

Ejection frequency of spallation particles from polymers during irradiation of Ar thermal plasmas with different molecular gases.

各種ガス系の混合 Ar 誘導熱プラズマ照射における
スプレーン粒子の飛翔頻度

Naoki Shinsei, Masahiro Ishida, Yasunori Tanaka, Yoshihiko Uesugi

Junichi Wada and Shigemitsu Okabe

新清直樹, 石田昌弘, 田中康規, 上杉喜彦

和田純一, 岡部成光

Kanazawa University, Kakuma-machi, Kanazawa, 920-1192, Japan

金沢大学 〒 920-1192 金沢市角間町

In this report, we estimated ejection frequency of spallation particles during irradiation of Ar thermal plasmas with different molecular gases. The arc plasma may contact the polymer materials, inevitably involving polymer ablation. We found out that not only polymer ablated vapor but also spallation particles were ejected from the polyamide materials surface during irradiation of Ar thermal plasma. Many spallation particle injection can affect the arc plasma through their much ablation.

1. Introduction

Polymer materials are widely used for insulator in low-voltage circuit breakers, and for gas flow nozzle high-voltage circuit breakers. In a current interruption process, the arc plasma is formed between the electrodes in the circuit breaker. The arc plasma may contact the polymer materials, inevitably involving polymer ablation. Effective utilization of such polymer ablation is expected to enhance the arc interrupting capability of the circuit breaker.

In our previous works, we found out that not only polymer ablated vapor but also spallation particles were ejected from the polyamide materials surface during irradiation of Ar thermal plasma [1]. Many spallation particle injection can affect the arc discharge further through much ablation inside the arc plasma. This report describes experimental results of Ar+N₂ and Ar+O₂ plasma irradiation to polymer materials. The molecular gas N₂ or O₂ was added to Ar plasma gas to study their effects on the spallation production. Ejection frequency of spallation particles was estimated for Ar, Ar+N₂ and Ar+O₂ plasmas irradiation.

2. Experimental setup and conditions

Fig. 1 shows the plasma torch, the specimen holder and the observation system used in this experiment. The torch is 345 mm long, and 70 mm ϕ in inner diameter. From the top of the torch, Ar gas is supplied along the wall as a sheath gas. Around the torch, an eight-turn induction coil is located to generate electromagnetic field inside the torch. This electromagnetic field then generates a thermal plasma inside the plasma torch. A reaction chamber is installed downstream of the plasma torch. Inside the reaction chamber, a movable water-cooled specimen holder made of stainless

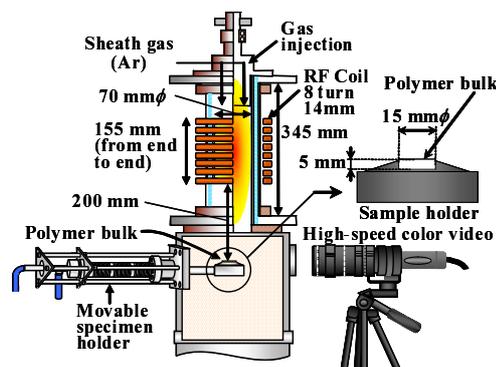


Fig. 1: RF plasma torch and high-speed video camera.

steel is located. A color high-speed video camera was used to observe polymer ablated vapor near the polymer surface from the observation window. The experimental condition was as follows: The gas flow rate was set to Ar:30 slpm in case of 100%Ar, Ar:50 slpm + N₂:1.5 slpm in case of 97%Ar+3%N₂, and Ar:50 slpm + O₂:2.5 slpm in case of 95%Ar+5%O₂. The input power to the thermal plasmas was controlled to equal irradiation heat flux onto the surface of the polymer specimen for any gas conditions. The pressure inside the chamber was 760 torr. The frame rate of the video recording was 1000 fps. Three kinds of polymer materials were used as a specimen; PTFE (polytetrafluoroethylene) [-C₂F₄-]_n, PA66 (polyamide-66) [-C₁₂H₂₂O₂N₂-]_n and PA6 (polyamide-6) [-C₆H₁₁ON-]_n. The diameter and the thickness of the cylindrical polymer specimen used here are 15 mm ϕ and 5 mm, respectively.

3. Results and discussions

3.1. High-speed video camera observation results

A color high-speed video camera was used to observe polymer ablated vapor near the polymer surface

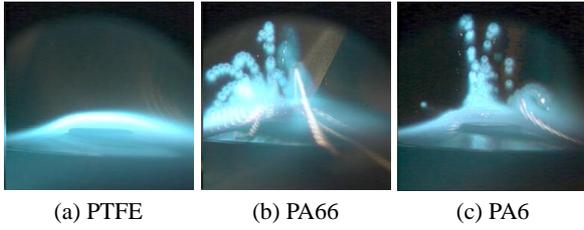


Fig. 2: Ablated vapor and spallation particles in case of Ar induction thermal plasma irradiation.

