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Investigations on residual chemical contamination on machining aluminum components of turbo molecular pumps

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ABSTRACT

In the recent Extreme Ultra Violet Lithography (EUVL) process developed in microelectronics, the presence of hydrocarbon molecules is critical for the performances of the optics. Hydrocarbons can cause carbon deposit on the mirrors surfaces which reduces the reflectivity of the mirrors (1 nm carbon deposit = 1% reflectivity loss). As the EUVL system cannot be baked in situ, the residual carbon contamination on each component integrated in the Extreme Ultra Violet (EUV) tool becomes critical. The study presented herein, deals with the problem of a possible carbon contamination source due to the EUVL pumping system. We report the study of a research method of the contamination sources of turbo molecular pumps (stator and rotor), suitable for the pump manufacturing environment. With the support of TD-GCMS/FID, a RGA characterization of the residual carbon contamination is made. A clear association between RGA spectrum features and characteristics of the cleaning process has been established. In particular, the final cleaning step in the pump manufacturing is a possible source of contamination. Therefore, the detergent concentration in the cleaning process was investigated. Correlations were made with XPS (X-ray photoemission spectrometry) characterizations of stator and rotor surfaces.

1. Introduction

Because of the complexity of the set-up, the recent EUVL systems can't be baked in situ in order to reduce the residual contamination of the experimental equipment. Thus, it becomes necessary to control and to eliminate each possible source of contamination, particularly the ones embodied by the components of the system itself, like the pumping system. In particular, the optics of the EUVL systems is very sensitive to hydrocarbon contamination. The EUVL uses a reflective based optics made up of a series of Mo/Si multilayers mirrors, instead of the projection based optics of classic lithography. The molecular bonds of the hydrocarbon molecules can be broken by the photon ($E_{ph} = 92$ eV) used in the EUVL process. The released carbon atoms can deposit on the mirrors and grow a carbon film on the mirrors surfaces. The presence of a carbon deposit on the surface of the mirror compromises its reflectivity: a carbon film of 1 nm thickness reduces the reflectivity of the mirror of 1%. As the theoretical maximum reflectivity of a Mo/Si mirror is 68% and the optical system is made up of several mirrors in series, as the EUV source power is limited, the presence of even a small hydrocarbon contamination of the EUVL equipment will degrade the transmitted EUV light power. Thus, it becomes very crucial to control the residual hydrocarbon contamination of each components of the whole EUVL system in order to manufacture hydrocarbon free pieces to be assembled in the final equipment. This involves also the pumping system. It's necessary to guarantee the cleanliness of the turbo molecular pumps (TMP) and especially to qualify the cleanliness of the products before the delivery to the customer. The goal of this study was to develop an organic contamination RGA based research method for TMP machined parts, which could be used directly in the pump manufacturing environment. Using this new method, we have analyzed the hydrocarbon contamination of TMP machined parts (stator and rotor). In the past, the outgassing of cleaned stainless steel and aluminum surfaces, as well as the impact of different surface treatments have been deeply studied

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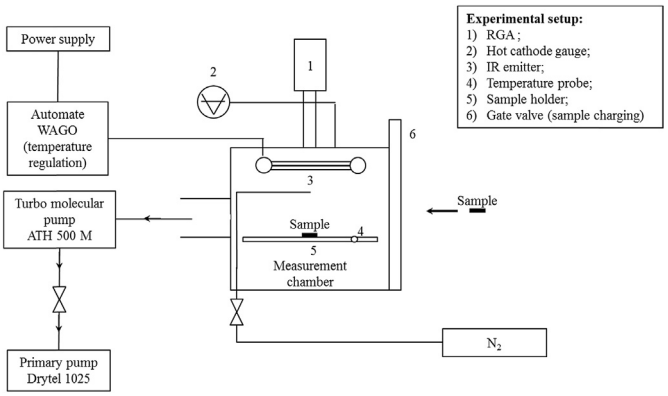

Fig. 1. A schematic diagram of the outgassing experimental setup used for the measurements in this study.

[1–10] for vacuum chamber applications. On the contrary, the study of the outgassing of a metal surface before baking, coming directly from its basic manufacturing process, represents a new challenge. We have studied the outgassing of a cleaned metal surface, and more specifically the hydrocarbon outgassing in order to investigate the contamination processes that can occur during the manufacturing process of these parts. After Dylla et al. [2], the XPS demonstrated to be a useful support in order to achieve this kind of study. The final goal is to use our method to optimize different cleaning processes in order to achieve a hydrocarbon free manufacturing process for TMP.

