

Fundamentals

Ambient Eberlin reactions via desorption electrospray ionization mass spectrometry

Sparrapan, R.; Eberlin, L. S.; Haddad, R.; Cooks, R. G.; Eberlin, M. N.; Augusti, R., Ambient Eberlin reactions via desorption electrospray ionization mass spectrometry. *J Mass Spectrom* **2006**, 41, (9), 1242-1246.

Droplet dynamics and ionization mechanisms in desorption electrospray ionization mass spectrometry

Venter, A.; Sojka, P. E.; Cooks, R. G., Droplet dynamics and ionization mechanisms in desorption electrospray ionization mass spectrometry. *Anal Chem* **2006**, 78, (24), 8549-8555.

Abstract

A droplet pickup and other mechanisms have been suggested for the ionization of biomolecules like peptides and proteins by desorption electrospray ionization. To verify this hypothesis phase Doppler particle analysis was used to study the sizes and velocities of droplets involved in DESI. It was found that impacting droplets typically have velocities of 120 m/s and average diameters of 2-4 μm . Small differences in sprayer construction influence the operating conditions at which droplets of these dimensions are produced. Under these conditions, the kinetic energy per impacting water molecule is less than 0.6 meV and sputtering through momentum transfer during collisions or ionization by other electronic processes is unlikely. Droplets arrive at the surface with velocities well below the speed of sound in common materials, thereby excluding the possibility of ionization by shockwave formation. Some droplets appear to roll along the surface, increasing contact time and presumably the amount of material that is taken up into droplets during conditions typical of the DESI experiment

Enhanced desorption ionization using oxidizing electrosprays

Nefliu, M.; Cooks, R. G.; Moore, C., Enhanced desorption ionization using oxidizing electrosprays. *J Am Soc Mass Spectrom* **2006**, 17, (8), 1091-1095.

Abstract:

A signal enhancement of two orders of magnitude was achieved when reactive desorption electrospray ionization (DEST) was used to investigate copper(II) dibutyl dithiocarbamate, $\text{Cu(II)(bu(2)dtc)(2)}$, found in a specialized polymer. Cu(II) was oxidized to Cu(III) during the DEST experiment by oxidants in the spray solvent. Such oxidants could be present or formed during electrospray (e.g., O_2) or deliberately added to the spray solvent (this approach is called reactive DEST). When a strong oxidizing agent (e.g., iodine) was added to the spray solvent, the signal increased by two orders of magnitude relative to the pure solvent spray. The correlation between the standard reduction potential of the oxidant and the signal intensity and signal to noise ratio of the product ion for various reagents, was tested and discussed. The observed DEST

enhancements in rates of oxidation are not observed in homogeneous solution. The major peaks in the collision induced dissociation (CID) spectrum of the complex ion [Cu(III)(bu(2)dtc)](+) were identified using isotopic distributions and MS3 data.

Desorption electrospray ionization in a small pressure tight enclosure

Andre Venter, R.Graham Cooks, "Desorption electrospray ionization in a small pressure tight enclosure", *Analytical Chemistry*, **2007**, 79 (16):6398-6403.

Incorporation of a flared inlet capillary tube on a Fourier transform ion cyclotron resonance mass spectrometer

Wu, S.; Zhang, K.; Kaiser, N. K.; Bruce, J. E.; Prior, D. C.; Anderson, G. A., Incorporation of a flared inlet capillary tube on a Fourier transform ion cyclotron resonance mass spectrometer. *J Am Soc Mass Spectrom* **2006**, 17, (6), 772-779.

