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Mesoporous tungsten titanate as matrix for matrix-assisted laser desorption/ionization time-of-flight mass spectrometry analysis of biomolecules

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Abstract

In this paper, mesoporous tungsten titanate (WTiO) with different nano-pore structures was utilized as matrix for the analysis of short peptides by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOFMS). Effect of characteristic features of mesoporous matrices on laser desorption/ionization process was investigated. Experiments showed that the ordered two-dimensional and three-dimensional mesoporous matrices were superior in performance to the non-ordered WTiO matrix. The dramatic enhancement of signal sensitivity by the ordered mesoporous matrices can be reasonably attributed to the ordered structure, which facilitated the understanding on structure–function relationship in mesoporous cavity for laser desorption process of adsorbed biomolecules. With the ordered mesoporous matrix, the short peptides are successfully detected. The presence of trace alkali metal salt effectively increased the analyte ion yields and the MALDI-TOFMS using the inorganic mesoporous matrices displayed a high salt tolerance. The developed technique also showed a satisfactory performance in peptide-mapping and amino-acid sequencing analysis.

Keywords: Mesoporous materials; Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry; Inorganic matrix; Biomolecules; Salt tolerance

1. Introduction

The matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOFMS) has increased the ability to analyze biomolecules [1]. The success of MALDI-TOFMS was attributed to the introduction of effective organic matrices, which possess the ability to incorporate and transfer absorbed energy to analytes. In the MALDI process, the ultraviolet (UV)-absorbing organic matrix is co-crystallized with analyte molecules and evaporated upon laser pulsed-radiation, causing the analyte to be carried into the gas phase [2]. Unfortunately, using organic matrix is not always effective. It is difficult for organic matrix to analyze short peptides because of the background ions in the low mass region. Moreover, metal salt contaminants may complicate MALDI analysis and decrease the sensitivity of MALDI mass spectra by forming cation adducts with biomolecules [3]. As a result of these obstacles, a new matrix more suitable for the analysis of small molecule is continuously in demand.

As an alternative to the conventional organic matrix, inorganic matrix (or matrix-free) has been gaining attention [4–18]. With good stability during the laser desorption process, inorganic matrix eliminates the high background noise in the low mass region. It is accepted that the inorganic matrix acts as an energy transfer medium by absorbing the UV radiation, leading to the desorption/ionization of analyte [5–8]. Factors that affect the analyte desorption/ionization have been widely studied in order to optimize the performance of MALDI-TOFMS using inorganic matrix [4], and these studies are also expected to provide criterions for the effective search of good inorganic matrices. Tanaka et al. first used a fine cobalt powder (30 nm) suspended in glycerol as matrix to analyze proteins and peptides, and mentioned that the nature of nano-powder cobalt with high photo-absorption, low heat capacity and large surface area provides "rapid heating" which is necessary to desorb analyte molecules without thermal decomposition [5]. Chen et al. employed carbon nano-tubes and titanium dioxide

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films as the assisted matrix for analysis when high concentration of citrate buffer was added [14,15]. The presence of citric acid improved mass spectral sensitivity because it provides an extra proton source for the protonation of analytes in the desorption/ionization process. Significantly, Wei et al. developed a matrix-free method by using porous silicon as a platform for laser desorption/ionization [8]. The silicon substrate with nano-meter-sized pores offered a prominent sensitivity among the reported inorganic materials and demonstrated the potential application to tandem mass spectrometry for small molecule characterization and protein identification [19]. Later, the porous substrate was extended to the deposited nano-structured silicon film [12] and nano-cavity arrayed silicon wafer [16]. According to these reports about silicon substrates, nano-porous silicon surfaces were considered to act as an energy receptacle for laser radiation, and to provide a framework to trap the analyte molecules, implying the nano-porous surface structure could be an essential factor for a good inorganic matrix in LDI-TOFMS analysis.

Recently, various multi-component mesoporous materials with ordered, large nano-pore and stable mesostructure have been successfully synthesized according to a new concept "acid–base pairs" [20]. These non-siliceous mesoporous materials including metal phosphates, metal oxides and mixed metal oxides, exhibit high thermal stability, tunable compositions, various morphologies and abundant properties, which are useful for the potential applications to the catalysis, optic and electronic devices and so on. Notably, the novel multi-component mesoporous tungsten titanate (WTiO) with

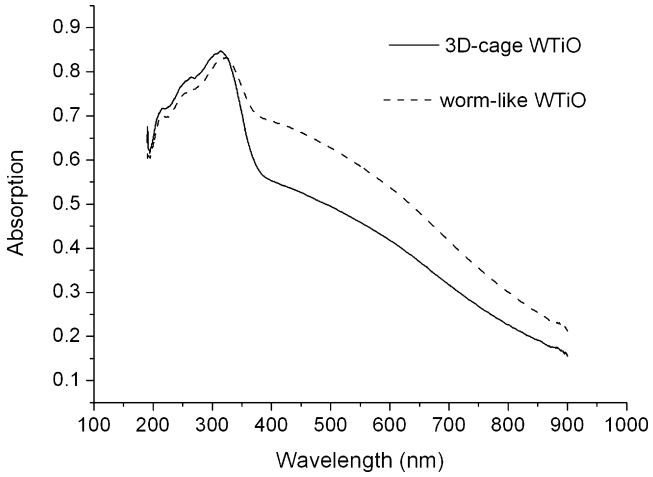

Fig. 1. UV absorption spectra of mesoporous WTiO materials.