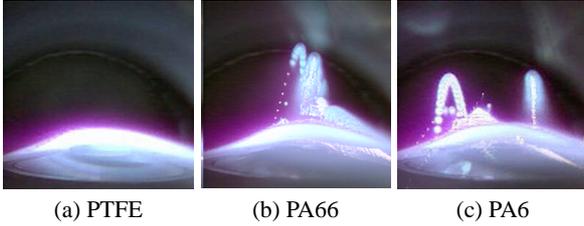


Fig. 3: Ablated vapor and spallation particles in case of Ar+N₂ induction thermal plasma irradiation.

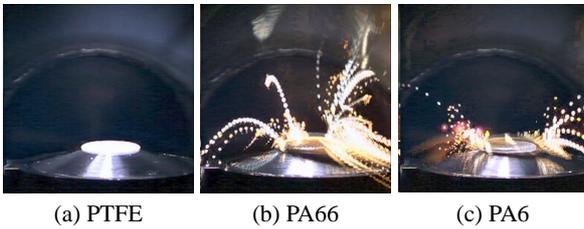
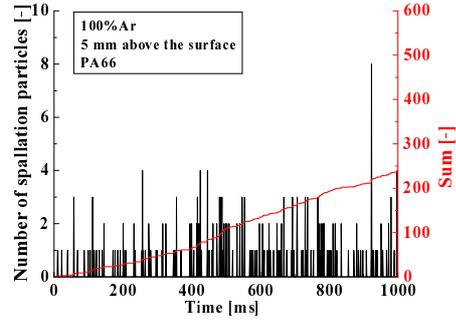


Fig. 4: Ablated vapor and spallation particles in case of Ar+O₂ induction thermal plasma irradiation.

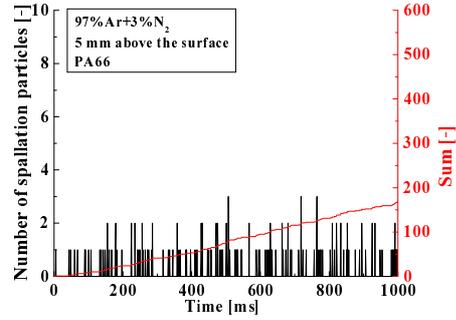
during irradiation of the Ar, Ar+N₂ and Ar+O₂ induction thermal plasmas. Figs. 2–4 present cumulative images to show the trajectories of spallation particles ejected from polymer materials. These figures were produced by combining 100 consecutive images of high-speed video camera. In case of PTFE irradiated Ar or Ar+N₂ thermal plasma, only ablated vapor cloud can be strongly seen near the surface of the PTFE specimen. The blue or blue-violet light are strongly observed from the polymer ablated vapors. This may be due to C₂ or CN molecular spectra originating from the polymer vapors. On the other hand, in cases of PA66 and PA6, spallation particles ejected from specimens can be found definitely. These particles were obviously found flying from the specimen surface to 25 mm or above against the eath gases flow from the upstream to the specimen surface.

3.2. Ejection frequency of spallation particles

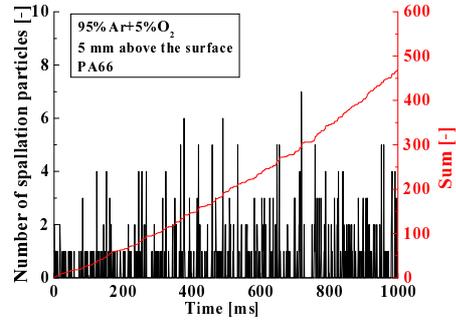
We estimated how often particles were ejected from the specimen. The bar chart in Fig. 5 shows the number of particles ejected from PA66 surface in 1000 ms during the irradiation of each thermal plasma. This figure also includes their accumulative number of the particles, which refers to the right vertical axis. As seen in this figure, spallation particles were ejected almost constantly. In case of Ar+O₂ thermal plasma irradiation, the most number of spallation particles were ejected from PA66 surface, and thus about 470 parti-



(a) Irradiation of Ar thermal plasma.



(b) Irradiation of Ar+N₂ thermal plasma.



(c) Irradiation of Ar+O₂ thermal plasma.

Fig. 5: Number of spallation particles(PA66)

cles were totally found to fly in 1000 ms. Therefore, the mean ejection frequency of the spallation particles can be estimated about 2.4 ms in Ar+O₂ plasma irradiation.

4. Conclusion

In this report, we investigated a dynamics behavior of spallation particles from polymers during irradiation of Ar thermal plasmas with different molecular gases. As a result, spallation particles also were ejected from polyamide materials in case of Ar+N₂ and Ar+O₂ thermal plasmas irradiation. These particles were found flying from the specimen surface to 25 mm or above against the eath gases flow from the upstream to the specimen surface. In case of Ar+O₂ thermal plasma irradiation, the most number of spallation particles were ejected from PA66 surface, and thus about 470 particles were totally found to fly in 1000 ms.

References

- [1] Y.Tanaka et al., “Spallation particle ejection from polymer surface irradiated by thermal plasmas”, IEEE Trans. Plasma Sci, 2011(to appear)