

Technical Report

Effects of Polarity Switching in High Speed LCMS Analysis

1. MS Limitation to Throughput

The introduction of high-speed analysis into the laboratory brings rapid improvements in efficiencies for businesses conducting research and development, testing and inspection, etc. As this liberates chemists from time consuming analytical operations, it opens up the possibility of using that time on other business-related activities.

In the case of LC, the advent of UHPLC (Ultra-High-Performance LC) has produced a positive effect on throughput which has fueled widespread proliferation of this technique. The same cannot be said of LCMS, in which high-speed analysis is not yet the norm. That is because several hurdles must be overcome to achieve higher speeds with LCMS. One key problem is that in multi-component analysis, it is frequently necessary to detect ions in both positive and negative modes simultaneously. However, the slow MS transition time between positive and negative ion modes (polarity switching) is a hurdle that still exists at this time. This problem effectively limits the use of MS as a detector to many UHPLC methods.

2. Polarity Switching Time

In order to measure both positive and negative ions in one analysis, the MS executes polarity switching during the analysis. The time required for switching between the positive-ion and negative-ion modes is called the "polarity switching time."

Since polarity switching was not conducted for analysis of the positive ions and negative ions shown in Fig. 1 (a) and (b), respectively, the problem of slow polarity switching is irrelevant.

On the other hand, when conducting simultaneous measurement of both positive and negative ions, as shown in Fig. 1 (c), the MS executes polarity switching during the analysis. Since data acquisition is temporarily interrupted during polarity switching, sufficient data points may not be collected, resulting in deformed peaks. Deterioration of the peak shape is a fatal problem in quantitative analysis due to the adverse effect on area repeatability.

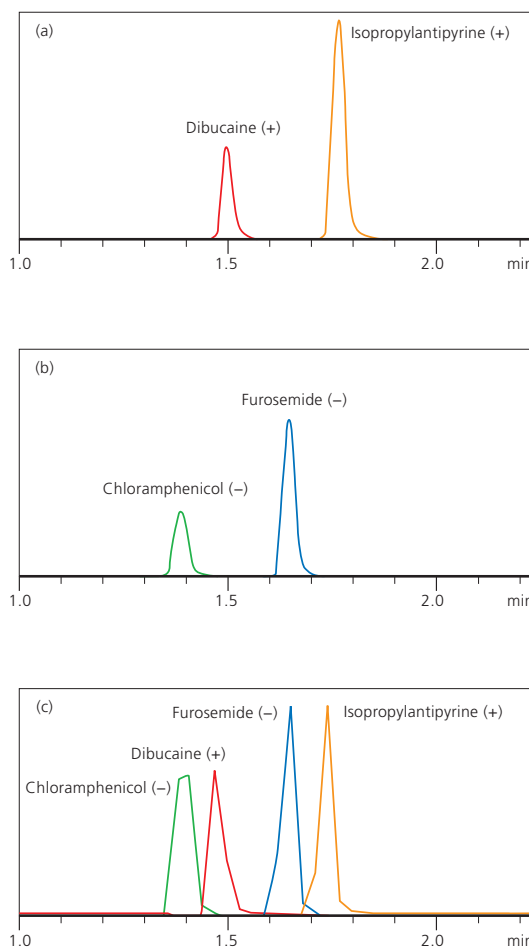


Fig. 1 Impact of Slow Polarity Switching

3. Ultra-High-Speed Polarity Switching

As explained above, polarity switching at higher speed is essential for simultaneous measurement of both positive and negative ions without sacrificing quantitation accuracy in high-speed LCMS analysis.

The two mass spectrometers that satisfy this need are the triple quadrupole LC/MS/MS "LCMS-8030" and the single quadrupole LC/MS "LCMS-2020."

Since both instruments achieve ultra-high-speed 15 msec polarity switching, using Shimadzu's Nexera UHPLC as the front-end permits ultra-high-speed LCMS analysis, demonstrating the full performance potential of Shimadzu's ultra-high-speed systems (see Fig. 2, 3).



Fig. 2 Triple Quadrupole LC/MS/MS System
Nexera + LCMS-8030

4. Polarity Switching Principles

Fig. 4 illustrates the principle of polarity switching in Electrospray Ionization (ESI).

