An Argon-Oxygen or Argon-Hydrogen Radio-Frequency Plasma Cleaning Device for Removing Carbon Contamination From Optical Surfaces

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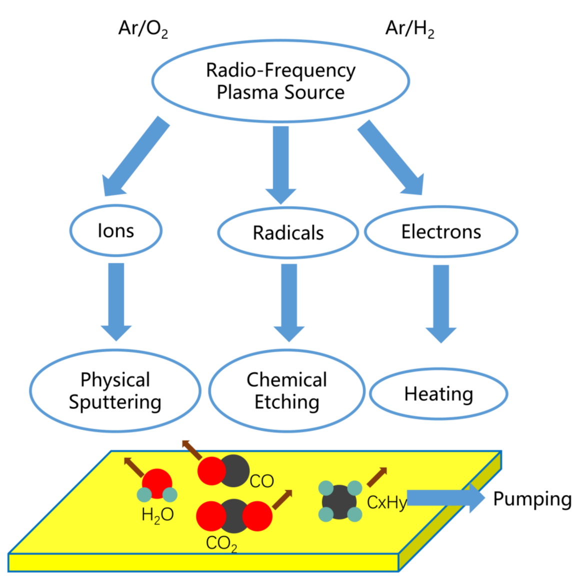
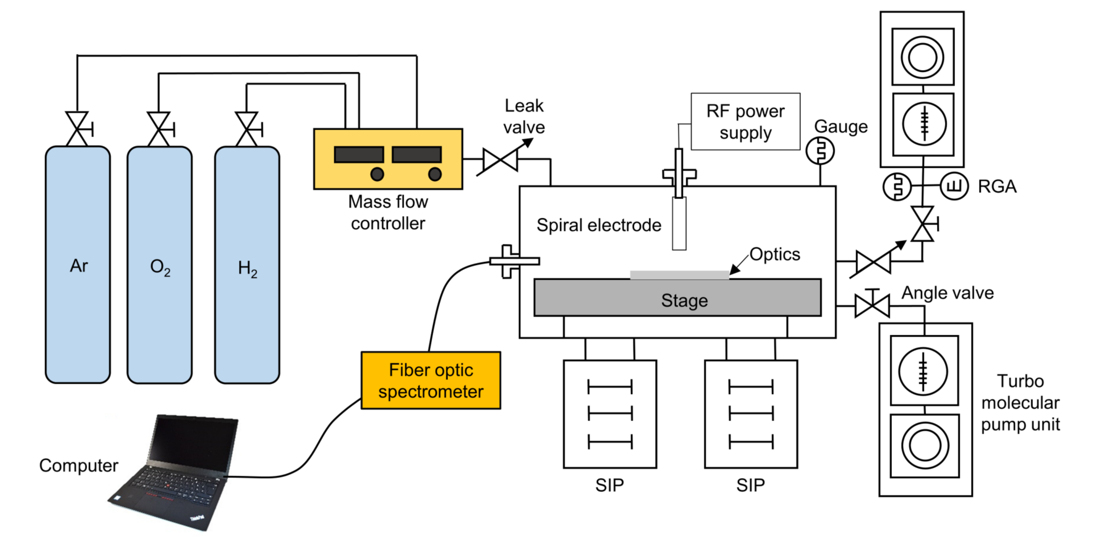
Abstract

Due to synchrotron radiation, carbon contamination on the surfaces of optical elements inside the beamlines, such as mirrors and gratings, remains an issue. Future beamline designs will select more optical element surface coating materials according to the specific needs, including gold, platinum, chromium, nickel, and aluminum, and a single cleaning method will not be able to adequately address the demands. We have studied the radio-frequency (RF) plasma cleaning of optical elements. After the argon/oxygen or argon/hydrogen gas mixture was injected into the chamber, glow discharge was carried out, and the carbon on the surface of the inert metal-coated optical element and oxidation-prone metal-coated optical element was removed by the oxidation or reduction reaction of radicals. In order to optimize the discharge parameters, it utilizes a differential mass spectrometry system and an optical emission spectrometer to monitor the cleaning process. This poster introduces the principles of the two cleaning methods as well as our existing cleaning device.

