§21. On Mechanism of Cs Coverage Maintenance in the Large Hydrogen Negative Ion Source

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H- ion beam production study with the direct cesium deposition (CD) to the 1/3 scale Hydrogen Negative Ion Source was done at NIFS NBI test stand[1]. A well defined cesium amount in the range 3 mg - 0.6 g was deposited with the help of small oven introduced into the NIS plasma chamber.

It was found, that a single 3 -10 mg CD produce 1.3 - 4 times increase of H- beam current, proportional to the deposited cesium, but the H- yield was degraded within several discharge pulses to the previous *non-cesiated* pure hydrogen value. A 4-5 fold enhancement of H- yield was recorded with the further increase of CD in the range 30 mg - 0.6 g. The larger cesium portion provides a longer period of enhanced operation, i.e. 0.2 g CD was enough for 2-5 day period of enhanced long-pulsed operation. H^- beam with current 3 A was produced from the 1/3 scale source with extraction area of 25x26 cm^2 at 50 kW arc power. It corresponds to 40 A H- yield for the full-scale LHD source. CD to the various plasma chamber walls shows the same H- increase. The inspection of PG surface after operation displays that it is covered by a thick uniform Cs/W film.

The obtained data supports the surface origin of H- yield enhancement[2] and displays the following mechanism of optimal Cs coverage maintenance in the source. H- yield enhancement, proportional to CD amount in the range 3-10 mg and yield saturation at larger CD shows, that 10 mg of cesium are enough for producing an optimal cesium coverage over the most of PG area. 3-10 mg cesium portion produce a multilayer coverage (5-15 monolayers per 1/3 scale source). No increase of H- yield was recorded after CD at initial source operation with the cold PG. PG heating to 200-250 °C enhances the H- yield due to thermodesorption of extra cesium and of volatile contaminants from the PG surface. Low residual value of H- current after 3-30 mg CD and a 50 shots/2 hours operation shows, that cesium flux from the PC volume does not compensate the PG cesium thermo-desorption. Small Cs deposits on anode surfaces are blocked by tungsten and impurities and it prevents the cesium PG coverage maintenance. The rate of tungsten evaporation from filaments for the emission-limited discharge mode is about 0.2 mg for 1 kA, 5 sec filament heating pulse, so a monolayer of tungsten will cover the PC surface in 20 shots. This rate correlates with the measured rate of H- current degradation after 3-30 mg cesium deposition.

The longterm H- yield enhancement for 0.1- 0.6 g CD shows that the thick cesium coverage arranged on the cold PC walls is more resistive to the blocking and provides cesium volume pressure of about 10^{-6}-10^{-5} Pa, enough for supporting the optimal cesium coverage on the PG surface with temperature 200-250 °C. The coadsorption of tungsten and cesium on the hot PG supplies the Cs/W film growth. This film with an optimal surface ratio of Cs and W (1:4) governs the enhanced H- production for large CD. Change of PG temperature in the range 100-300 °C during the non-stop operation[1] or during the operation with elongated pulses[3] does not influence the optimal Cs/W ratio at the PG surface and does not change the H- yield. Larger cesium portions (or cesium addition to the Cs/W *reservoir* supply a longer H- enhanced operation. The blocking of Cs layer diminishes the cesium escape from the source.

The increase of *residual* value of H- current (after 50-100 shots/2-3 hour operation) proportionally to the total amount of the deposited cesium shows that the cesium replenishing flux to PG hot surface (i.e. volume pressure) is proportional to the total deposited cesium. It confirms, that the rate of cesium blocking is decreased with the cesium amount increase. Lower tungsten evaporation during the 8 filaments discharge operation produces a longer enhancement of H- beam production as compared with that during 12 filaments non-uniform operation. Cesium deposition to the surface, polluted by water leak[1], produces the same temporal H- yield increase, as in the case of deposition to the wiped surface, but a lower residual steady-state H- current level. It shows, that both depositions supply the similar optimal PG coverage on initial heating, but the replenishing cesium flux is lower from the cesium reservoir on the polluted surface.

Cesium plasma deposition to the wiped source provides the lower H- enhancement as compared with the deposition by cesium atoms[1]. The deposition of cesium ions, made onto the Cs-W reservoir decreases the H- production in the source, previously cesiated by atoms[1]. Cesium ions attached well to the surface and it decreases the cesium replenishing on PG surface.

Reference,

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