1. Introduction

The objective of this project was to improve analytical performance of Desorption Electrospray Ionization (DESI) coupled to a high resolution Fourier Transform Mass Spectrometer (FT-MS) and gain more insight into the DESI mechanism and underlying processes. DESI surface imaging ion source is not currently commercially available for high-end FT-ICR instruments and its construction and optimization for biological samples was one of the important parts of the project. DESI is a novel ionization method, that combines features of electrospray ionization (ESI) with those of the family of desorption ionization (DI) methods. The DESI experiment allows molecules present on surfaces to be analyzed by mass spectrometry without requiring the sample to be introduced into the vacuum system of the mass spectrometer. DESI differentiates itself from other DI methods in mass spectrometry because the sample can be analyzed outside the mass spectrometer in an open laboratory environment. Custom built DESI platforms used for this project can be seen in Figure 1.

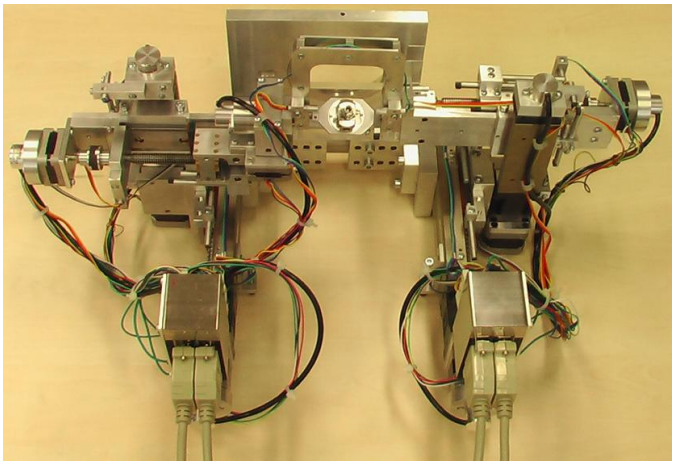


Figure 1 DESI ion source. A custom automated DESI platform that mounts on the atmospheric pressure inlet of the Bruker FT-ICR instrument. *Analytical Chemistry* 81(20): 8479-8487, 2009, doi: 10.1021/ac901368q

2. DESI mechanism

An important part of the project was the investigation of the DESI mechanism. Electron scanning microscopy was used to visualize surfaces that underwent DESI process with ferromagnetic nanoparticles solvated in DESI mobile phase mixture. It seems (Figure 2) that nanoparticles adopt certain pattern on the surface that is a direct result of the force equilibrium on the surface. This provides a new view into the DESI mechanism.

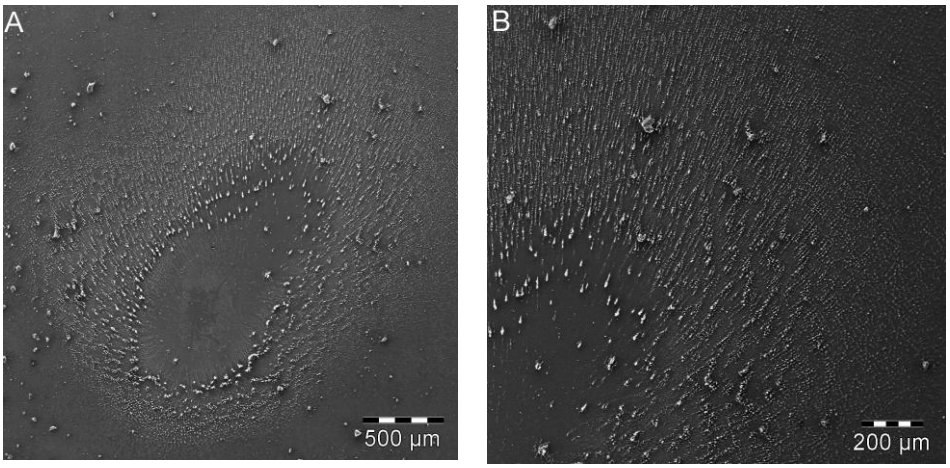


Figure 2 Nanoparticles in DESI. Scanning electron microscopy images show the regularity of the deposited aggregates on the surface that was sprayed by the mixture with solvated nanoparticles. Panel A shows overall view of the impact area, Panel B is focused view. Details in: *Journal of Mass Spectrometry* 46, 256-261, 2011, doi:10.1002/jms.1888