Experimental Principle and Setup

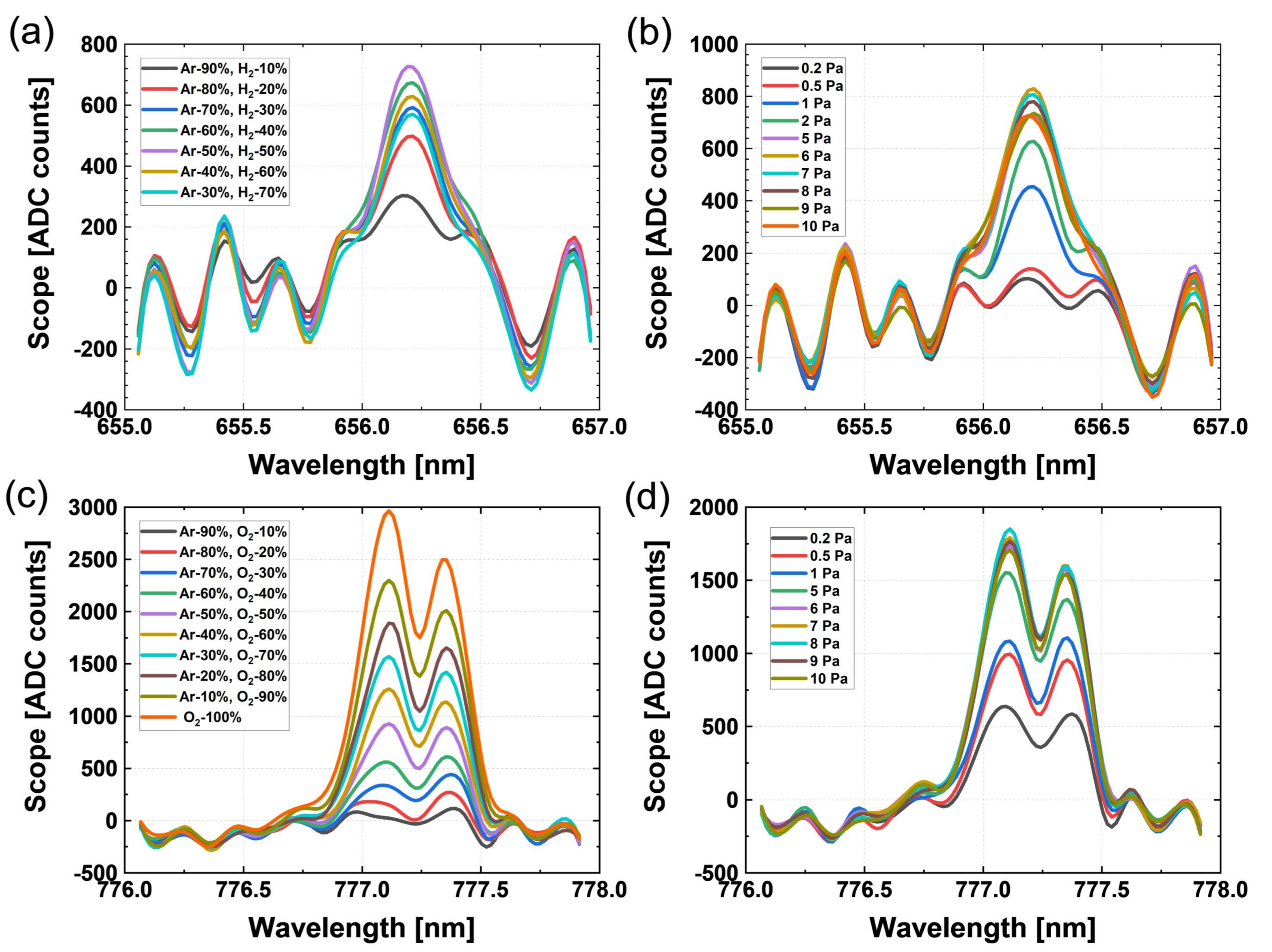
The experimental equipment includes: cleaning chamber, gas mixing chamber, RF power supply and RF matching device, vacuum pumping system, etc. Ar/O_2 or Ar/H_2 enter the gas mixing chamber with a certain ratio through the mass flow meter. The mixed gas enters the cleaning chamber through the needle valve. By adjusting the needle valve and the pumping speed of the molecular pump unit, the cleaning chamber is maintained at a certain pressure. Turn on the RF power supply, adjust the RF matcher to find the appropriate discharge power, and perform glow discharge.



