SHIMADZU

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Novel High Sensitivity Detector for GC/MS

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Overview

- We have developed a novel high sensitivity detector which has a simple structure to achieve high ion transmission and eliminate neutral molecules simultaneously.
- Signal to noise ratio (S/N) was 1.5 times higher than that with a conventional detector.

1. Introduction

In GC/MS, numerous neutral molecules originated from carrier gas pass through quadrupole mass filter without being removed, and thereby they are finally transferred to ion detector. When they enter the detector, they may cause noise in the detecting signal. For this problem, some detector structures have already been proposed to remove these neutral molecules. However, they have complex structures and the room for improvement of ion transmission. In this study, we have developed the new high sensitivity detector which has a simple structure to achieve high ion transmission and to eliminate neutral molecules simultaneously.

2. Materials and Methods

Figure 1 shows the structure of a new detector. The detector consists of an inlet aperture, a new neutral shield electrode, a conversion dynode, and an electron multiplier. The neutral shield electrode has a unique optimized shape to transport ions toward the conversion dynode efficiently and to block neutral molecules passed through the inlet aperture. It has an approximate shape of an equipotential surface between the inlet aperture and the conversion dynode when there is no shield electrode. This concept leads to high ion transmission equal to that without the shield electrode. The shape and voltage of the shield electrode were optimized through simulations. In this experiment, we are simulated the equipotential surface and ion trajectory to verify the validity of the concept and prepare a prototype detector. At last, signal intensity, noise, and signal to noise ratio were measured with gas chromatograph mass spectrometer, GCMS-QP2050 (Shimadzu Corporation, Kyoto, Japan) as shown in figure 2.

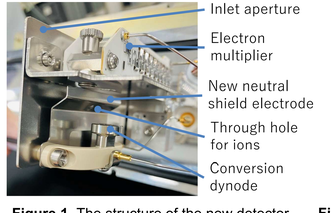

Figure 1. The structure of the new detector developed in this study

Figure 2. Gas chromatograph mass spectrometer, GCMS-QP2050

3. Results

At first, we simulated the equipotential surface in the new detector to verify the validity of the concept. The inlet aperture and conversion dynode was applied to 0 V and -10 kV, respectively. Figure 3 shows the simulation result of the equipotential surface. By placing the shield electrode along the equipotential surface on the blue line and applying -2 kV corresponding to the equipotential surface, it was possible to prevent neutral particles without affecting the ion trajectory. The ion trajectory when the shield electrode is placed was simulated and compared it with the conventional detector and the new detector. Figure 4 shows the simulation results in (a) conventional detector and (b) new detector. In the conventional detector, neutral particles enter the strong electric field generated by the conversion dynode which is applied to -10 kV, where they would be ionized and detected as noise. On the other hand, in the new detector, the shield electrode prevents neutral particles while smoothly drawing ions into the conversion dynode. This simulation result shows approximately 100% ion transmission from the inlet aperture to the conversion dynode.

We designed the new detector based on the simulation result and evaluated the performance. Signal intensity, noise, and signal to noise ratio were evaluated. The noise was measured by the signal intensity at m/z without peaks. The signal intensity of ions obtained with the new detector was increased by 1.2 times compared with the conventional detector. On the other hands, the noise was reduced by approximately 20% as shown in figure 5 (a). Finally, the signal to noise ratio with the new detector was 1.5 times higher than that with the conventional detector as shown in figure 5 (b).

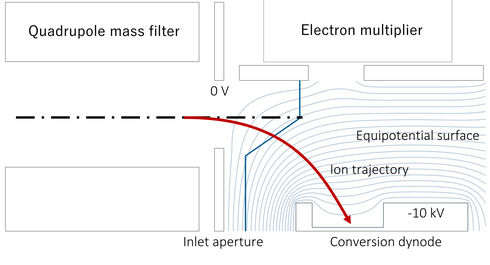

Figure 3. The simulation result of the equipotential surface. By placing the shield electrode along the equipotential, it was possible to prevent neutral particles without affecting the ion trajectory.