3. Analysis of aconitine by DESI-MS

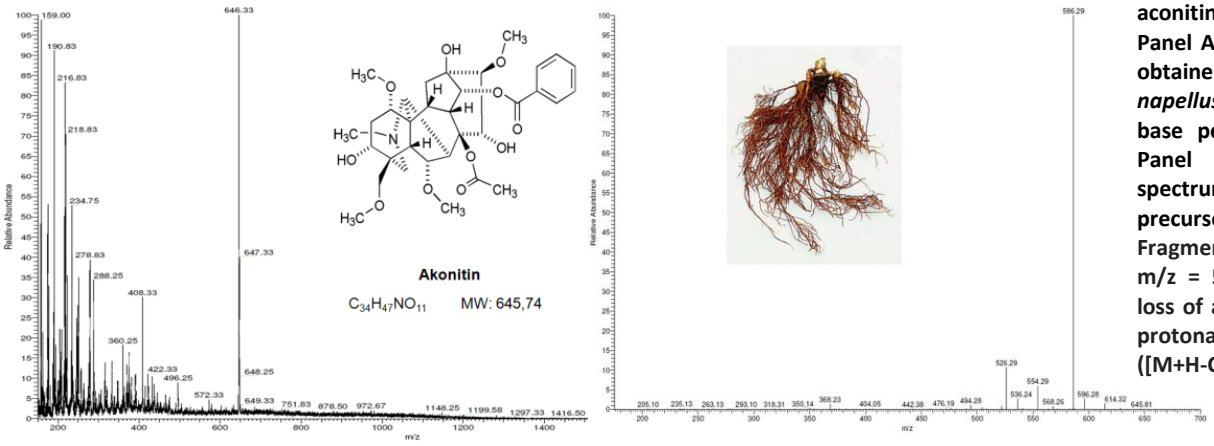
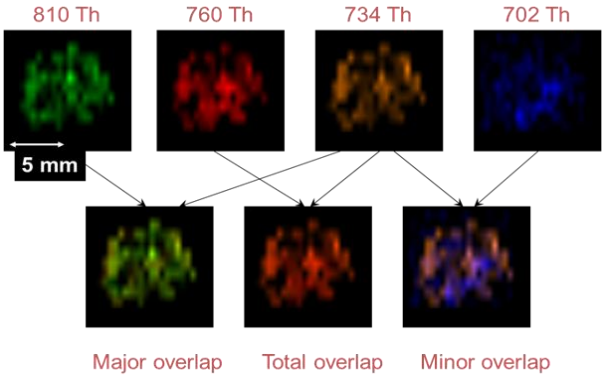


Figure 3 DESI-MS of aconitine in plant samples. Panel A: DESI-MS spectrum obtained from *Aconitum napellus*. Aconitine is the base peak at m/z = 646. Panel B: DESI-MS/MS spectrum of aconitin precursor ion. Fragmentation product at m/z = 586 corresponds to loss of acetic acid from the protonaited *aconitine* ($[M+H-CH_3COOH]^+$.