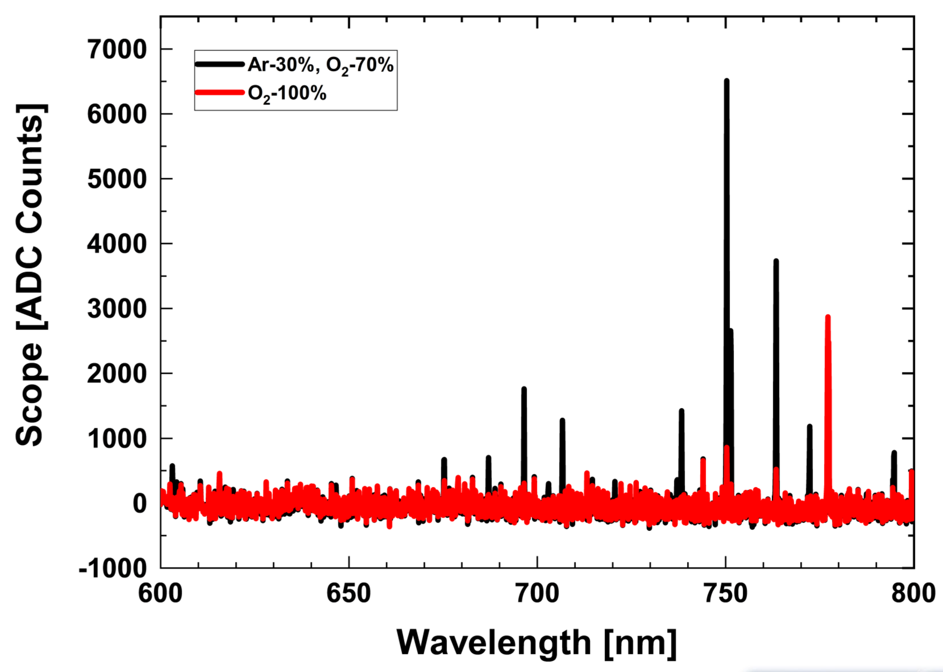


Optimization of cleaning parameters

In order to study the optimization of cleaning parameters for cleaning synchrotron radiation optical components with RF plasma, a cleaning parameter optimization system based on fiber optic spectrometer and quadrupole mass spectrometer was built.