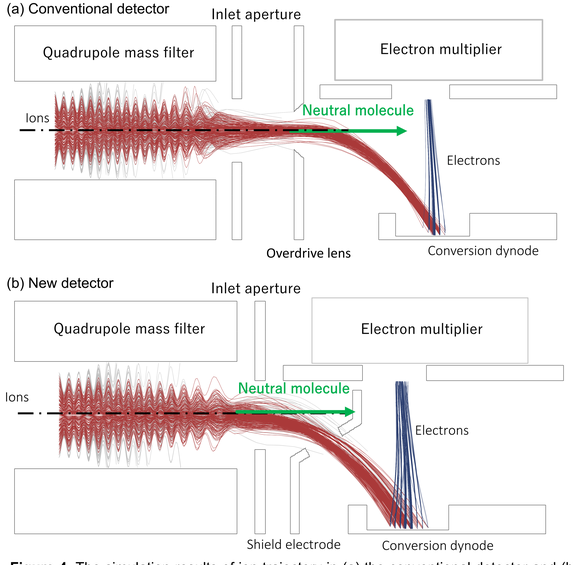

Figure 4. The simulation results of ion trajectory in (a) the conventional detector and (b) new detector. In the conventional detector, neutral particles enter the strong electric field, where they would be ionized and detected as noise.

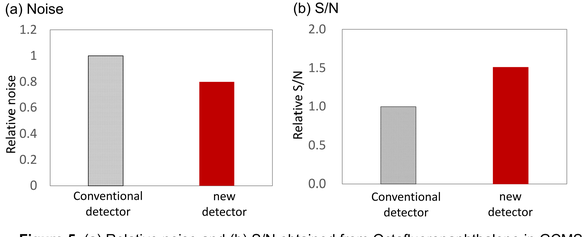

Figure 5. (a) Relative noise and (b) S/N obtained from Octafluoronaphthalene in GCMS-QP2050. The noise was measured by the signal intensity at m/z without peaks.

4. Discussion

Most of the neutral particles in GC/MS come from the carrier gas. The higher the flow rate of the carrier gas, the more noise from neutrons is generated. Therefore, we measured the noise for each helium flow rate to verify the neutral particle reduction effect of the new detector. Figure 6 shows the relationship between the relative noise and He carrier at the flow rate of 1.0, 1.5, 2.0 mL/min. The noise was reduced by approximately 20% at 1.0 mL/min, while the noise was reduced by approximately 30% at 2.0 mL/min. This result suggested that the noise reduction effect of the new detector was more effective at higher flow rate. In addition, this detector is promising to extend the lifetime of the detector due to less contamination from neutral particles in the conversion dynode and electron multiplier.

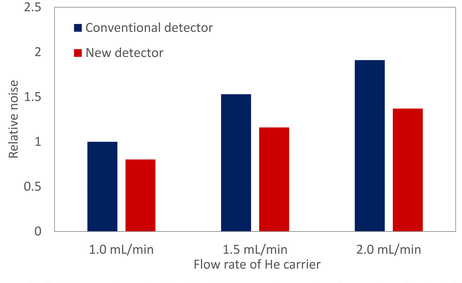

Figure 6. Relative noise obtained with He carrier at the flow rate of 1.0, 1.5, 2.0 mL/min. The noise reduction effect of the new detector was more effective at higher flow rate

5. Conclusions

- We have developed the new high sensitivity detector and achieved the high ion transmission and removal of neutral molecules simultaneously.
- Signal intensity was increased by 1.2 times and noise was reduced by about 20%, S/N was 1.5 times higher than that with the conventional detector.
- This noise reduction effect will be larger in the high flow analysis. In addition, this detector is promising to extend the lifetime of the detector due to less contamination from neutral particles in the conversion dynode and electron multiplier.