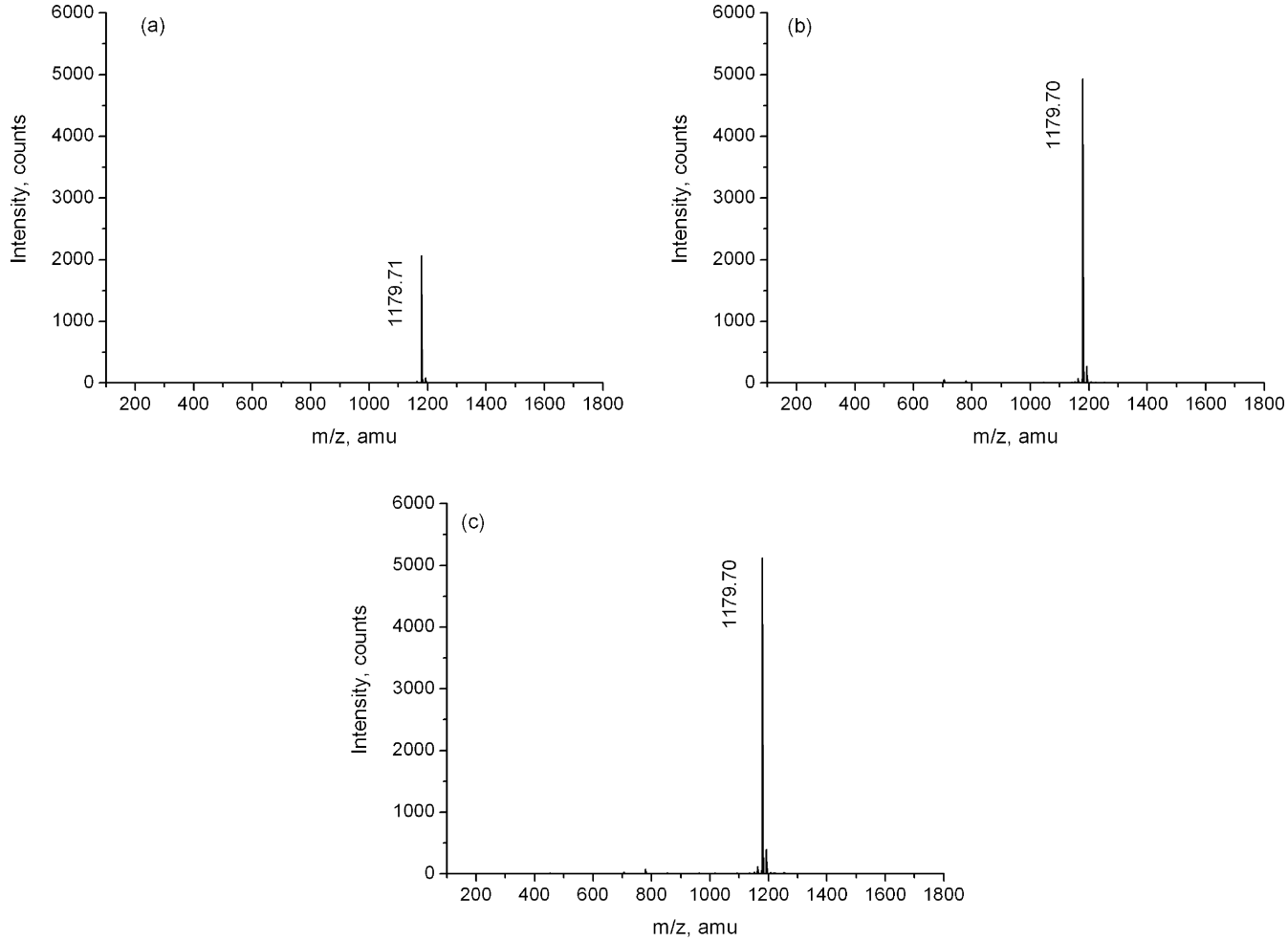

Fig. 2. MALDI mass spectra of gramicidin S (M_W 1140, 20 pmol μL^{-1}) with (a) worm-like, (b) ordered 2D-hexagonal and (c) ordered 3D-caged mesoporous WTiO materials as matrix; the peaks of *m/z* 1179 correspond to the potassiated analytes.