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The Side Effects of Hydrogen Ions on Tungsten Surface Due to Glow Discharge Cleaning Procedure in DAMAVAND Tokamak

Farid Sedighi[1], Chapar Rasouli[1] , and Davoud Iraji[2]

1) Plasma Physics and Nuclear Fusion Research School, Atomic Energy Organization of Iran (AEOI), Tehran, Iran

2) Energy Engineering and Physics Department, Amirkabir University of Technology (AUT), Tehran, Iran

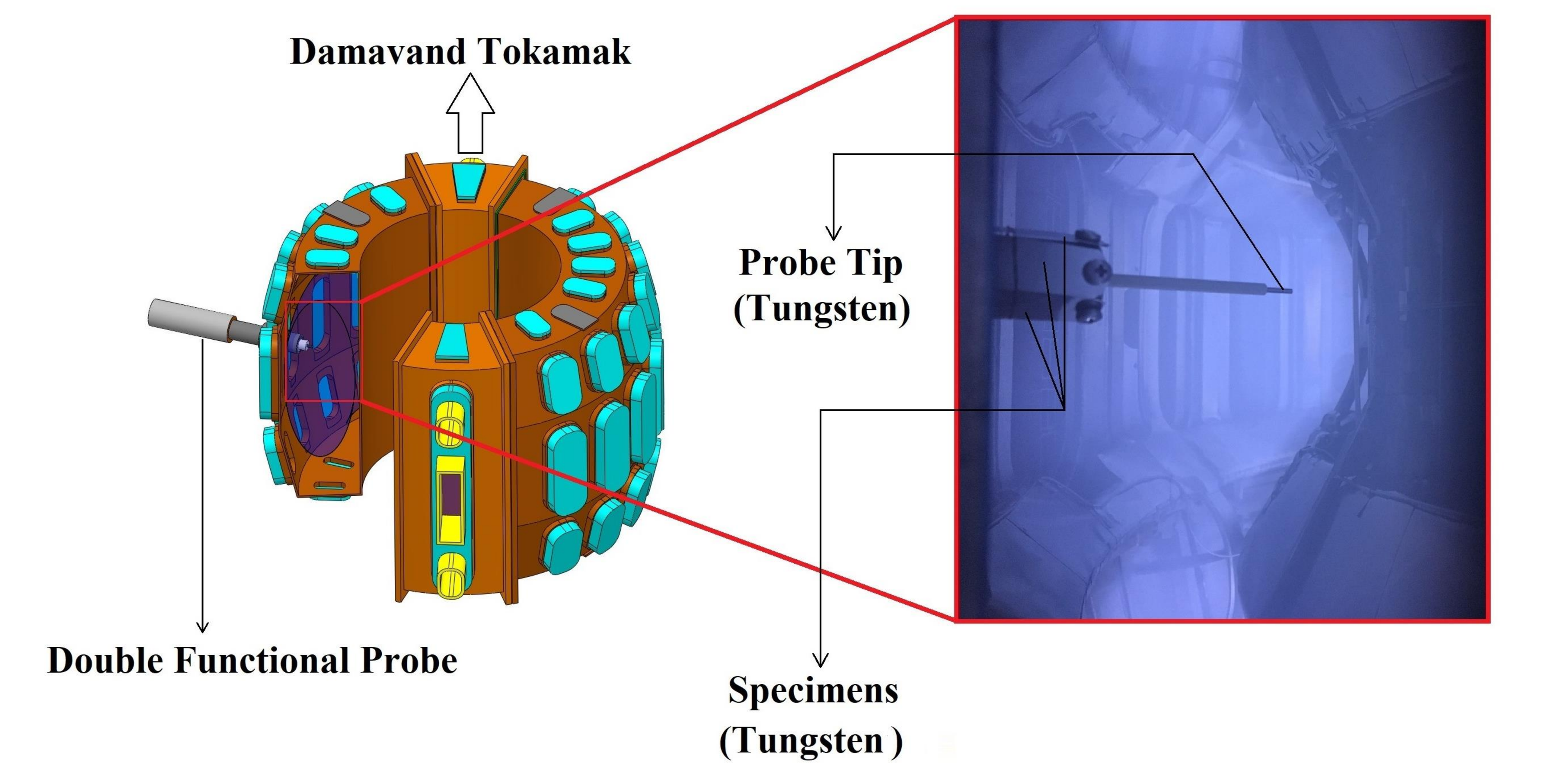
E-mail: fsedighi@aeoi.org.ir ,and **iraji@aut.ac.ir**

