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Erosion/deposition of doped graphite tile with SiC coating under a long term plasma operation in HT-7

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In order to achieve long plasma in HT-7(R=1.22m, r=27cm), the limiter system was upgraded in the end of 2003[1]. The GBST1308 (1%B, 2.5%Si, 7.5%Ti) doped graphite with 50~100µm SiC gradient coatings was used as limiter material [2][3]. In the 2004 campaign of HT-7, a total of 11079 plasma shots with more than 200 shots longer than 100s and several tens high performance discharges over one minute were operated. The longest plasma was reached 240s with a central electron density 0.8E19m^{-3} and temperature over 1.0keV. The highest temperature detected at 3mm under plasma surface was below 400^{O}C in long plasma discharges. Most tiles, 198 in 223 tiles, were observed with light erosions and thin deposition (see Fig.1(a)). Only two group tiles were destructed due to bolt melt and impacting of comparatively high parallel heat flux of plasma (see Fig.1(b,c)). Apparent flakes were observed at both sides of the poloidal limiters tiles and on the liners (see Fig.1(d,e). Dust can be also observed on the limiters and liners.

Analysis methods

After venting the HT-7 vessel, samples with erosions/depositions cut from the tiles were analyzed by scanning electronic microscopy (SEM), X-ray photoelectron spectrum (XPS), X-ray fluoroscopy (XRF) and Electron Dispersive Spectrum (EDS).

Results

In most case, although the surface was preserved without macroscopic damage and SiC grains linked very well, the SiC coating became anomalistic due to light erosion. The head of ‘outstanding’ SiC grains were eroded out (see Fig.2(a)). Owning to the fast particles from plasma, SiC grains became honeycomb-liked with the small holes, which are the apparent impacted marks of particles from plasma due to physical sputtering (see Fig.2(b)).Due to the un-smooth surface of the SiC coating, installation irregularity and the ripple of magnetic field, the deposits film near light erosions are formed from a few tens nm covered only on the top of the 'outstanding' SiC grains to a few tens µm filled up the concaves of SiC coating (see Fig.2(c)). A very thin flake was formed on thick deposition. The deposited carbon with very small grain was closely joined but with a many hollows with a few µm in the length (see Fig.2(d)). The ratios of C/Si changed from 0.11 to 1.85 at various places, which seemed different thickness of carbon film. The picture of C density shows the carbon was deposited on the surface or filled into the gap of SiC grains. The Fe, representing stainless steel material, has decreasing grads from the surface. The depth profile of the deposition in the first 1.6um was analyzed with XPS after sputtering surface about 3nm is shown in the Fig.3. The percentage of B, Si, Ti, Fe decreased from surface whereas that of carbon increasing till top percentage of carbon reached. Then due to SiC coating, the percentage of Si increased whereas that of C decreased.

A few similar characteristic areas were selected to analyze destructed surface morphology, which schematic locations were marked in Fig.1(b,c). The micro-picture at center of zone A appears to be one of mechanical separation of the graphite particles and an accumulation as a consequence of the extremely high thermal loading(see Fig.4(a)). The edge of zone A seems that the ablated graphite was directly dragged out by the ablation of considering large fragments at the center (see Fig.4(b)). The zone B with noticeable 'metal' shine has rich averagely distributed Ti. Thin film was formed (see Fig.4(c)) One sample film about 600µm at zone B' was grown (see Fig.4(d)). The film seems that part of sputtered graphite transferred and deposited in a short distance. Hard film up to 100µm was observed at the root of the film with apparent strides. About 500µm soft film was formed at the top. Beside 72.1% carbon, there is 21.17%Ti and 5% Si. At zone C, micro-photos shows there are light erosions as similar as shown in the Fig.2. At zone D, the SiC coating remained very well. Dusts are easily observed on the zone E.

Dotted dust on the thin film show the depositing process before forming film (see Fig.5(a)). In most case, dust dimension is different, from very small to a few µm (see

Fig.5(b)). The density pictures showed that powder 1 is a typical Al dust and the powder 2 is a typical carbon dust. The dusts are a mixture with different material. For example, dust 1 has 29.5%B, 15.7%C, 22.6%Si, 19.3%Al, 1.1%Ti, 1.8%Fe.

Flakes, formed a typical arc about 40mm far from the LCFS of plasma at the side of the graphite tile of poloidal limiter, see Fig.12(a). The composition is 45% C, 16.7% Fe, 13.6% Si, 10.5% Cu, 5.3% Cr, 2.9% Mn, 1.9% Ni, 1.7% Ti 1.2% Mo and 0.7% Al in the collected flakes, which seems that it is a mixture. Flakes were also observed on the surface of liners where SOL is only about 30mm, shorter than normal distance 40mm. The composition is about 23.8% Mn, 22.8% Al, 17.5% Fe, 15.0% C, 7.7% Si, 7.0% Cr, 3.9% Cu, 1.3% Ca and 0.9% Ni in the collected flakes. It indicted that the metal element are dominant materials. Dust also concentrated on the liners near the strongly eroded tiles. The collected powders from the liners have 73% carbon, 7 %Fe, 9% silicon, 2.7% Cr, 2.5% Ni.