A capillary tube is positioned in the center of the ESI probe and surrounded by gas flow.

Ionized sample and mobile phase eluted from the column are nebulized as electrically charged fine droplets. Applying a high voltage to the spray region causes a preferential charge on the droplets.

As shown in Fig. 4 (a), when a positive high-voltage charge is applied to the probe, positive ions are emitted, and conversely, applying a negative high-voltage charge emits negative ions. Switching between positive and negative ionization modes is accomplished by switching the voltage polarity.



Fig. 3 Single Quadrupole LC/MS System
Nexera + LCMS-2020

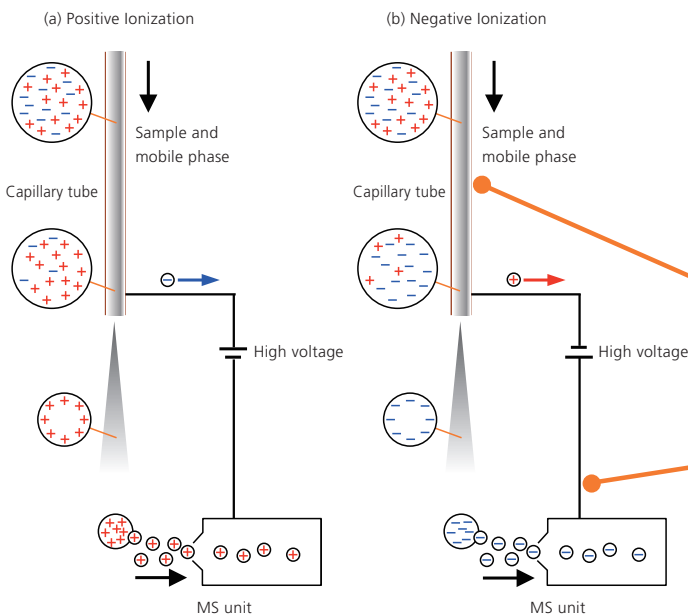


Fig. 4 Electrospray Ionization Principles



Fig. 5 LCMS-8030 ESI Probe

A conventional high-voltage polarity switching circuit consists of two high-voltage power sources. In this type of circuit, a positive (+) high-voltage power source and a negative (-) high-voltage power source are arranged in parallel.

Positive and negative ionization are switched using a (+) and (-) switching function. Positive ionization is achieved by switching ON the (+) high-voltage power source and switching OFF the (-) high-voltage power source, thereby supplying a positive voltage to the ionization probe. Conversely, negative ionization is achieved by switching OFF the (+) high-voltage power source and switching ON the (-) high-voltage power source, thereby supplying a negative voltage to the ionization probe.

The time required for switching between positive and negative ionization with this system corresponds to the polarity switching time. Since ionization is not conducted during the ionization mode switching interval, data generation is interrupted. Therefore, the longer the time required to accomplish polarity switching while switching between ionization modes, the fewer the acquisition points that are available for generating an acceptable chromatogram, resulting in deteriorated peak shapes (see Fig. 6 (II)).

Fig. 7 (II) shows an example of voltage changes during switching using the traditional switching method. From the figure, it is clear that the time required for voltage polarity switching is on the order of hundreds of milliseconds.

To resolve this problem, the (+) / (-) switching functions were removed from the high-voltage polarity switching circuit in the LCMS-8030 and LCMS-2020. Instead, the positive and negative polarity high voltage power sources were arranged in series, and by adding a bypass circuit to both power sources, instantaneous actuation of the (+) or (-) power source was successfully accomplished. Thus, high-speed switching between ionization polarities was achieved.

Fig. 7 (I) shows an example of the voltage change using this circuit, in which the time required for switching is on the order of milliseconds, thereby achieving ultra-fast switching of ionization polarity. Results of LCM-8030 MRM measurements using high-speed switching are shown in Fig. 6 (I). When comparing this to the results of Fig. 6 (II), it is evident that the polarity switching time in high-speed LCMS analysis greatly affects peak shape, and that superior quantitation accuracy can be obtained with high-speed polarity switching.

