Outgassing characteristics of ceramic shell material and microchannel plates of third-generation low-light-level image intensifiers

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1. Introduction

Low light level image intensifiers are the core devices of low light level night vision systems. They convert the targets, which cannot be clearly recognized by human eyes under the weak illumination, into the visible light images easily observed through the photoelectric conversion of photocathodes, electrical signal amplification of microchannel plates (MCPs) and electro-optic conversion of fluorescent screens. Image intensifiers are a kind of ultra-high vacuum devices, which need to operate under the condition of an internal vacuum of less than a pressure of 1.0×10^{-6} Pa. However they have a very narrow vacuum microcavity and a large internal surface area, so it is a great challenge to sustain this ultra-high vacuum for several years. The main factors causing the vacuum deterioration of image intensifiers are as follows: material outgassing, gas leakage through leak holes in intensifier shell and defects in sealing seams, and external gas penetration through fluorescent screen, photocathode, ceramic/metal shell and sealing materials.

The outgassing characteristics of several materials in low-light-level image intensifiers such as MCPs and photocathodes have been investigated. However, the research on the outgassing characteristics of ceramic shell material (95 alumina ceramic) has not been reported. In addition, the previous research works on the outgassing characteristics of MCPs mainly focuses on the released gas composition measurement, but lacking deep investigations on the proportion of each component in the released gas and outgassing mechanism of MCPs, which are critical for exploring surppressing methods of MCP outgassing. In this work, the outgassing rates and component ratios of the released gas from ceramic shell material and MCPs of third-generation low-light-level image intensifiers were measured with the static pressure-rising method and residual gas analysis by a quadrupole mass spectrometer, and their outgassing mechanisms were further analyzed.