Conclusions

Under a long term plasma operation, the doped graphite tiles with 50~100µm SiC coating has high resistance to physical sputtering, shown by most tiles. The un-smooth surface of the tiles, installation irregularity and ripples of magnetic field could influence the distribution of erosions/depositions. The deposited material filled up the concaves of tiles and gaps of SiC coating. The deposited carbon film is denser than the doped graphite. Due to mechanical separation of the graphite fragment and the accumulation of physical sputtering as a consequence of the extremely high thermal loading, the leading edges of a few tiles were strongly damaged. The graphite particles with different quantity in various plasmas fast deposited on the nearby tiles cause the formation of thick and multi-layer film. The Ti re-deposited at both side of destructed zone given a metal shine surface. Dusts are a mixture. Flakes is easy formed on discontinue position of the parallel transport direction or on the liners near plasma.

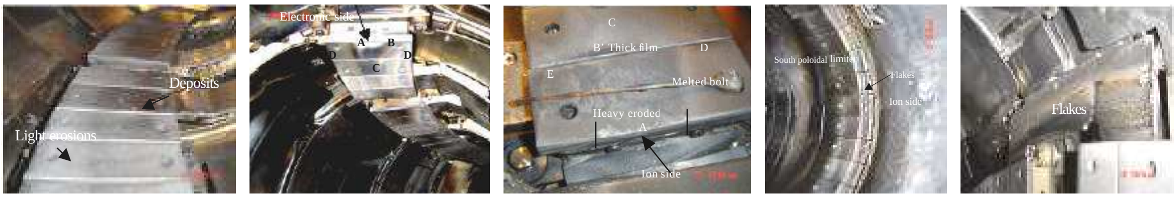
Reference

[1] J.S Hu, J.G Li, X.D Zhang, et al., J., Fus. Eng. Des. Vol 72/5(2005)377-390

[2] Quangui Guo, Jiangang Li et al., J Nucl Mater 313 (2003)144-148

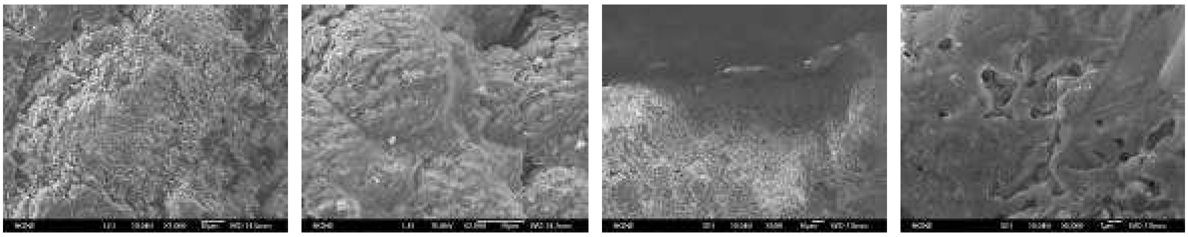
[3] J.Li, Y.P.Zhao, B.N.Wan et al, J Nucl Mater 313-316(2003)1188-1191

Fig.1 Typical surface of the graphite tiles of the toroidal limiter after a long plasma operation (a, typical light erosions/depositions; b, Destructed leading tiles near ICRF antenna; c, Destructed tiles due to bolt melted; d, Flakes on the poloidal limiter; e, Flakes on the liners.)



(a) (b) (c) (d) (e)

Fig.2 Typical light erosions (a,b) and typical depositions in the concaves of the SiC coating surface of tiles (c. Section; d. Inner structure)



(a) (b) (c) (d)

Fig.3 Typical depth profile of deposition

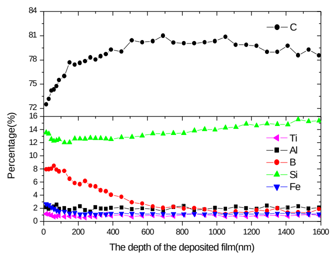
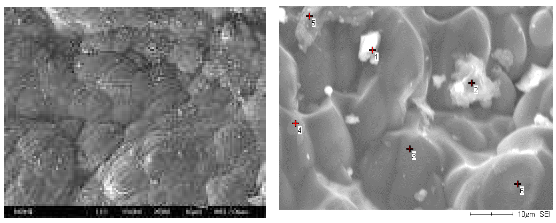
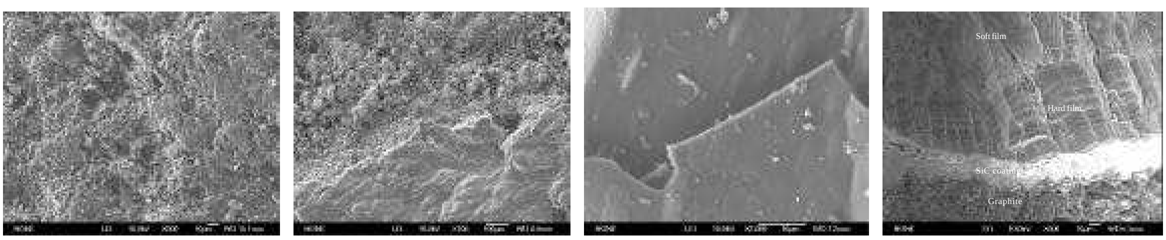


Fig.5 Dust in the gap among SiC grain



(a) (b)

Fig.4 Typical surface of destructed tile (a, destructed zone; b, transition area; c, metal shine zone; d, Thick film.)



(a) (b) (c) (d)