Investigation on different cutting approaches of boron-doped diamond electrodes for heavy metal sensing

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This article shows the effect of hand-cleaved (HC), Nd:YAG laser, and femtosecond (FS) laser cutting of boron-doped diamond (BDD) electrodes on the sensing performance of heavy metal. Scanning electron microscopy (SEM) confirms diamond structures and Raman spectroscopy confirms changes in sp^2 and sp^3 contents in BDD microfiber electrodes (BDDMEs) under various cutting conditions.

1. Introduction

In recent decades, boron-doped diamond (BDD) electrodes are getting more interest due to their unique properties of the largest electrochemical potential window, small and stable background current, low capacitance, resistance to biofouling, and biocompatibility [1]. BDD has been used in different applications including energy storage, electrocatalysis, biosensors, water treatment, and so on [2]. In this article, we study the electrochemical sensing performance of BDDMEs prepared using HC as well as Nd:YAG and FS laser cutting, and explore their potential application for heavy metal ion detection in acetate buffer solution (pH 4.8) including cadmium (Cd), lead (Pd), and mercury (Hg).

2. Results

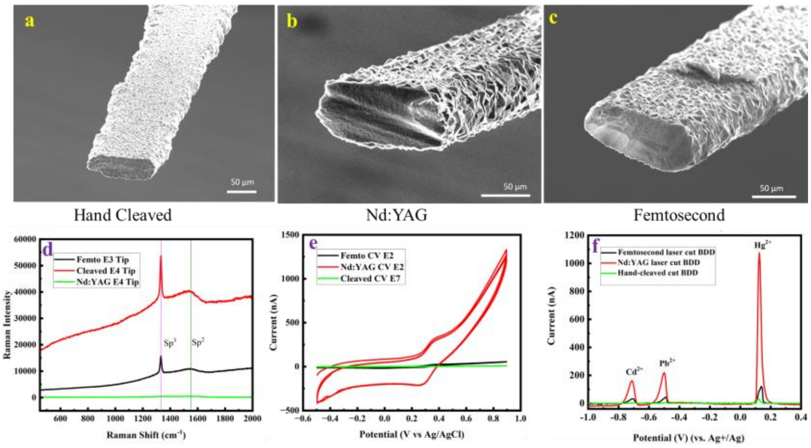

Figure 1: SEM images of HC (a), Nd:YAG laser cut (b), and FS laser (c) cut BDDMEs, and their Raman spectra (d), CV curves measured in 1 mM FeCOOH in phosphate-buffered saline (pH 7.4), with six segments -0.2 V to 0.8 V at 100 mV/s (e), and DPV curves for detecting 1.2 mg/L concentration of various metal ions, in acetate buffer (pH 4.8) with a plating deposition of -0.7 V for 120 s; voltage ramped to 0.8 V with 60 Hz frequency, 50 mV amplitude, and 5 mV increment voltage (f).

Figure 1 (a)-(c) shows the scanning electron microscope (SEM) images of HC, Nd:YAG laser (λ=1064 nm, f=5 KHz, P=12 W) and FS laser (λ=800 nm, f=1 KHz, P=5 W) cut BDDMEs. HC and FS laser (Fig. 1a and 1c) were able to get smooth and clean cuts with minimal particles, allowing the BDD core to be well resolved, whereas the Nd:YAG laser resulted in a rough surface, indicating a high graphitic content with dark spots. The Raman spectra (Fig. 1d) confirm high sp^3 contents at the tips of HC and FS laser cut BDDMEs, while both the sp^3 and sp^2 peaks in the Nd:YAG laser cut sample disappeared at the tip. Additionally, the Nd:YAG laser cut sample shows relatively higher capacitive background current in cyclic voltammetry (CV) (Fig. 1e), indicating that some surface modification may have incurred during laser cutting, as observed by SEM to enhance the solution charge transfer, or change the surface area. Metal sensing was done by differential pulse voltammetry (DPV) and three distinguishable peaks of Cd^{2+}, Pb^{2+}, and Hg^{2+} were observed (Fig. 1g). The Nd:YAG laser cut sample shows a higher peak current and improved sensitivity due to its surface changes and potential increase in electroactive area.

3. References

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