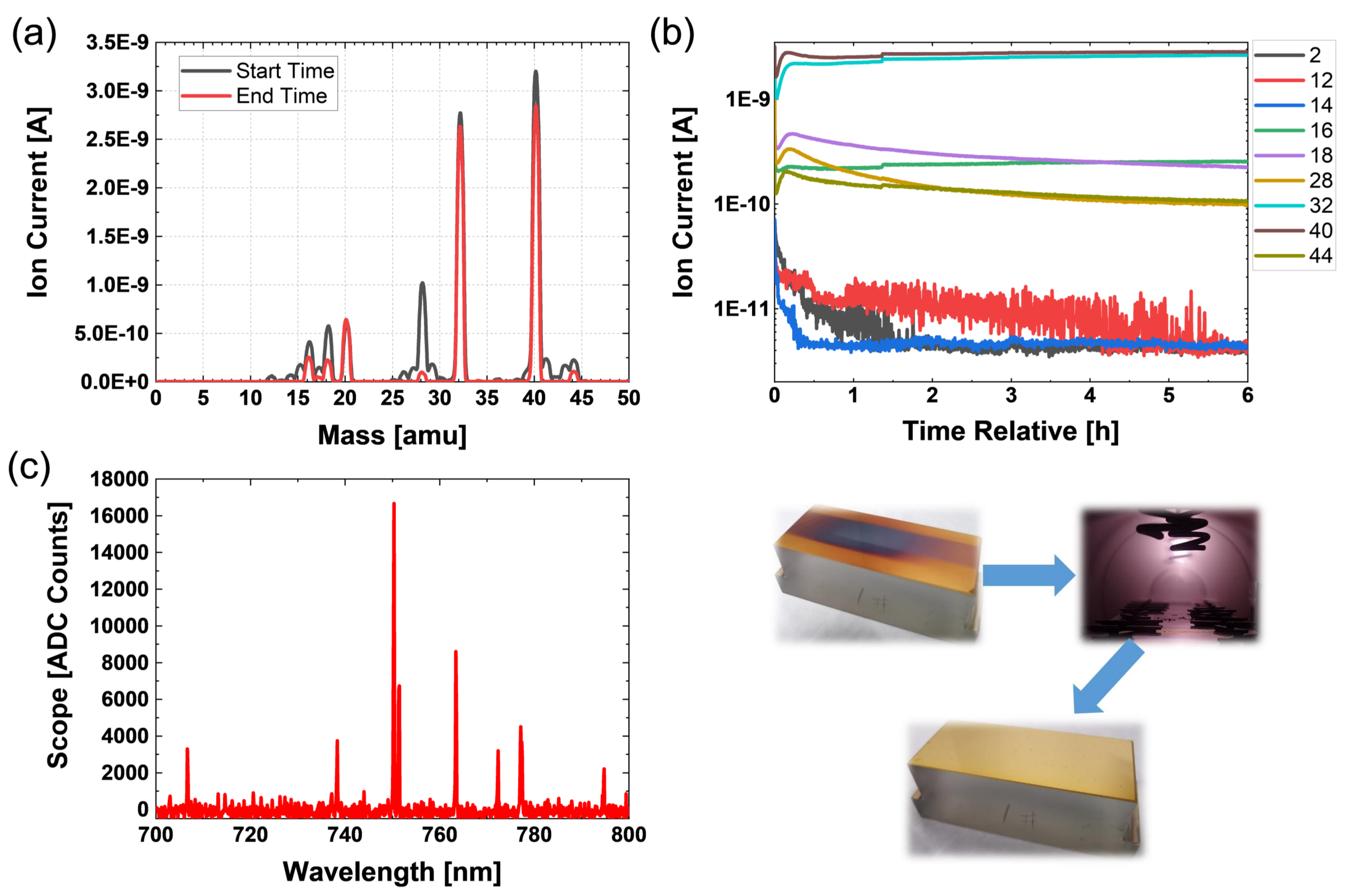


In Ar/O_2 plasma cleaning, although 100% oxygen produces more reactive oxygen species, the total number of ions in the chamber will be less, as shown in the figure below. Considering the physical sputtering effect during cleaning, the Ar/O_2 plasma cleaning ratio will be adjusted to 30%-70%.



