DSOL-36 Effect of damaged tungsten on operations

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| **TG priority:** High | **Start date:** 2016 | **Status:**  New | **Personnel exchange:**  Yes |
| **IO priority:**   | **End date:** Not fixed | **Motivation:** Plasma Operations |

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| **Device /Association** | **ContactPerson** | **2016 TGRequest** | **Activity (from JEX/JA spreadsheet)** |
| **2016** | **2017** | **2018** | **2019** |
| ITER | G. De Temmerman | Desirable |   |   |   |   |
| MAGNUM | T.W. Morgan | Desirable |   |   |   |   |
| DIII-D | D. Rudakov/T. Abrams | Desirable |   |   |   |   |
| AUG | K. Krieger/J.W. Coenen | Desirable |   |   |   |   |
| LHD | S. Masuzaki | Desirable |   |   |   |   |
| NSTX | M. Jaworski | Desirable |   |   |   |   |
| JUDITH | T. Loewenhoff | Desirable |   |   |   |   |
| KSTAR | S.H. Hong | Desirable |   |   |   |   |
| WEST | E. Tsitrone | Desirable |   |   |  |  |

**Purpose**

In the recent past, a significant body of work has been performed to understand the damage mechanisms of tungsten under high heat fluxes. While the high stored energy in ITER makes tungsten melting possible during uncontrolled transient events, or even in steady-state for leading edges, significant surface damage can also happen for transient events with energy density lower than the melting threshold. Indeed, for cycle numbers approaching the anticipated number of mitigated ELMs in ITER, and even energy densities corresponding to strongly mitigated ELMs, pronounced surface roughening (due to plastic deformation) and even localized melting has been observed in electron-beam facilities. There are also indications that intense plasma exposure will lead to material embrittlement, effectively implying that tungsten surface damage will be almost unavoidable during ITER operations. Experiments in the Magnum-PSI linear plasma device have showed that the thermo-mechanical properties of damaged surface can deteriorate quickly under plasma exposures mimicking ELMing H-mode operations in ITER. According to infrared data analyses, there is evidence for an increase with time of the ELM-induced temperature excursion -of about 40%- occurring over the course of the Magnum-PSI exposure (equivalent to 3-4 ITER discharges in terms of fluence) indicating changes in the thermal response of the W monoblocks and then indicating that the material thermal properties were affected by the pre-damaged step.

Most of these studies focused on the material side of the problem, characterizing the nature of the surface damage and its evolution, and the properties of the damaged material. It is however not clear whether and how those effects might affect the material compatibility with high performance plasmas. To be more precise the question that this DSOL aims at addressing is: “what impact does the surface damage have on the operational window of the machine?” This will help understand how much damage can be tolerated before impeding plasma performances.

To assess this, the basic methodology will be to create damage in a controlled fashion on dedicated samples to be subsequently exposed in various devices to characterize the sputtering properties, impurity emission and power handling capabilities of those damaged surfaces

**Plans for 2016**

* **Magnum-PSI:** following its relocation to the campus of the Eindhoven University of technology, Magnum-PSI will resume operations in mid-2016 and will be upgraded with a superconducting coil allowing true steady-state operations. It is planned to continue the study of the change in power handling capabilities of a transiently melted surface, and extend it to much higher pulse durations to determine whether any saturation effect exists.
* **DIII-D:** The DIMES divertor manipulator is proposed to be used to study the erosion behavior and power handling of pre-damaged tungsten buttons. The focus will be on He-induced pre-damage, and also cracking and roughening generated in an electron beam facility.
* **ASDEX-Upgrade**: the AUG divertor manipulator will be used to expose two bulk tungsten tiles pre-damaged using the JUDITH e-beam facility (to generate intense surface cracking from exposure to high number of ELM-like cycles) and the GLADIS ion beam facility (to generate melting) to study further damage progression (under DSOL **XX)** under ITER baseline plasma scenario and the effect of those damaged surfaces on plasma operations.
* **JUDITH:** the JUDITH facility will have a pivotal role in its ability to prepare samples with controlled level of damage which can then be exposed in various devices.
* **KSTAR:** in 2015, KSTAR has installed a variety of tungsten samples with different shaping as part of DSOL33. A similar approach will be used to install several pre-damaged samples into the KSTAR divertor and follow their erosion and power handling properties over the experimental campaign. The experiment will benefit from the recently upgraded IR system of KSTAR.
* **NSTX-U:** discussions are ongoing to see how NSTX could contribute. Contribution could be expected in 2017, as the installation of a dedicated tile would be required.
* **LHD:** The LHD sample manipulator would be used to exposed pre-damaged samples to the LHD divertor plasma. Details of the experiment will be finalized over 2016 as the experiment could only be carried during the next LHD campaign in 2017.
* **WEST:** the assessment of plasma operations on damaged tungsten is a big part of the WEST research plan. Dedicated experiments would only occur in 2017, and details will be discussed throughout 2016.