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A repetitive table top pulsed plasma device to study materials under intense fusion relevant pulses

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One of the pressing problems in the design and construction of nuclear fusion reactors is the selection of candidate materials for its plasma-facing components. The essential constraint is that such a material has to be able to withstand extreme heat fluxes, together with high fluxes of neutrons, ions beams, and He and H isotopes such as deuterium.

The time of interaction, peak power and deposited energies on materials in inertial and magnetic confinement differ. However, the parameter defined as $Q \times t^{1/2}$ (with Q the power flux and t the time of interaction with the material), known as damage factor F, reach values as high as ≥ $7 \times 10^3 (Wcm^{-2}s^{1/2})$ for both, ELM´s in ITER divertor and in the first wall in a typical direct drive target 1. For similar F values, similar thermomechanical effects are produced. These thermomechanical effects, are the results of heat, ion-matter interactions resulting in defect production. Thus, the determination of the materials damage threshold is an important issue to study different materials for plasma-facing components of nuclear fusion reactors.

The dense plasma focus (DPF) produce a pinch plasma and is a pulsed source of radiation and particles as x-rays, ion and electron beams, neutron bursts [2], plasma shocks [3] and plasma jets [4]. DPF discharges are being used as pulsed radiation sources to explore applications, for both industrial and to other sciences. For instance, in non- destructive analysis, pulsed x-rays and neutron imaging, and as non-radioactive sources for field application, as well as in material [5] and nanoscience, and recently in biological research [6]. In addition, the dense plasma focus (DPF) has the distinctive feature that is a self-scale kind of z-pinch [7].

DPF devices are unique tool for these studies with the added advantage that the damage factor F varies smoothly with the energy of the device E, as $F \alpha E^{1/6}$. In addition, F has a strong dependence with the distance to the target. Therefore, by changing the distance to the target it is possible tune the value of damage factor. Thus, in a table top plasma focus device of low energy (few joules to hundred joules) the same damage factor than the obtained in mega joules plasma foci can be obtained. In particular, using the scaling rules for the damage factor with the energy of plasma foci, it results convenient develop a tunable pulsed irradiator device based on the PF-2J. Thus, a portable repetitive plasma focus device of 2J stored energy was design and constructed (PF-2J: 120nF, 6-8kV, 2-4J, 10-15kA achieved in 110ns) [8]. The device, including capacitor, spark-gap, discharge chamber and power supply are portable in a hand luggage. As the damage factor F, has a strong dependence with the distance to the target, a micrometer positioner for the material samples was designed and constructed recently. At present, this device allows repetition rate of $\sim$ 0.1Hz, thus is possible irradiate a material with 10, 100, and 1000 shots in 100 s, 20 min, and 3.2 hours, respectively. In the future could be possible operate this device at 1Hz. A feature of plasma focus is that the emitted radiation varies shot to shot, so, a characterization of its statistical reproducibility and a reliability analysis is indispensable.

In this work is presented: a) A statistical study and reliability analysis for table top plasma focus PF-2J. b) The use of this repetitive table top pulsed irradiator to test materials samples at different positions from the anode top, 2.8, 3.6 and 5.4 mm producing a damage factor $F \sim 10^4, \sim 10^3, \sim 10^2 (Wcm^{-2}s^{1/2})$, respectively. The damage factor F was estimated from the scale rules and a calibration of F vs. the axial distance from the anode top is being developed.

From voltage and current derivative signals an analysis of the probability and frequency of the pinch occurrence for different hydrogen pressure of operation (2, 3 ,4 ,5 ,6 ,7 ,8 ,9 10 mbar) was found that the optimum pressure for the presence of the pinch is 6 mbar. More than 2×10^4 shots in hydrogen were recorded. It was found that the optimum pressure for the presence of the pinch is 6 mbar. Furthermore, an analysis of its life cycle to the decay of the system was done. It was found that the life cycle for the pinch plasma voltage and for the depth in the current derivative signal is more than 1×10^4 without changes in the voltage pinch and with a decrease of 10% in the depth dip of the current derivative [8].

The PF-2J repetitive table top pulsed irradiator was used to test SS (AISI 304), tungsten and molybdenum samples at different positions from the anode top, from 2.8 to 5.4 mm producing a damage factor $F \sim 10^4 - 10^2 (Wcm^{-2}s^{1/2})$ per shot, respectively. At 2.8 mm, i. e. $F \sim 10^4 (Wcm^{-2}s^{1/2})$ per shot, 1, 10, 100 and 1000 shots were accumulated in the samples. Thousands of shots were accumulated in 3 to 4 hours.

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