ABSTRACT

- Hydrogen glow discharge cleaning (H-GDC) is a routine conditioning procedure for the present tokamaks and future fusion machines, including the ITER.
- Due to the low energy of hydrogen ions in glow discharge plasmas, the probability of any considerable damage to the plasma-facing components was mainly ignored among researchers in the field.
- In this work, Tungsten, as the primary candidate for the plasma-facing materials in tokamaks, is considered for studies regarding the effects of the H-GDC procedure on the material during a routine vacuum vessel conditioning in Damavand tokamak.
- After performing routine H-GDC using pure hydrogen, the formation of loosely attached nano-structure bundles (NSBs) on the surface of the tungsten samples was observed.

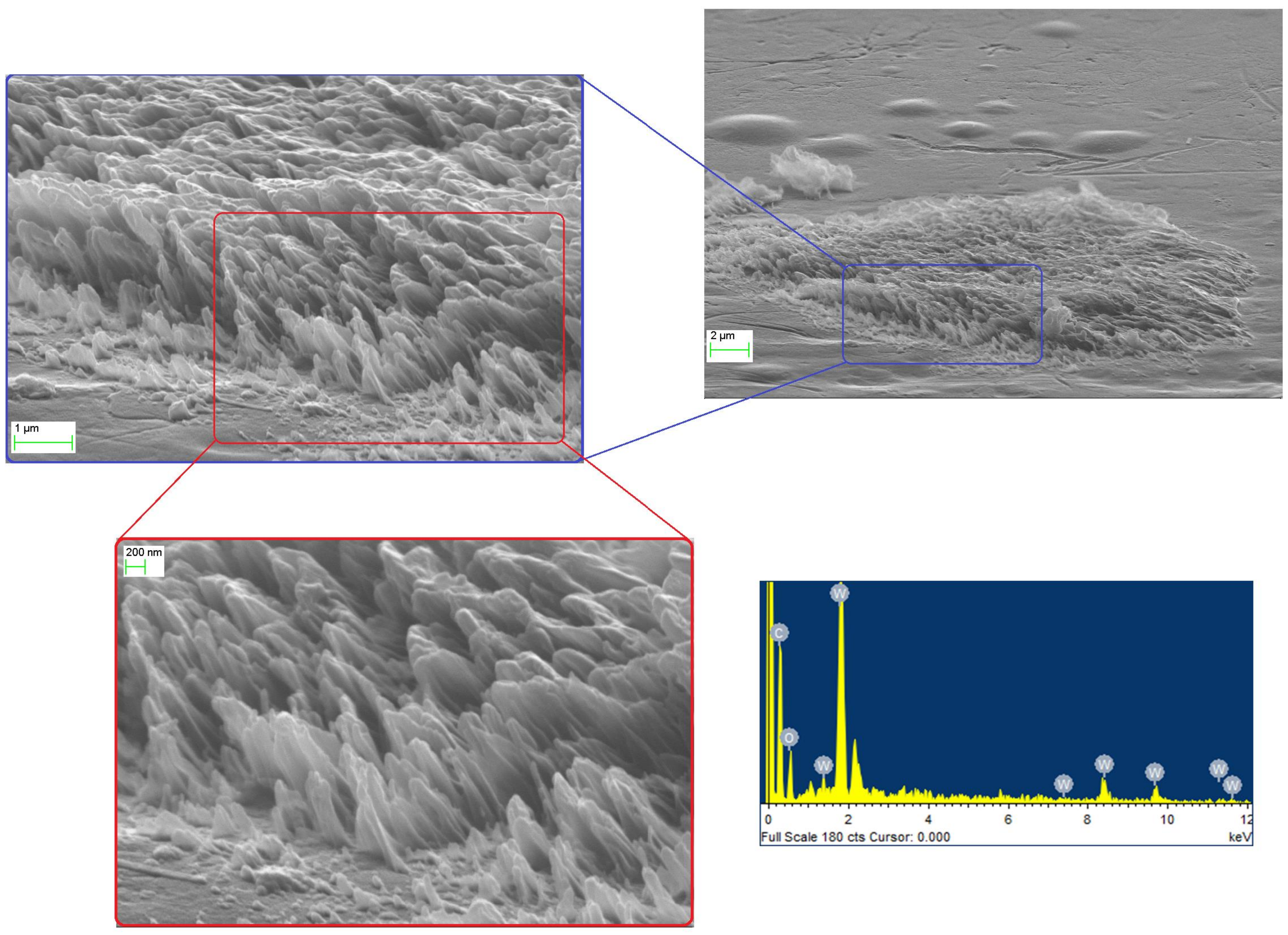
EXPERIMENTAL PROCEDURE

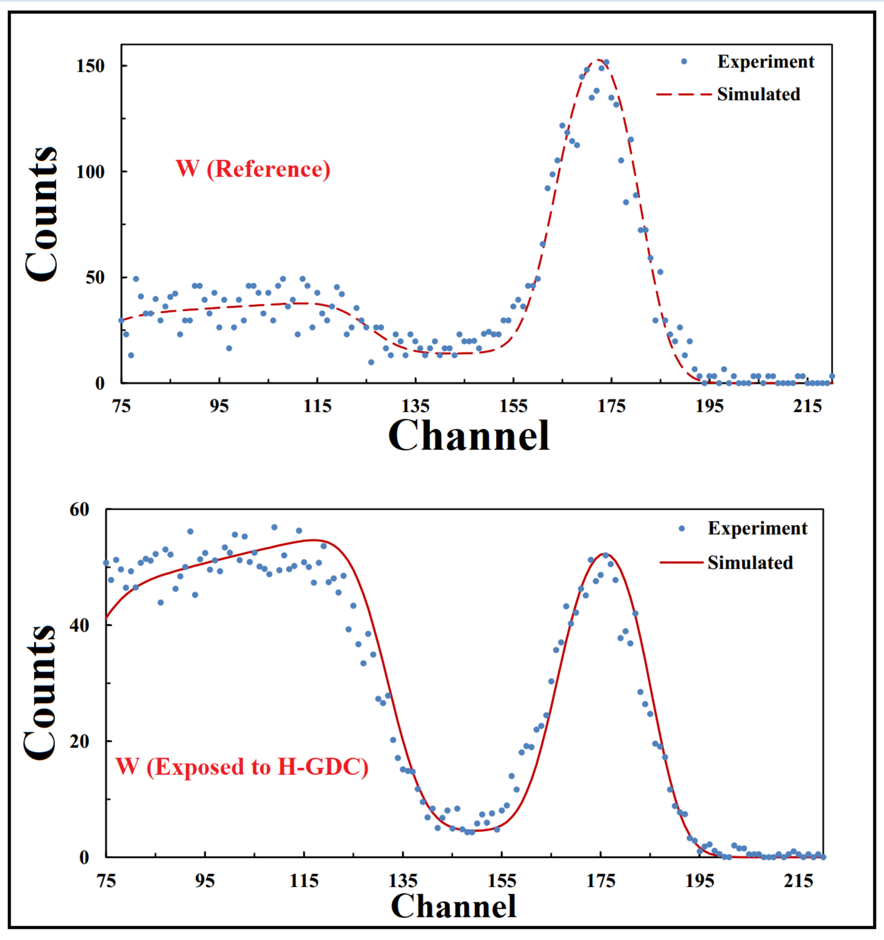
- The experiments were performed at the Damavand tokamak.
- The polished samples were mounted on a movable holder as a material probe. The material probe is a Langmuir probe, while its body is designed to be used for mounting the specimens. The probe body, where the samples are mounted, is electrically connected to the vacuum vessel.
- A typical H-GDC procedure using hydrogen with a purity of 99.9995% at pressure of 2.5×10^{-3} Torr is performed for 2.5 to 4 hours with discharge parameters of 1.5 A and 450 VDC. The temperature of the specimens during the H-GDC was below 370K. It was measured by a pyrometer.
- Using Langmuir probe, plasma properties such as plasma potential, ion density, electron temperature, and the Debye length can be obtained. The results are 236V, 1.17×10^{15} m^{-3}, 5.8 eV, and 520 µm, respectively. Hence, the plasma sheath thickness, which is between 3 and 5 times the Debye length, will be ~2.5 mm.
- The flux is about 2.36×10^{18} ions/s m^2, and the hydrogen ions energy, in their collisions with the wall, is about 240 eV.
- The depth profiles of hydrogen were determined by the Elastic Recoil Detection Analysis (ERDA) technique. The ERDA spectra were measured by the 1800 keV He+ ions beam generated by the 3 MV Van de Graaff accelerator of NSTRI with an energy resolution of ±1 keV.