2. Measurement Methods

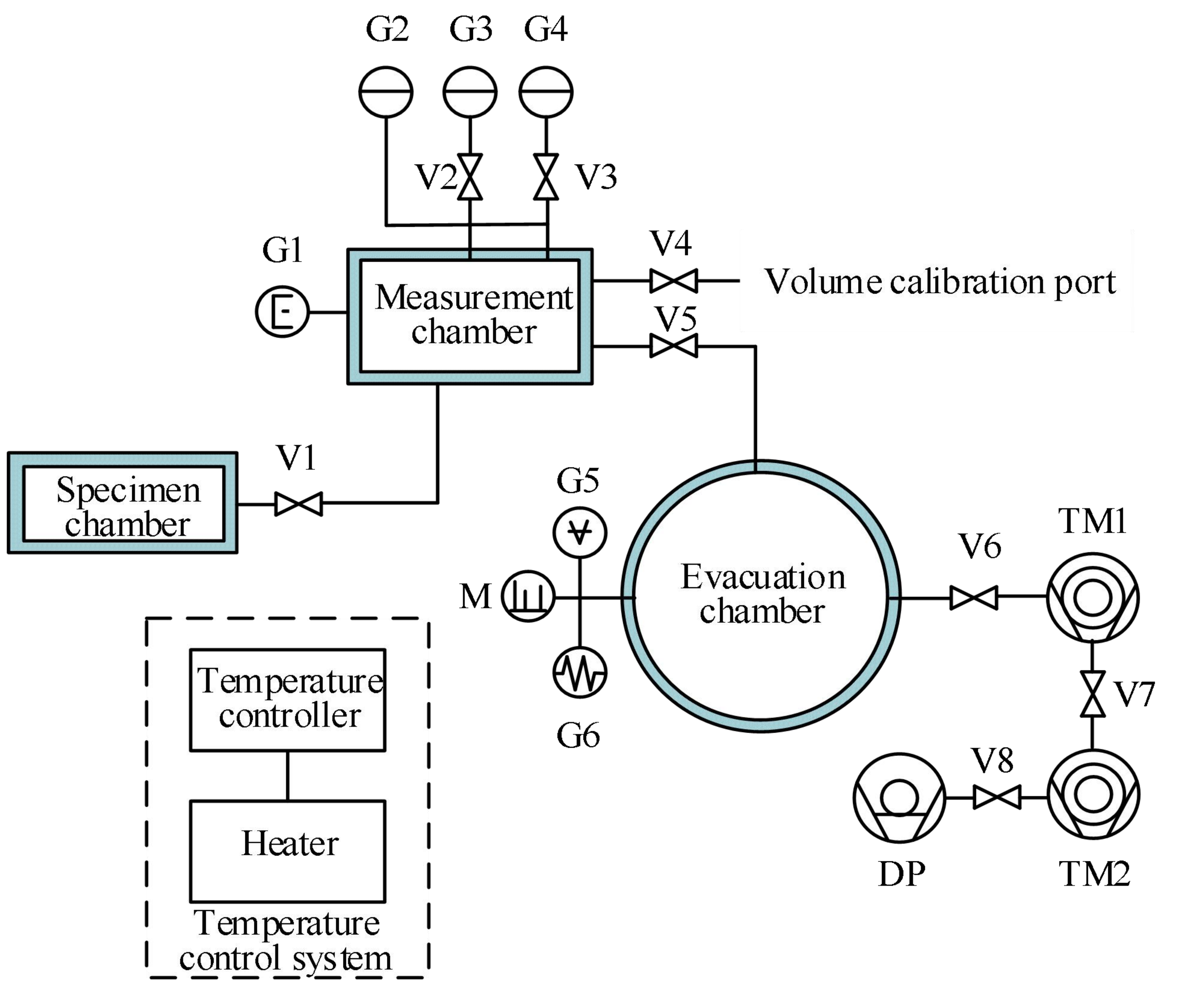
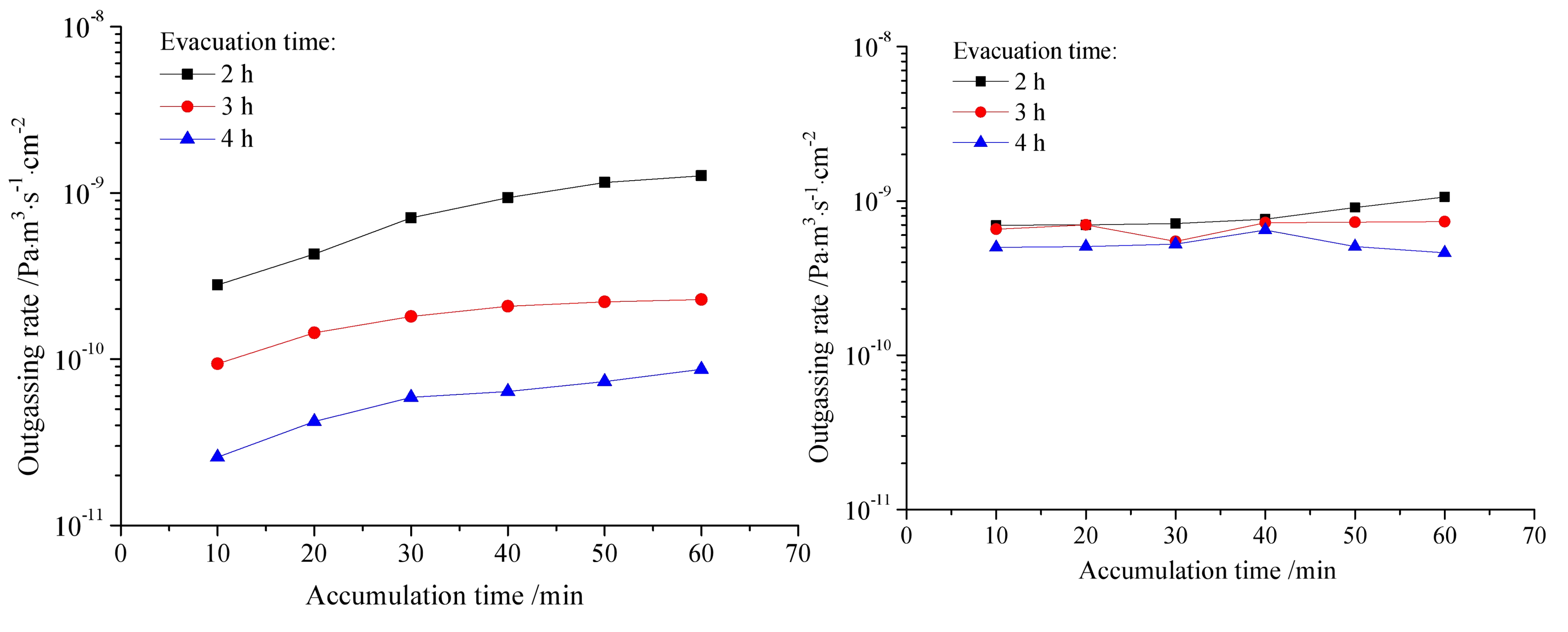