Abstract

Flared inlet capillary tubes have been coupled with a Fourier transform ion cyclotron resonance (FT-ICR) mass spectrometer to help the ion transmission from the atmospheric pressure to the first vacuum region. We investigated different types of atmospheric pressure ionization methods using flared inlet tubes. For most of the ionization methods, such as EST and DESI, increased ion current transmitted from the atmospheric pressure ion source to the first stage vacuum system was observed with the use of our enhanced ion inlet designs. The corresponding ion intensity detected on a FT-ICR mass spectrometer was also observed to increase two- to fivefold using EST or DESI with the flared tube inlet. Moreover, increased spray tip positional tolerance was observed with implementation of the flared inlet tube. We also include our preliminary results obtained by coupling AP-MALDI with flared inlet tube in this paper. For AP-MALDI, the measured ion current transferred through the flared inlet tube was about 2 to 3 times larger than the ion current through the control non-flared inlet tube.

Simulation of Atmospheric Transport and Droplet Thin-Film Collisions in Desorption Electrospray Ionization

Anthony B. Costa, R. Graham Cooks, "Simulation of Atmospheric Transport and Droplet Thin-Film Collisions in Desorption Electrospray Ionization", *Chemical Communications*, **2007**, 3915-3917.

Abstract:

Computational fluid dynamics is used to model atmospheric transport and droplet–thin film (surface) collisions in desorption electrospray ionization; experimentally obtained droplet properties are replicated in the simulations while a “droplet pick-up” mechanism of analyte transport is confirmed.

Surface effects and Electrochemical Cell Capacitance in Desorption Electrospray Ionization

Michael Volný, Andre Venter, Scott A. Smith, Marco Pazzi and R. Graham Cooks

Surface effects and Electrochemical Cell Capacitance in Desorption Electrospray Ionization, *Analyst*, **2008**, 132(4), 525-531

Abstract

Time resolved measurements show that during a desorption electrospray ionization (DESI) experiment, the current initially rises sharply, followed by an exponential decrease to a relatively steady current. When the high voltage on the spray emitter is switched off, the current drops to negative values, suggesting that the direction of current flow in the equivalent DESI circuit is reversed. These data demonstrate that the DESI source behaves as a dc capacitor and that the addition of a surface between the sprayer and the counter electrode in DESI introduces a new electrically active element into the system. The charging and discharging behavior was observed using different surfaces and it could be seen both by making current measurements on a plate at the entrance to the mass spectrometer as well as by measuring ion current in the linear ion trap within the vacuum system of the mass spectrometer. The magnitude of the steady state current obtained without analyte present on the surface is different for different surface materials, and different capacitor time constants of the equivalent RC circuits were calculated for different DESI surfaces. The PTFE surface has by far the greatest time constant and is also able to produce the highest DESI currents. Surface properties play a crucial role in charge transfer during DESI in addition to the effects of the chemical properties of the analyte. It is suggested that surface energy (wettability) is an important factor controlling droplet behavior on the surface. The experimental data are correlated with critical surface tension values of different materials. It is proposed, based on the results presented, that super-hydrophobic materials with extremely high contact angles have the potential to be excellent DESI substrates. It is also demonstrated, using the example of the neurotransmitter dopamine, that the surface charge that develops during a DESI-MS experiment can cause electrochemical oxidation of the analyte.

Salt Tolerance of Desorption Electrospray Ionization (DESI)

Ayanna U Jackson, Nari Talaty, R. G. Cooks and Gary J. Van Berkel, "Salt Tolerance of Desorption Electrospray Ionization (DESI)", *Journal of the American Society of Mass Spectrometry*, **2007**, 18, 12, 2218-2225.

Abstract:

Desorption electrospray ionization (DESI) mass spectrometry was evaluated for the characterization of glycerophospholipid standards, including glycerophosphocholine (GPCho), glycerophosphoglycerol (GPGro), glycerophosphoethanolamine (GPEtn), glycerophosphoserine (GPSer), glycerophosphoinositol (GPIIns), cardiolipin (CL), and sphingolipid standards, including sulfatides (ST) and sphingomyelin (SM). Of specific interest were the effects of surface and solvent composition on signal stability and intensity, along with the ions observed in the full scan mode and the fragmentations seen upon collisional activation for each of the above classes. These experiments were performed without the addition of matrix compounds to the sample and were conducted in the free ambient environment at atmospheric pressure. The compounds GPSer, GPGro, GPIIns, ST, and CL were best analyzed in the negative ion mode while PE was