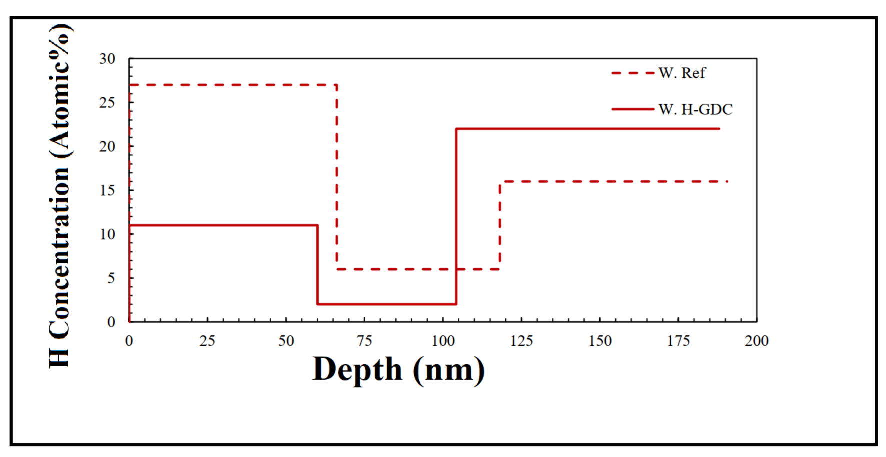


RESULTS

- H-GDC has notable side effects on W surface.
- Growth of loose nano-structure bundles (NSBs) is observed due to a routine H-GDC procedure.
- The area of a majority of these islands is about 400 μm^2.
- These loose NSBs could be a source of dust and contamination.
- Oxygen and carbon were detected on NSBs.
- ERDA analysis states that after H-GDC, the bulk concentration of hydrogen is increased indicating that it could be a relation between hydrogen retention and blisters formed on W samples. These results confirm the earlier reports investigating the hydrogen retention and blister formation on tungsten.







Experimental and simulated spectra for ERDA with 1800 keV incident ^{4}He ions on W specimens and resultant depth profiles of hydrogen in reference and irradiated W specimens.

CONCLUSION

The nano-structure bundles are loosely attached to the surface. Tungsten is among the primary candidates for plasma-facing materials of the future tokamaks as fusion reactors. Therefore, the formation of loose nanostructures on the wall of plasma confinement vessels, due to H-GDC, which is a routine procedure for wall conditioning in tokamaks, draws attention to the probable damaging effects of this phenomenon upon functionality and outcomes of tokamaks.