Patterned arrays of vertically aligned carbon nanotube microelectrodes on carbon films prepared by thermal chemical vapor deposition

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Abstract

A straightforward procedure is described for preparation of arrays of microdisk electrodes comprising bundles of vertically aligned carbon nanotubes (VACNTs). The arrays are fabricated by thermal chemical vapor deposition synthesis directly on a planar carbon film support. Use of standard micro- and nanolithography procedures for patterning the bilayer catalyst spots enables arrays to be grown with controlled electrode diameters and spacings. The minimum accessible VACNT

bundle diameter, and hence microelectrode diameter, is 2 μm. After insulating the arrays with SU-8 epoxy and exposing the VACNT ends by polishing or treating with O_2 plasma, the microdisk electrodes exhibit attractive electrochemical properties.

Table 1. Layout of Catalyst Microdisk Patterns and Patterning Method

disk diameter (μm)	patterning method	number of disks	minimum spacing between disks (μm)
100	shadow mask	16	900
10	EBL	77	155
2	EBL	400	50

Table 2. Voltammetric data (scan rate = 100 mV s^{-1}) for 1 mM FcOH in 0.1 M KCl

array	treatment	i_{lim} (nA)	i_{cal} (nA)[a]	$E_{3/4}$- $E_{1/4}$ (mV)
16 x 100 μm	polished	190[b]	216	61
77 x 10 μm	polished	141	104	63
77 x 10 μm	O_2 plasma	178	104	67
400 x 2 μm	polished	157	108	72
400 x 2 μm	O_2 plasma	152	108	70

[a] Calculated from eqn (1) assuming $D = 7.0 \times 10^{-6}$ cm^2 s^{-1}
[b] voltammogram recorded with scan rate = 5 mV s^{-1}

Figure captions

Figure 1. SEM images of patterned VACNT pillars grown using thermal CVD: (a) array of 16 x 100 μm pillars; (b) single 100 μm pillar; (c) array of 77 x 10 μm pillars; (d) single 10 μm pillar; (e) array of 400 x 2 μm pillars; (f) single 2 μm pillar

Figure 2. SEM images of VACNT microdisk electrode arrays, insulated with SU-8 epoxy. (a) 77 x 10 μm array and (b) single 10 μm electrode, after polishing; (c) 77 x

10 μm array and (d) single 10 μm electrode, after treatment with O_2 plasma; (e) 400 x 2 μm array and (f) single 2 μm electrode after polishing; (g) 400 x 2 μm array and (h) single 2 μm electrode, after treatment with O_2 plasma.

Figure 3. Steady-state voltammograms of 1 mM FcOH in 0.1 M KCl obtained at a) polished 16 x 100 μm array; b) polished 77 x 10 μm array; c) O_2 plasma-treated 77 x 10 μm array; d) polished 400 x 2 μm array and e) O_2 plasma-treated 400 x 2 μm array. a) scan rate = 5 mV s^{-1}; b) - e) scan rate = 100 mV s^{-1}. All scale bars represent 20 nA.

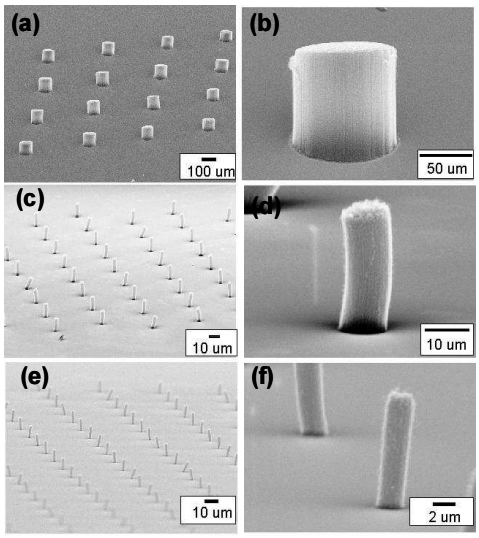

Figure 1.

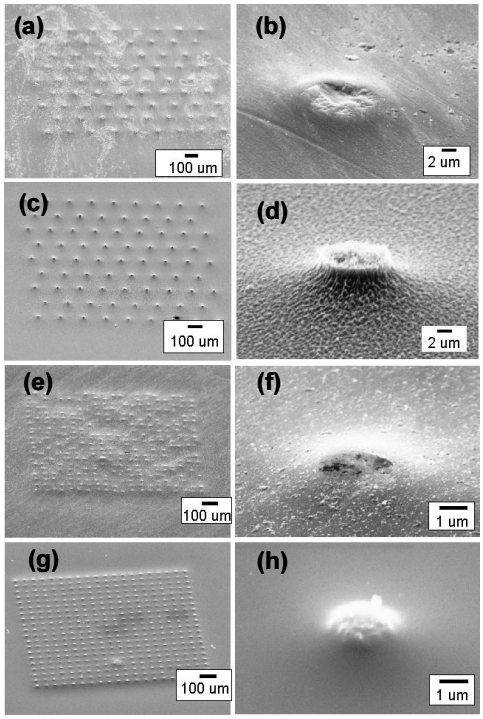

Figure 2

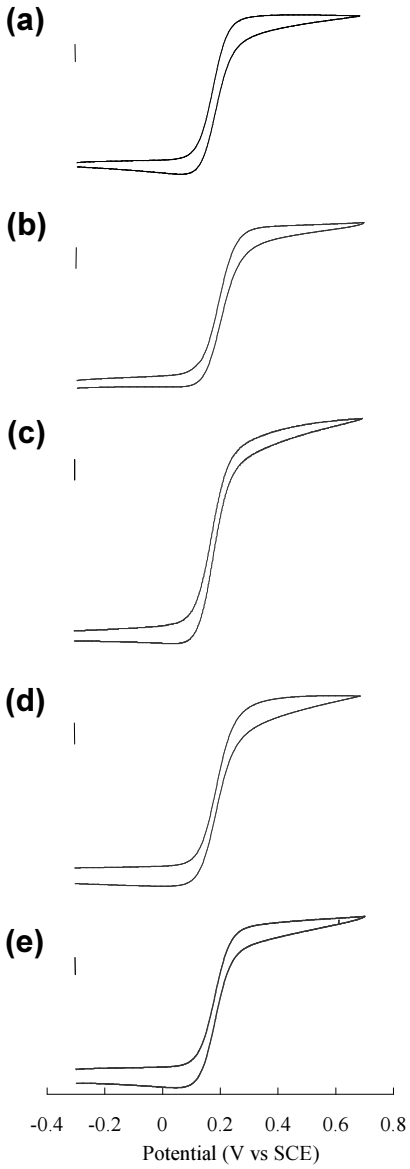

Figure 3