RF Plasma Cleaning of ITER Diagnostic Mirrors

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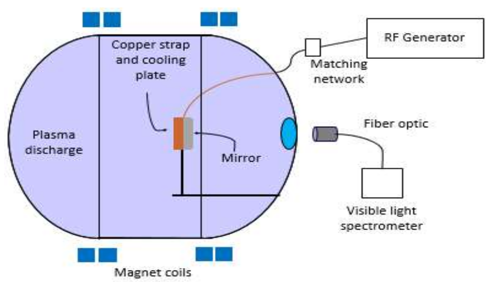
INTRODUCTION

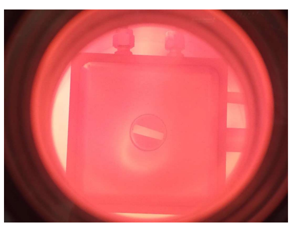
Due to the harsh conditions inside of a fusion tokamak, refractive components of optical diagnostics must use metallic first mirrors to view the plasma indirectly [1]. The reflective and polarization properties of these mirrors are integral in the characterization of the plasma via optical diagnostics. Due to the location of these mirrors, they are subject to deposition of first wall materials such as beryllium and tungsten. These materials must be actively cleaned from the mirrors in order to maintain the optical properties of the mirror surface. Currently an in-situ plasma discharge cleaning method is considered the most promising method of removing depositions [2, 3].

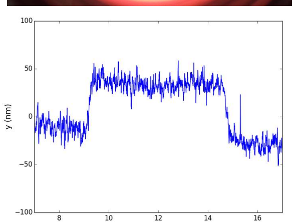
OBJECTIVES

- To understand the effect of operating parameters such as pressure, radiofrequency power, field strength, and plasma species on mirror self-bias.
- To observe sputtering of material from the surface of the mirror using optimized parameters.

EXPERIMENTAL SETUP



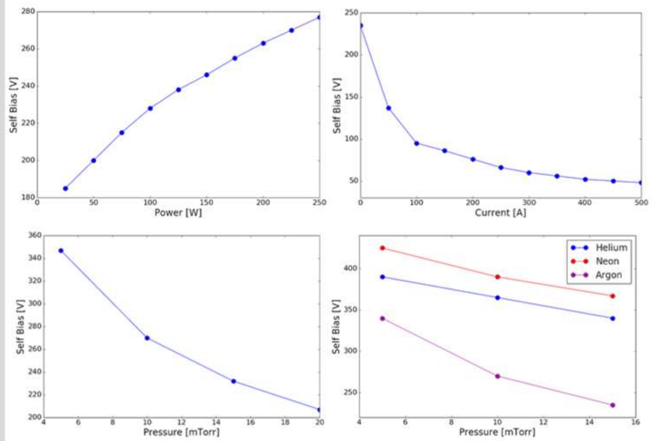




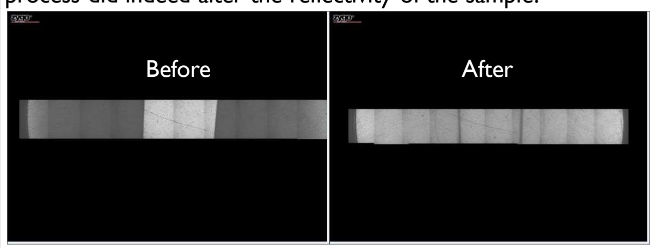
The cleaning process begins with applying an RF voltage to the mirror, mounted to which is a stainless steel coupon with a thin Al coating, as a substitute for Be. The larger ground chamber wall creates a DC self-bias voltage on the mirror [4]. This accelerates ions towards the mirror surface, sputtering the Al. The coating was prepared by sputtering 50 nm of Al for 8 minutes using a magnetron.

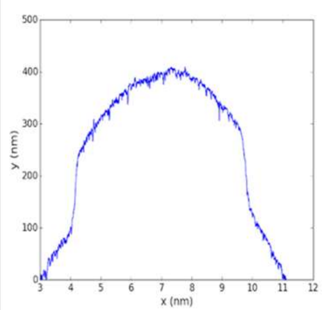
RESULTS

Self-bias measurements were studied in an argon plasma with varying input power, field strength, and plasma pressure. Self-bias in argon, helium, and neon were compared at varying pressure.



The data show self-bias is maximized at high RF power, low pressure, and low field strength. For the sputtering test, Self-bias was maintained at 425 V, at 100 W RF power, 5 mTorr fill pressure, and 0 A coil current. Pre- and post-sputtering images taken with a white light interferometer (WLI) show that the process did indeed alter the reflectivity of the sample.





The surface analysis results from the WLI are inconclusive; the step height rose from ~50 nm to ~100 nm. The leading explanation is that we are sputtering the stainless steel surrounding the Al, and that a thin oxidation layer on the Al is significantly lowering the yield there, effectively milling around the coupon.

CONCLUSIONS

- Characterized the parameter space for the cleaning process within the operating parameter spaces
- Reproduced results of trends between self-bias and various operating parameters (RF power, pressure, field current)
- Currently, sputtering results are inconclusive from spectral analysis. Possible explanations for this include:
  - The low quantity/density of emitters
  - The difficulty of differentiating between lines of sputtered species and operating gas/other contaminants
- Surface analysis is pending; current results from white light interferometry are inconclusive as to the presence and extent of the sputtering process.

FUTURE WORK

- Improve spectral analysis techniques and separate operating gas and contaminant lines from deposit materials
- Complete improved surface analysis using X-ray photoelectron spectroscopy and scanning electron microscopy for enhanced depth profiling and material composition.
- Test new coating materials: aluminum oxide, tungsten, tungsten oxide
- Test new mirror substrates: molybdenum, rhodium
- Observe cleaning process within an applied magnetic field and the effect on sputtering yield

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