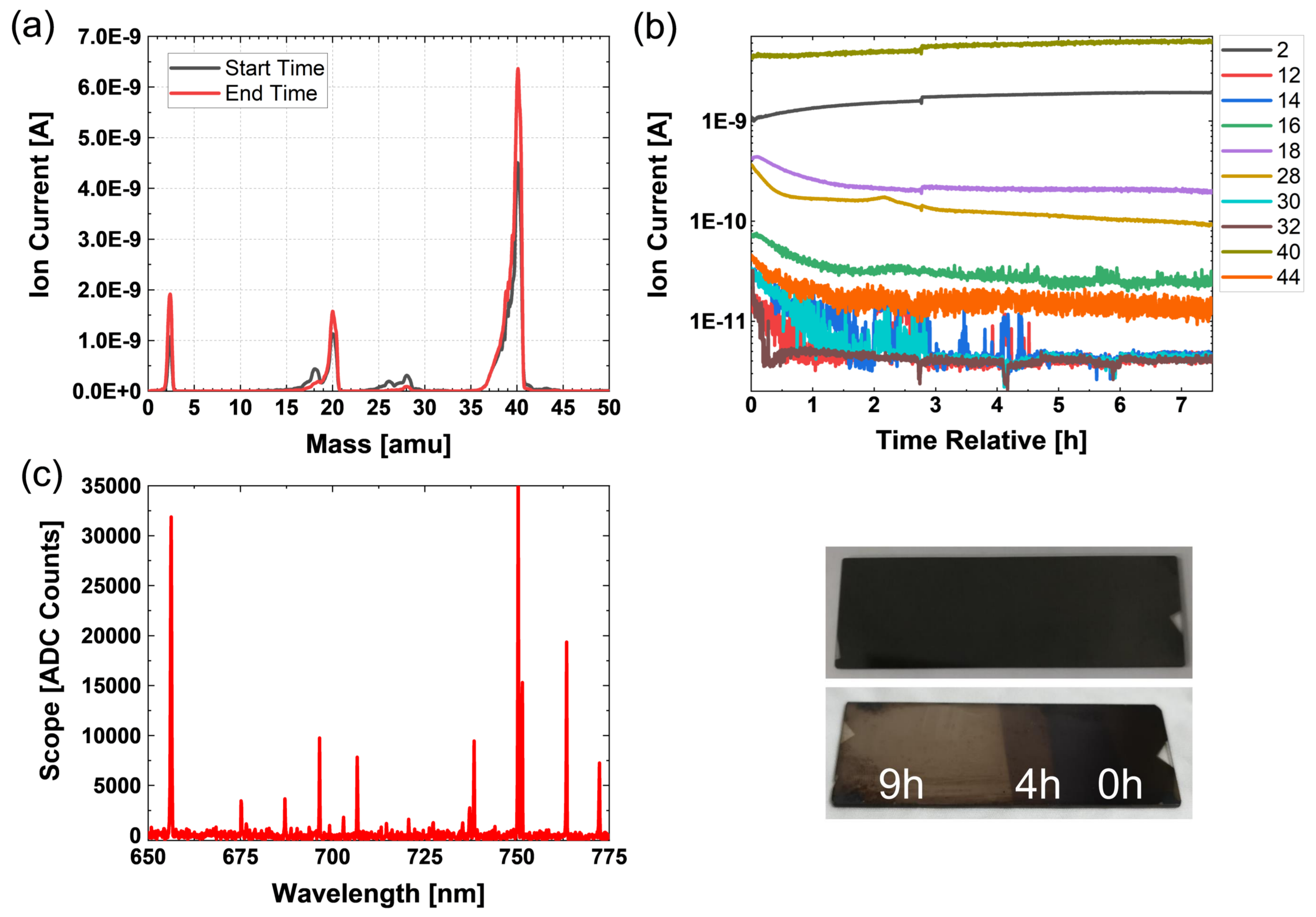
Cleaning of Au-coated grating with Ar/O_2

The carbon-contaminated Au-coated grating was cleaned with Ar/O_2 plasma for 6h, the cleaning pressure was 8 Pa, and the Ar/O_2 mixing ratio was 30%-70%. The cleaning effect was shown as follows.



Cleaning of Al-coated mirror with Ar/H_2

The carbon-contaminated Al-coated mirror was cleaned with Ar/H_2 plasma for 4h/9h, the cleaning pressure was 6 Pa, and the Ar/H_2 mixing ratio was 50%-50%. The cleaning effect was shown as follows.



Conclusion

A system for RF plasma cleaning with Ar/O_2 and Ar/H_2 was constructed, and optical and mass spectrometers were used to optimize the discharge parameters and determine the cleaning cutoff point. The system can be used to remove carbon contamination from the surface of optical elements coated with easily oxidized or inert metal in the beamlines, enhance reflectivity, and boost photon flux. To create an ultra-clean, ultra-high vacuum environment, the method can also be used to clean superconducting RF cavities and storage rings.

References

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