2. Material and methods

2.1. RGA

In order to achieve our study, a dedicated RGA test bench has been designed. The RGA apparatus has been developed to be used in an industrial environment and to measure samples of different dimensions, as rotor/stator blades, as well as bigger samples, as a whole rotor. In addition, this apparatus allows us to measure a whole turbo molecular pump, running as well as in standby mode. For this purpose, the design of the vacuum chamber allows to assemble a TMP directly to the gate valve, by the atmospheric side (see Fig. 1). The sample pump is then sealed for TMP measurement in standby mode or connected to a primary pumping system for running TMP measurement. The requested versatility of the measurement chamber prevents us from using a load-lock to load the samples. This characteristic, together with the great inner surface of the measurement chamber, entails an important background noise of the measurement. To prevent the background noise from invalidating the measurement results, an IR heating system of the samples has been designed in order to enhance the surface outgassing of the tested sample only.

Fig. 1 shows a schematic diagram of the apparatus used for the outgassing measurements presented in this article.

The measurement chamber (a 300 mm × 250 mm electropolished type 304 stainless steel cylinder) is designed in order to give the possibility to use different measurement configurations for the RGA (HAL 201 RC by Hiden). The reference pressure in the chamber is measured by a hot cathode gauge (AHC 2010 by aVP). The chamber is vented with nitrogen through a micro-leak. The pumping system is made up of a turbo molecular pump ATH 500 M by aVP and a primary pump Drytel 1025 by aVP, that lets achieve a base pressure of 1×10^{-9} mbar. Inside the measurement chamber, the sample holder is made of a 200 mm × 200 mm type 304 stainless steel plate. A temperature probe (a resistance thermometer Pt100) is fixed on the sample holder and it's exposed to IR heating system. The whole setup is equipped with a heating system (heating bands by Wattco and heating strings by Vitelec) for the baking of the chamber.

Like it is shown in Fig. 2, the sample heating system is made up of two IR emitters (two twin tubes QRC (Quartz Reflective Coating) emitters by Heraeus) positioned inside the chamber in order to focus the IR radiation on the center of the sample holder. As a result it selectively heats the sample, enhancing its surface outgassing while the inner surface of the measurement chamber remains at room temperature. The IR heating is set to reach a temperature, measured by the Pt100, of 90 °C.

In our study, the following measurement procedure was employed:

1) Under 1×10^{-6} mbar, to bake the chamber in vacuum at 140 °C for 4 h;
2) To cool down to ambient temperature;
3) RGA evaluation of the residual contamination (average of three measurements), at room temperature and $P \approx 1 \times 10^{-9}$ mbar;
4) To open the micro-leak valve (N_2) and to stop the pumping system in order to vent the chamber to atmospheric pressure;
5) To open the gate valve and to load the sample (or to simulate sample loading: 2 min air exposure) keeping micro-leak valve

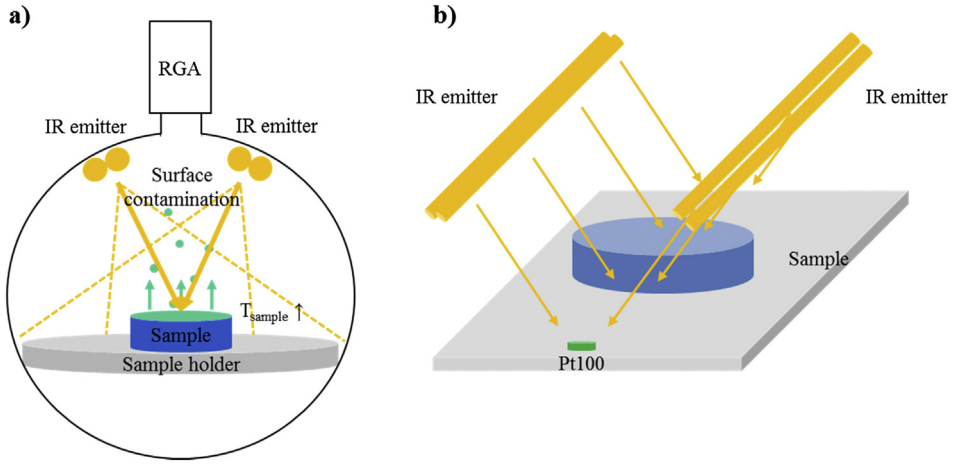

Fig. 2. Schematic views, (a) and (b), of the IR heating system used to enhance the outgassing of the surface contamination of the sample only.