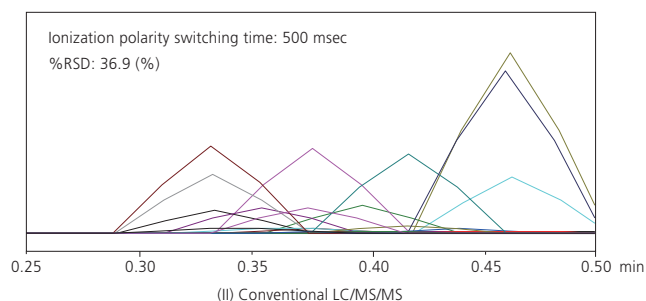
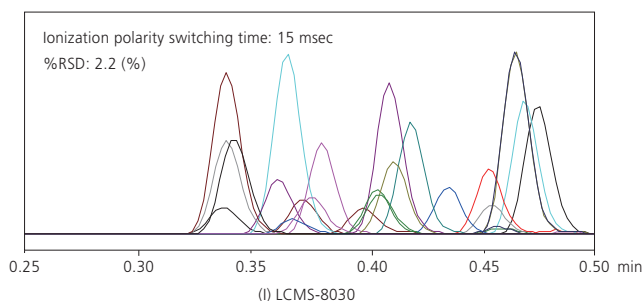


Fig. 6 Simultaneous MRM Measurement of Both Positive and Negative Ions

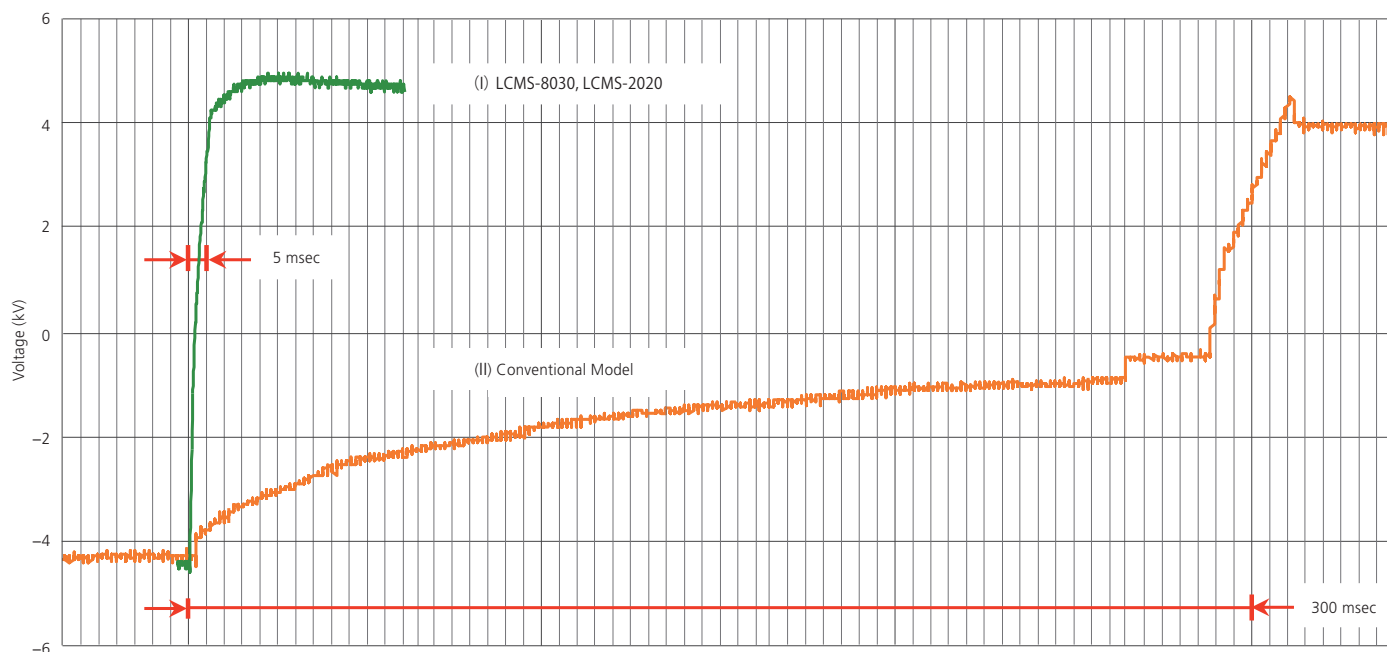


Fig. 7 Voltage Changes During Ionization Polarity Switching

5. Sensitivity with Ultra-High-Speed Polarity Switching

Ultra-high-speed ionization polarity switching in the LCMS-8030 and LCMS-2020 not only achieves excellent repeatability, but also is accomplished without loss of sensitivity. As seen from the LCMS-8030 data shown in Fig. 8, sensitivity is undiminished when high-speed polarity switching is executed.

