World Academy of Science, Engineering and Technology
International Journal of Biotechnology and Bioengineering
Vol:11, No:08, 2017

Flexible Ethylene-Propylene Copolymer Nanofibers Decorated with Ag Nanoparticles as Effective 3D Surface-Enhanced Raman Scattering Substrates

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Abstract : With the rapid development of chemical industry, the consumption of volatile organic compounds (VOCs) has increased extensively. In the process of VOCs production and application, plenty of them have been transferred to environment. As a result, it has led to pollution problems not only in soil and ground water but also to human beings. Thus, it is important to develop a sensitive and cost-effective analytical method for trace VOCs detection in environment. Surface-enhanced Raman Spectroscopy (SERS), as one of the most sensitive optical analytical technique with rapid response, pinpoint accuracy and noninvasive detection, has been widely used for ultratrace analysis. Based on the plasmon resonance on the nanoscale metallic surface, SERS technology can even detect single molecule due to abundant nanogaps (i.e. 'hot spots') on the nanosubstrate. In this work, a self-supported flexible silver nitrate (AgNO3)/ethylene-propylene copolymer (EPM) hybrid nanofibers was fabricated by electrospinning. After an in-situ chemical reduction using ice-cold sodium borohydride as reduction agent, numerous silver nanoparticles were formed on the nanofiber surface. By adjusting the reduction time and AgNO3 content, the morphology and dimension of silver nanoparticles could be controlled. According to the principles of solid-phase extraction, the hydrophobic substance is more likely to partition into the hydrophobic EPM membrane in an aqueous environment while water and other polar components are excluded from the analytes. By the enrichment of EPM fibers, the number of hydrophobic molecules located on the 'hot spots' generated from criss-crossed nanofibers is greatly increased, which further enhances SERS signal intensity. The as-prepared Ag/EPM hybrid nanofibers were first employed to detect common SERS probe molecule (p-aminothiophenol) with the detection limit down to 10-12 M, which demonstrated an excellent SERS performance. To further study the application of the fabricated substrate for monitoring hydrophobic substance in water, several typical VOCs, such as benzene, toluene and p-xylene, were selected as model compounds. The results showed that the characteristic peaks of these target analytes in the mixed aqueous solution could be distinguished even at a concentration of 10-6 M after multi-peaks gaussian fitting process, including C-H bending (850 cm-1), C-C ring stretching (1581 cm-1, 1600 cm-1) of benzene, C-H bending (844 cm-1 ,1151 cm-1), C-C ring stretching (1001 cm-1), CH3 bending vibration (1377 cm-1) of toluene, C-H bending (829 cm-1), C-C stretching (1614 cm-1) of p-xylene. The SERS substrate has remarkable advantages which combine the enrichment capacity from EPM and the Raman enhancement of Ag nanoparticles. Meanwhile, the huge specific surface area resulted from electrospinning is benificial to increase the number of adsoption sites and promotes 'hot spots' formation. In summary, this work provides powerful potential in rapid, on-site and accurate detection of trace VOCs using a portable Raman.

Keywords : electrospinning, ethylene-propylene copolymer, silver nanoparticles, SERS, VOCs
Conference Title : ICNB 2017 : International Conference on Nanotechnology and Biosensors
Conference Location : Venice, Italy
Conference Dates : August 14-15, 2017