§57. On the Choice of Material for the "First Mirrors" of LHD Diveror Plasma Thomson Scattering System

V.Voitsenya, V.Konovalov (IPP, Kharkov, Ukraine); O.Motojima, K.Narihara, (NIFS)

Due to peculiarities of the LHD port construction, mirrors of laser scattering system for divertor plasma have to be placed inside the vacuum vessel, close to outer X-point [1]. Because of their location, these "first laser mirrors" (FLM) will be subjected to flux of CX atoms resulting in gradual increase of roughness of mirror surface. In turns, this leads to increase of adsorptance of a laser beam by mirror surfaces and to decrease of a laser-induced damage threshold (LIDT).

With increasing number of laser shots, N, the LIDT value (i.e., F_N) decreases due to accumulation of different defects in the area illuminated with a laser beam. Data published in [2,3] predict that after 10^5 laser shots the F_N values will be near ≤10%, ~30% and ~25% of the respective LIDT values measured for Cu, Ag and Mo after one laser shot (i.e., F_1). This number of laser shots (10^5) corresponds to <10^3 plasma pulses, because during every plasma pulse FLM will be exposed to several hundreds of laser shots [1]. It means that to safe the copper mirror during 10^5 shots the energy density of a laser beam has not to exceed the level ~$0.1 \cdot F_1$. The values of F_1 for copper mirror at λ =1.06µm with ~10ns laser shot duration was found to be in the range 2-4 J/cm^2 [4, 5] and thus the permissible value of laser beam energy in every shot is to be limited by 0.4 J/cm^2. For the number of shots exceeding 10^5, the energy for the laser pulse have to be even lower.

Bombardment of mirror surfaces with CX atoms will quicken their degradation and shorten the time of a proper operation. The rate of FLM degradation in any given conditions will depend on mirror material because of big differences in sputtering coefficient values and in dependencies of microrelief amplitude growth rates on the sputtering time. There is limited information on this subject, and to estimate the rate of degradation of FLM reflectivity due to CX atom flux we used the data that have recently been obtained for copper mirrors after exposure to a deuterium plasma with a mean ion energy ~650 eV. It was shown that for copper mirrors the decrement of relative reflectance ($\Delta R/R_0$) was ~10% in visible and the nearest UV regions after a layer of $\delta \approx 0.1$µm in thickness have been sputtered.

Thus, if taking δ=0.2µm as the critical thickness of sputtered layer for a mirror to be destroyed (λ=1.06µm [1]), it will be possible to range metals on their properties to save a reflectance being bombarded with CX atoms. This means that we suppose an equal relative degradation of reflectance after equal thickness of sputtered layer independently on the mirror material. For the mean energy of CX atoms the value of a few hundreds eV can be used based on results obtained PLT [6] and ASDEX [7] experiments.

Table 1 shows the results of estimations of the time (in seconds) that needs to sputter 0.2µm layer for metals which are prospective for manufacturing FLM from the view point of their optical properties.

It is seen that Al, Cu and Ag which are widely used as a mirror material will not withstand even 10^4 plasma pulses of 10 seconds duration with deuterium as a working gas. The best candidates for laser mirror material with this pulse number are gold and rhodium. But if change of mirrors inside the vacuum vessel is possible after 10^5 plasma pulses, only materials with low sputtering coefficient (Mo, Nb, Ir, Ta, W) can be taken as prospective ones.

References

1 K.Narihara, et al. Paper T3-12 presented at the Conf. Fusion Plasma Diagnostics (Toki-7) 1995.
2. N.Koumvakalis, et al. Opt. Eng., 22 (1983) 419.
3. M.F.Becker, et al. Appl. Opt., 30 (1991) 5239.
4. T.T.Saito et al. NBS, Sp. Publ. N435 (1975) 29.
5. I,Goldstein, et al. - Ibid, p. 41.
6. D.N.Ruzik, et al. J.Nucl.Mater., 145-147 (1987) 527.
7. H.Verbeek, et al. Plasma Phys. Contr. Fusion, (1990) 651.
8. Y.Yamamura, H. Tawara. NIFS-DATA-23 (1995).

Table 1. Estimated time for 0.2µm thickness layers of indicated metals to be sputtered with CX atoms of $2 \cdot 10^{15}$/cm^{2}s flux density and 300 eV mean energy.

Metal	Y(D), at/at [8]	$t_{0.2\mu m}$, s	Reflectance, λ = 1.06µm
Al	$4.3 \cdot 10^{-2}$	$1.4 \cdot 10^4$	0.94
Cu	$5.0 \cdot 10^{-2}$	$4.7 \cdot 10^4$	0.97
Ag	$4.0 \cdot 10^{-2}$	$1.5 \cdot 10^4$	0.98
Au	$7.5 \cdot 10^{-3}$	$8.0 \cdot 10^4$	0.98
Rh	$7.0 \cdot 10^{-3}$	$1.0 \cdot 10^5$	0.82
Mo	$2.5 \cdot 10^{-3}$	$2.3 \cdot 10^5$	0.67
Nb	$2.4 \cdot 10^{-3}$	$2.3 \cdot 10^5$	0.81
Ir	$8.0 \cdot 10^{-4}$	$9.0 \cdot 10^5$	0.79
Ta	$1.5 \cdot 10^{-4}$	$3.6 \cdot 10^6$	0.87
W	$1.2 \cdot 10^{-4}$	$5.5 \cdot 10^6$	0.56