ionized inefficiently in both positive and negative ion modes. SM and GPCho, which typically generate more abundant ions in the positive ion mode, could be analyzed in the negative ion mode by the addition of anionic reagents such as acetate to the spray solvent. Full scan DESI mass spectra and tandem (MS/MS) spectra for this representative set of physiological phospho/sphingolipids are presented. Similarities with other ionization methods in terms of fragmentation behavior were strong, although ambient ionization of untreated samples is only available with DESI. The effect of surface and solvent properties on signal intensity and stability were determined by depositing standard compounds on several different surfaces and analyzing with various proportions of methanol in the aqueous spray. Analysis was extended to complex mixtures of phospholipids and sphingolipids by examining the total lipid extract of porcine brain and by direct analysis of rat brain cryotome sections. These types of mixture analyses and molecular imaging studies are likely to represent major areas of application of DESI.

Internal Energy Distributions in Desorption Electrospray Ionization (DESI)

Marcela Neffliu, Jonell N. Smith, Andre Venter, and R. Graham Cooks, Internal Energy Distributions in Desorption Electrospray Ionization (DESI), *Journal of Amer. Soc. Mass Spectrom.*, **2008**, 19, 420-427.

Abstract:

The internal energy distributions of typical ions generated by desorption electrospray ionization (DESI) were measured using the “survival yield” method, and compared with corresponding data for electrospray ionization (ESI) and electrosonic spray ionization (ESSI). The results show that the three ionization methods produce populations of ions having internal energy distributions of similar shapes and mean values (1.7–1.9 eV) suggesting similar phenomena, at least in the later stages of the process leading from solvated droplets to gas-phase ions. These data on energetics are consistent with the view that DESI involves “droplet pick-up” (liquid-liquid extraction) followed by ESI-like desolvation and gas-phase ion formation. The effects of various experimental parameters on the degree of fragmentation of p-methoxy-benzylpyridinium ions were compared between DESI and ESSI. The results show similar trends in the survival yields as a function of the nebulizing gas pressure, solvent flow rate, and distance from the sprayer tip to the MS inlet. These observations are consistent with the mechanism noted above and they also enable the user to exercise control over the energetics of the DESI ionization process, through manipulation of external and internal ion source parameters.

Unexpected analyte oxidation during desorption electrospray ionization mass spectrometry

S.P. Pasilis, V. Kertesz, G.J. Van Berkel, Unexpected analyte oxidation during desorption electrospray ionization mass spectrometry, **2008**, 80, 4, 1208-1214.

Abstract:

During the analysis of surface-spotted analytes using desorption electrospray ionization-mass spectrometry (DESI-MS), abundant ions are sometimes observed that appear to be

the result of oxygen addition reactions. In this investigation, the effect of sample aging, the ambient lab environment, spray voltage, analyte surface concentration, and surface type on this oxidative modification of spotted analytes, exemplified by tamoxifen and reserpine, during analysis by DESI-MS was studied. Simple exposure of the samples to air and to ambient lighting increased the extent of oxidation. Increased spray voltage also led to increased analyte oxidation, possibly as a result of oxidative species formed electrochemically at the emitter electrode or in the gas phase by discharge processes. These oxidative species are carried by the spray and impinge on and react with the sampled analyte during desorption/ionization. The relative abundance of oxidized species was more significant for the analysis of deposited analyte having a relatively low surface concentration. Increasing the spray solvent flow rate and the addition of hydroquinone as a redox buffer to the spray solvent were found to decrease, but not entirely eliminate, analyte oxidation during analysis. The major parameters that both minimize and maximize analyte oxidation were identified, and DESI-MS operational recommendations to avoid these unwanted reactions are suggested.