Development of ambient desorption/ionization source using ultrafast laser and nonthermal atmospheric pressure helium plasma jet for ambient imaging mass spectrometry

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We report a high spatial resolution ambient mass spectrometry (MS) system that allows us to sensitively image the live hippocampal tissue at ambient environment in the subcellular level. The method is based on an efficient desorption process by femtosecond (fs) laser assisted with nanoparticles and a subsequent ionization step by applying nonthermal plasma for ambient MS imaging. The desorption of molecules from live tissues was found to be greatly enhanced by the strong photothermal effect of gold nanorods and fs laser. The subsequent ionization process with nonthermal atmospheric helium plasma jets enabled production of sufficient amounts of molecular ions of important molecules from a live hippocampal tissue. Combining the ambient nanoPALDI with microscopic sample scanning, MS imaging with spatial resolution of 1.4 μm could be obtained with a sampling depth down to several tens of μm.

1. Introduction

Although ambient ionization mass spectrometry (MS) is a promising analytic technique for biological samples because of its ambient analytic process and no or minimal sample pretreatment [1-3], their applications are still limited due to the insufficient spatial resolution of several tens and hundreds micrometers. Here, we report a new ambient imaging mass spectrometric method with high spatial resolution based on gold nanorod assisted femtosecond laser desorption and subsequent non-thermal plasma induced ionization, termed ambient nanoparticle and plasma assisted laser desorption ionization (ambient nanoPALDI) MS.

2. Methods

Non-thermal helium atmospheric pressure plasma jets (APPJs) and femtosecond near infrared lasers are used as ambient sampling/ionization sources. The energetic light generated by femtosecond lasers focuses on a very small spot of the sample through the objective lens. At same time, non-thermal atmospheric pressure plasma jet device forms the plasma medium on the sample. The desorption of molecules from live tissues is found to be greatly enhanced by the strong photothermal effect of gold nanorods and femtosecond laser, and the subsequent ionization process with nonthermal atmospheric helium plasma jets enabled production of sufficient amount of molecular ions of important molecules from a live hippocampal tissue.

3. Experimental Results

Combined the ambient nanoPALDI with microscopic sample scanning, MS imaging with spatial resolution of 1.4 μm can be obtained with a sampling depth down to several tens of μm. The linear crater generated by ambient nanoPALDI on a hippocampal tissue is exceptionally sharp with the side wall width of around 1 μm and a flat plateau in the bottom. Gold nanorods are uniformly distributed over tissues by cellular uptake of live cells in tissues without any toxic effects and responsible for the high molecular ion intensity and the high spatial resolution. Our ambient nanoPALDI-MS effectively ablates the bulk molecular constituents down to at least several tens of μm while keeping the high spatial resolution which minimizes the sampling problem to represent the whole tissue. From the mouse hippocampal tissue, MS imaging of bio-molecules including monoacylglycerols, cholesterols, ceramides, fragments of sphingolipids and glycerophospholipids has been obtained.

4. Conclusion

A subcellular ambient image mass spectrometric system termed ambient nanoPALDI-MS is reported for live tissue analysis. It enables monitoring biological molecules without pretreatment and verify the molecular chemical properties, elemental compositions and chemical structures.

5. References

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