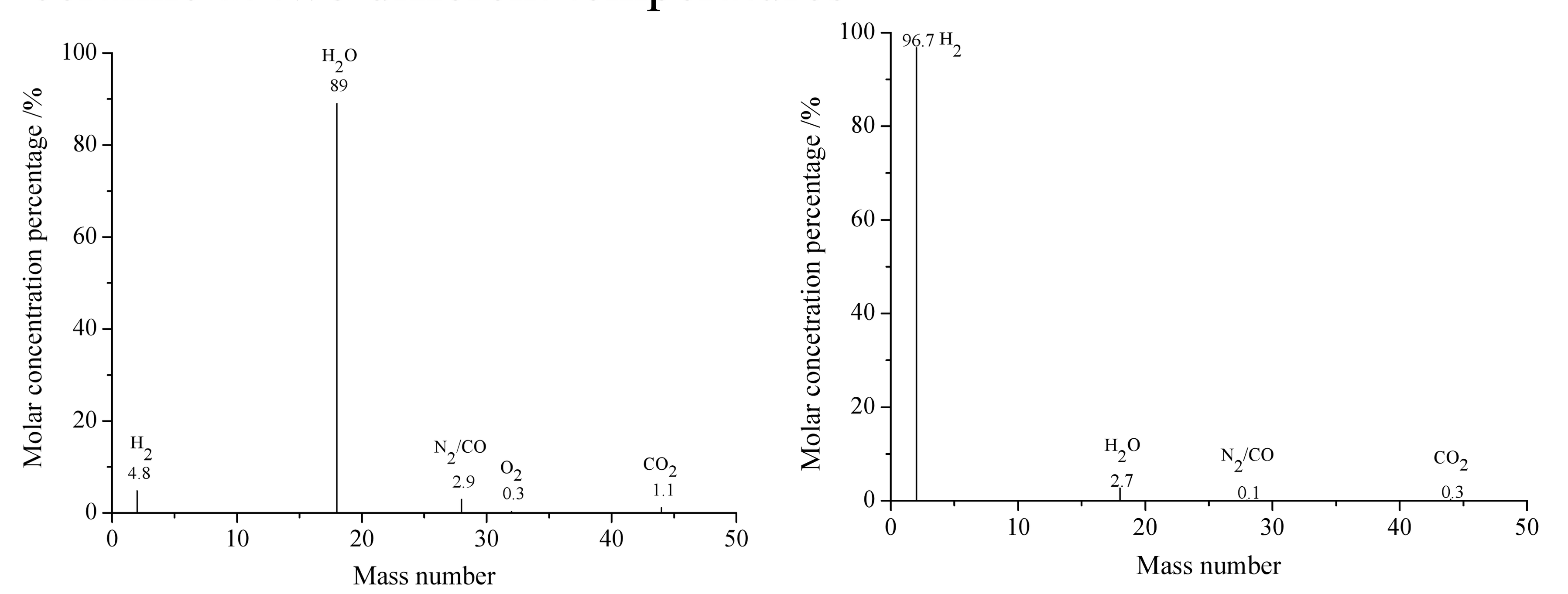
Fig. 1 Structure diagram of the measurement system