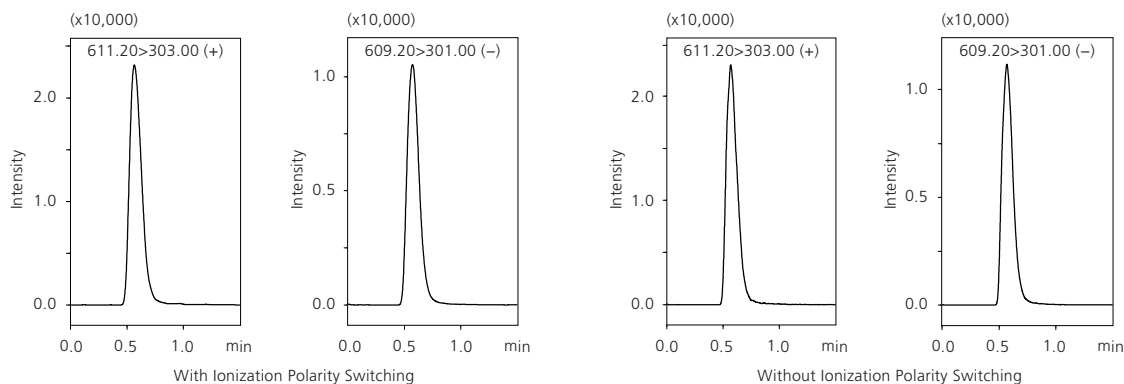


Fig. 8 Sensitivity with and without Polarity Switching Using LCMS-8030

Fig. 9 shows an example of analysis using the LCMS-8030 with the Nexera as the front-end LC. Simultaneous dual ion MRM measurement was accomplished with extremely sharp peaks for 316 pesticide compounds (positive ion: 286 channels, negative ion: 30 channels). This further demonstrates that ultra-high-speed polarity switching is indispensable to achieve faster LCMS analysis.

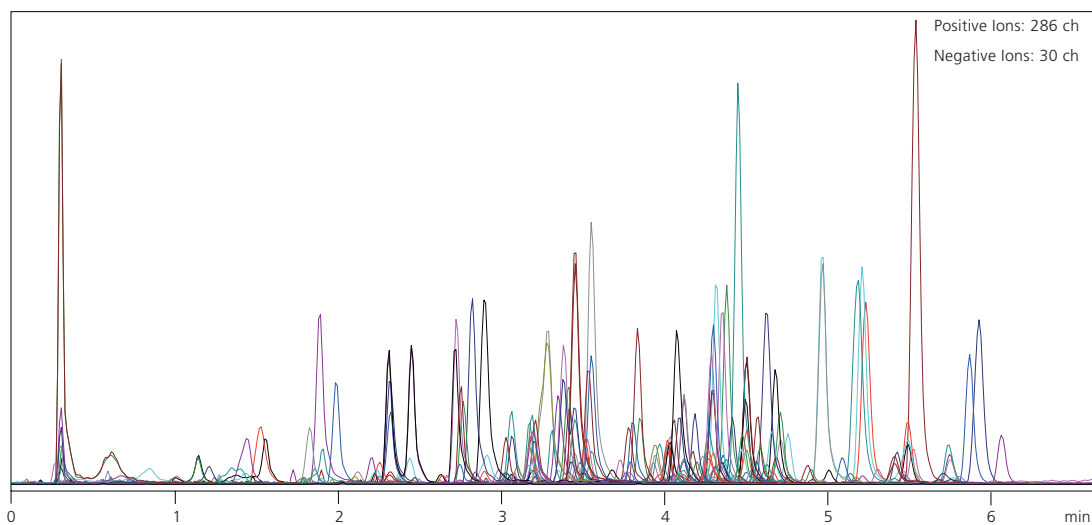


Fig. 9 MRM Dual Ion Simultaneous Measurement of 316 Pesticides Using LCMS-8030