4. DESI imaging on commercial FT-ICR-MS

There are two novel aspects of the DESI imaging coupled to the 9.4T FT-ICR-MS. Ones is the utilization of such ultrahigh resolution with ambient ionization. The other novel aspect is in the integration of the atmospheric pressure ionization imaging into the existing software for MALDI imaging, which allows the user of this commercial dual source mass spectrometer to perform MALDI-MS and different ambient MS imaging from the same user interface and to utilize the same software tools. Desorption electrospray ionization (DESI) and Desorption atmospheric pressure photoionization (DAPPI) were used to test the ambient surface imaging capabilities of this new ionization platform. Results of DESI imaging experiments performed on brain tissue sections were in agreement with the previous MS imaging reports obtained by DESI imaging but due to the high resolution and mass accuracy of the FT-ICR instrument it was possible to resolve several ions at the same nominal mass in the DESI-MS spectra of brain tissue. These isobaric interferences at low resolution are due to the overlap of ions from different lipid classes with different biological relevance. It is demonstrated that using high resolution MS fast imaging screening of lipids can be achieved without any pre-separation steps. Examples are in Figure 4.



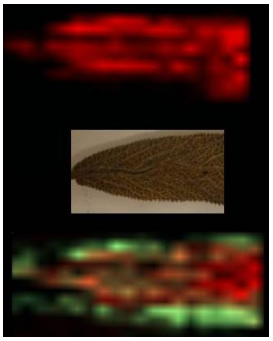


Figure 4 Ambient imaging. Panel A: DESI imaging of mouse brain tissue sections. The images show distributions of different phospholipid species. Panel B: DAPPI imaging of parched salvia leaf. The distribution of two different m/z is shown. Details in: *Analytical Chemistry* 81(20): 8479-8487, 2009, doi: 10.1021/ac901368q

5. NALDI ionization studies

One of the often investigated aspects of ambient ionization is the influence of the surface that functions as a substrate for the sample. It was previously reported that commercially available nanostractured NALDI surfaces are advantageous as substrates for DESI ionization as well. Further investigation of this phenomena resulted in the discovery of NALDI imprinting imaging technique. This novel imaging technique has several advantages compare to standard MALDI and DESI imaging (Figure 5). The work of the researcher during the second part of the project revealed that NALDI surfaces can also be used for a simple determination of a double bond position by a laser desorption ionization mass spectrometry. The procedure is based solely on the catalytic properties of nanostructured NALDI surfaces. These surfaces can induce oxidation of analytes, which results in a mass shift that can be detected by mass spectrometry after the analyte is ionized and transported into the mass spectrometer. (Figure 6)

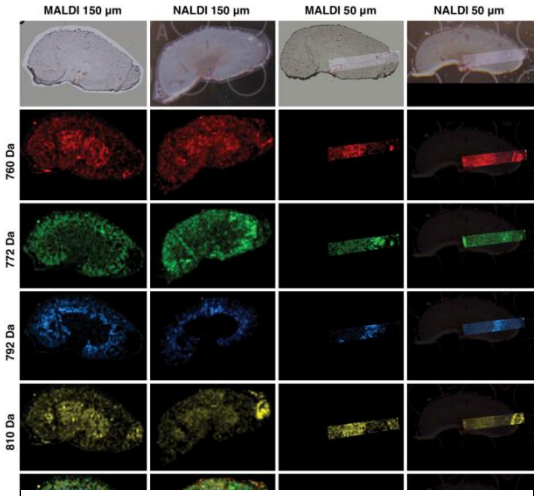


Figure 5 Comparison of standard MALDI imaging with the matrix-free NALDI approach. The images show different lipid composition of cortex, medulla, pelvis and adrenal gland. Details in: *Analytical Chemistry* 82(12): 4994-4997, 2010, doi: 10.1021/ac100661h

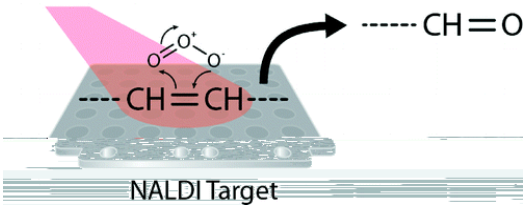


Figure 6 Oxidation of double bonds on NALDI and subsequent desorption-ionization into the mass spectrometer. The ionization impulse can be a laser (laser desorption ionization) or DESI spray. Details in: *Analytical Chemistry* 83, 5661-5665, 2011 doi:10.1021/ac200801t