3. Results and Discussion



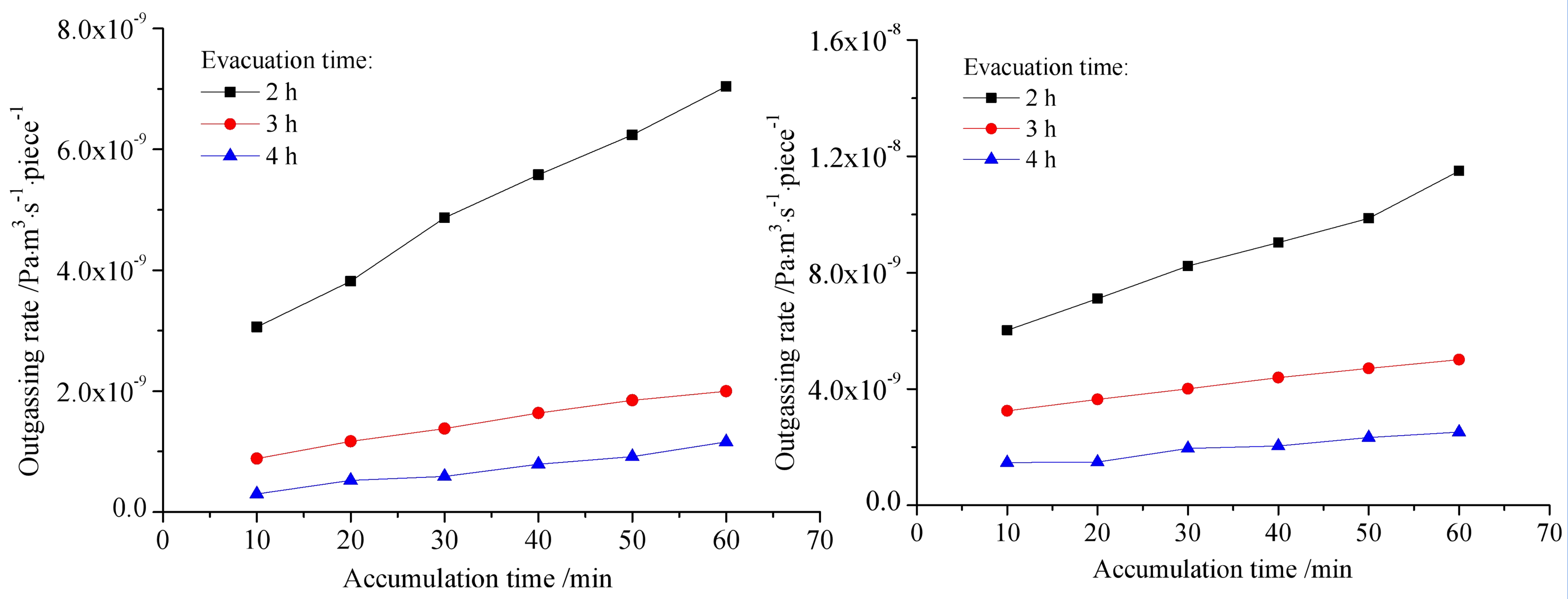
(a) 23℃ (b) 150℃

Fig. 2 Variation curves of the outgassing rate of the 95 alumina ceramic at two different temperatures



