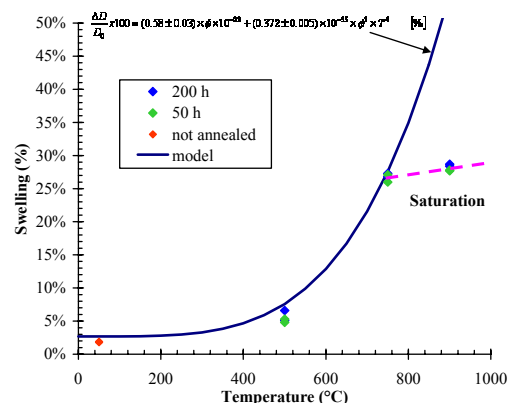
Creep results are presented in the figure below as a function of temperature and applied stress (the disk is proportional to the measured secondary creep rate). From this figure, we can clearly see that temperature and stress strongly increase the creep rate. It is also found that irradiation increase material susceptibility to creep.



Secondary creep rate of Beryllium as a function of temperature and stress

### Beryllium annealing and He-content/swelling/ $\mu$ -structure evaluation

In 2004 the microstructure and He content was already reported on [3]. We performed the remaining and key measurement is the evaluation of swelling in 2005 using a mercury pycnometry available in hot-cell. Swelling has been measured on beryllium irradiated and annealed for 50 and 200 hours at different temperature. Results presented in the figure below shows that swelling increase with annealing temperature. The swelling level does not depend on the annealing duration. Therefore, we can claim that swelling occurs in relatively short time scale (<50 hours). Swelling increases exponentially with temperature up to 750 °C. Above this temperature, saturation occurs. Using the conjunction of helium and optical microscopy results we can explain this saturation by the fact that the generated helium release through percolation and venting. Once helium is release swelling due to high internal helium bubble pressure is disable. A model proposed in [4] allows rationalizing swelling as a function of temperature and fluence. The model applies very well to the generated data up to the saturation level.



Swelling measured on highly irradiated beryllium

### Future developments

Ongoing studies are done to understand the physical reason and mechanism for creep and swelling. It will allow useful predictive model to be developed.

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### Main reference

- [1] L. Sannen, M. Scibetta, S. van den Berghe, A. Leenaers, G. Verpoucke, *Thermal activated helium induced swelling of Beryllium irradiated up to fusion reactor relevant doses*, to be presented at ICFRM12 December 2005, and published in Journal of Nuclear Material
- [2] M. Scibetta, E. Rabaglino, A. Pellettieri, L. Sannen, *Experimental Determination of Creep Properties of Beryllium Irradiated to Relevant Fusion Power Reactor Doses*, to be presented at ICFRM12 December 2005 and published in Journal of Nuclear Material
- [3] [http://www.sckcen.be/sckcen\\_en/activities/research/reactorsafety/fusion/annualreport2004](http://www.sckcen.be/sckcen_en/activities/research/reactorsafety/fusion/annualreport2004)
- [4] L. Sannen, F. Moons, Y. Yao, *Helium content and swelling of low temperature irradiated/post-irradiation annealed beryllium*, Paper presented at the IEA "workshop on beryllium for fusion applications" at Karlsruhe, 4-5 October 1993