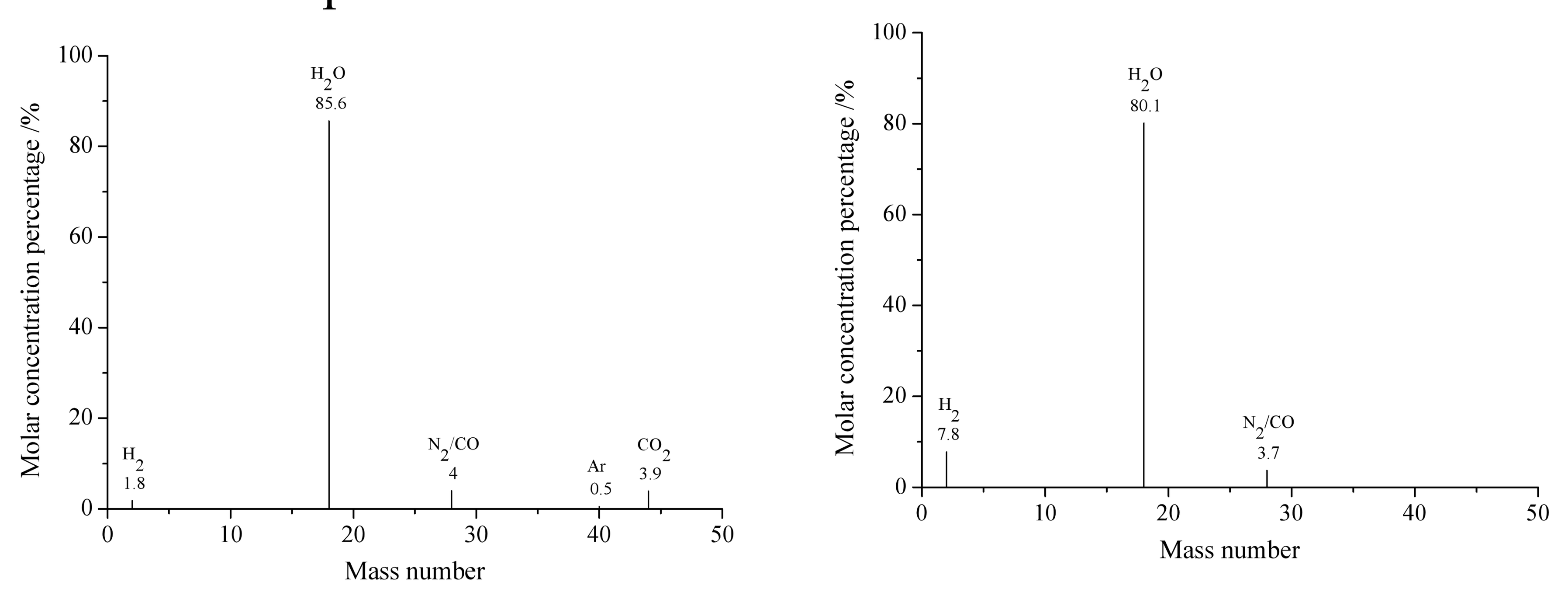
(a) 23℃ (b) 150℃

Fig. 3 Gas components released from the 95 alumina ceramic at two different temperatures



(a) 23℃ (b) 150℃

Fig. 4 Variation curves of the outgassing rate of the MCPs at two different temperatures



(a) 23℃ (b) 150℃

Fig. 5 Gas components released from the MCPs at two different temperatures

4. Conclusions

The 95 alumina ceramic and MCPs have the outgassing rates of in the order of magnitude of about 10^{-11} $Pam^3s^{-1}cm^{-2}$ and 10^{-10} $Pam^3s^{-1}piece^{-1}$ at 23 ℃ after the evacuation of 4 hours, respectively. The outgassing rate of the 95 alumina ceramic rises by an order of magnitude at 150 ℃, while the outgassing rate of the MCPs at 150 ℃ is only half order of magnitude higher than that at 23 ℃. The main gas components released from the 95 alumina ceramic and MCPs are H_2O, H_2, N_2/CO and CO_2 in order of the outgassing rate from high to low at 23 ℃. For the 95 alumina ceramic at 150 ℃, the molar ratio of the released H_2O gas reduces remarkably, while that of the released H_2 gas rises greatly. For the MCPs, the molar ratios of the released H_2O and H_2 gases both only have slight changes at 150 ℃. The reasons leading to these outgassing characteristics of the 95 alumina ceramic and MCPs are mainly attributed to a higher diffusion coefficient and a higher desorption rate of gas molecules at a higher temperature, together with the high flow resistance of microchannels in the MCPs.