Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.

Supplementary information

Metal based bracken-like single sided dye sensitized solar cells with horizontal separation

Fatemeh Behrouznejad[a], Nima Taghavinia[a,b], Meysam Pazoki[c], Fariba Tajabadi[d]*

[a] Institute for Nanoscience and Nanotechnology, Sharif University of Technology, Tehran 14588, Iran.

[b] Department of Physics, Sharif University of Technology, Tehran 14588, Iran Fax: +98-21-66022711; Tel: +98-21-6616 4532.

[c] Department of Chemistry-Ångström Laboratory, Uppsala University, Box 523, SE-751 20 .Uppsala, Sweden.

[d] Nanotechnology and Advanced Materials Department, Materials and Energy Research .Center, Karaj 31787-316, Iran.

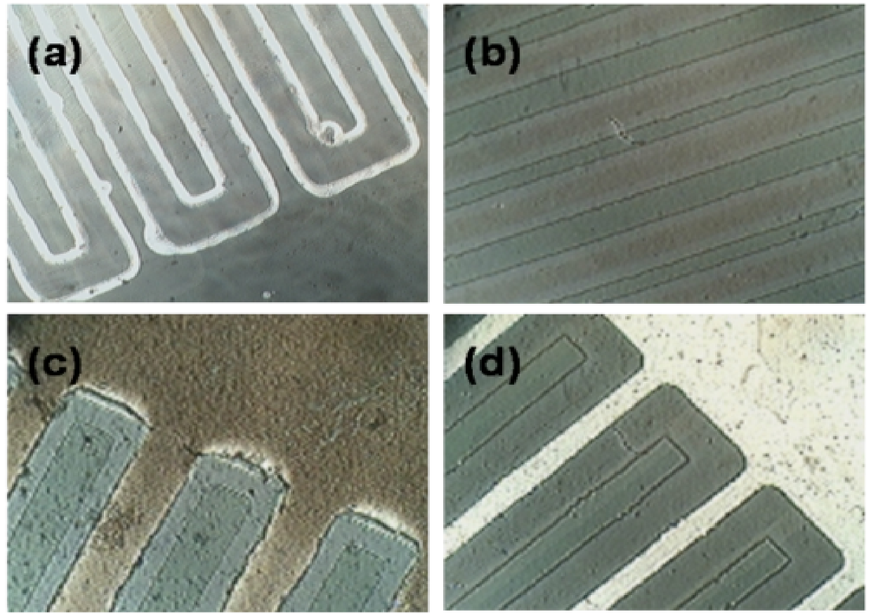

Fig. S1 Problems that can be produced by FTO wet etching, (a): brighter lines are Sn lines that are produced due to HCl penetrating under edges of photo-resist pattern, (b): Patterned FTO with over-etching is shown. Brighter lines have less thickness. Sometimes, the problem of over-etching can be removed by depositing second conducting layer such as Pt (c) and Ni (d).

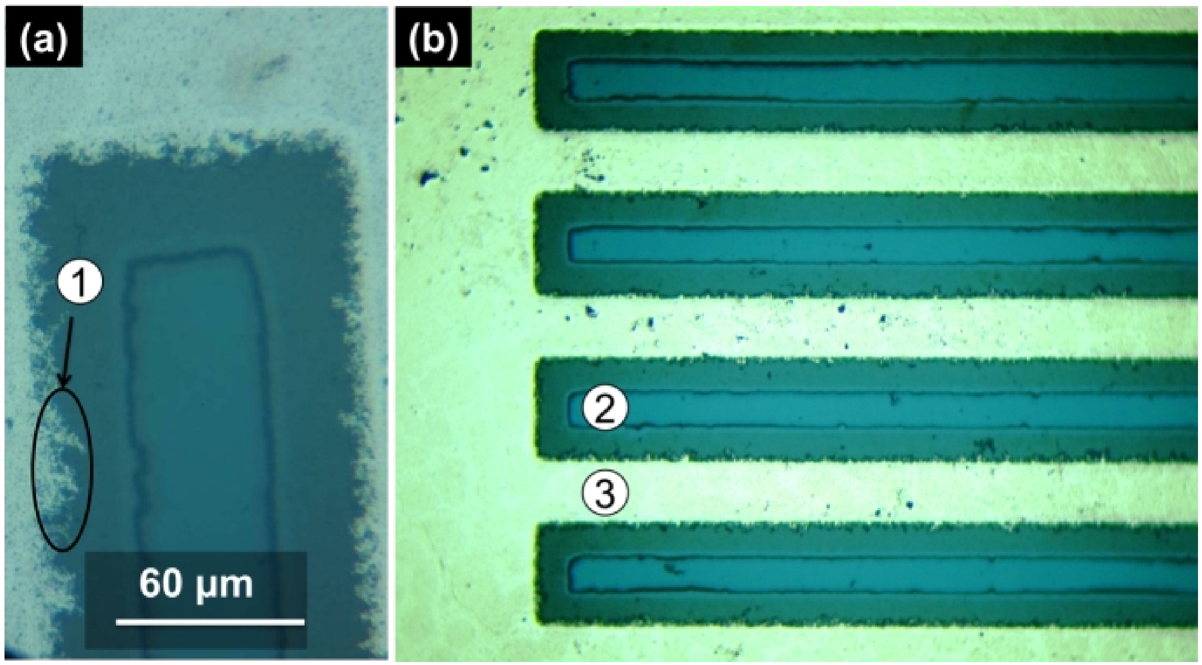

Fig. S2 Ni electrodeposition (3) on the patterned FTO (2). The fast growth of metallic layers (1) may cause a short circuit between lines of photoanode and counter electrode.

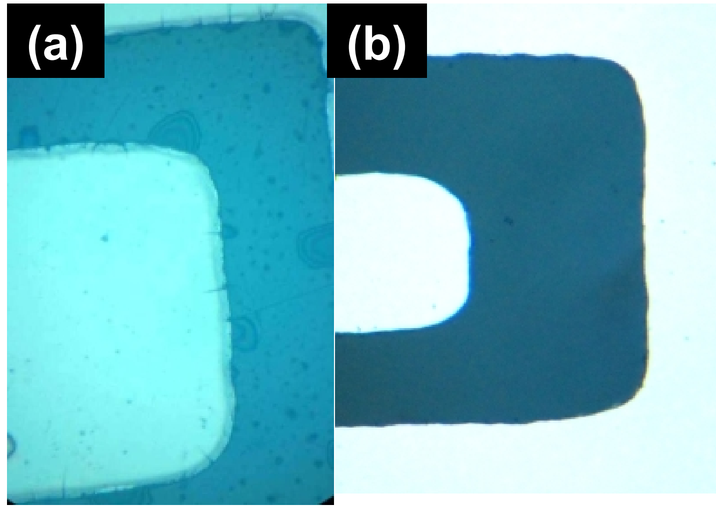

Fig.S3 Preparing bracken-like patterns on Cr thin film in comparison with Ni thin film. In case of Cr (a), the pattern is sharp, while for Ni (b) many cracks are observed near the edges. This can be attributed to the good adhesion of Cr to the glass substrate. Ni adhesion is not as perfect as Cr.

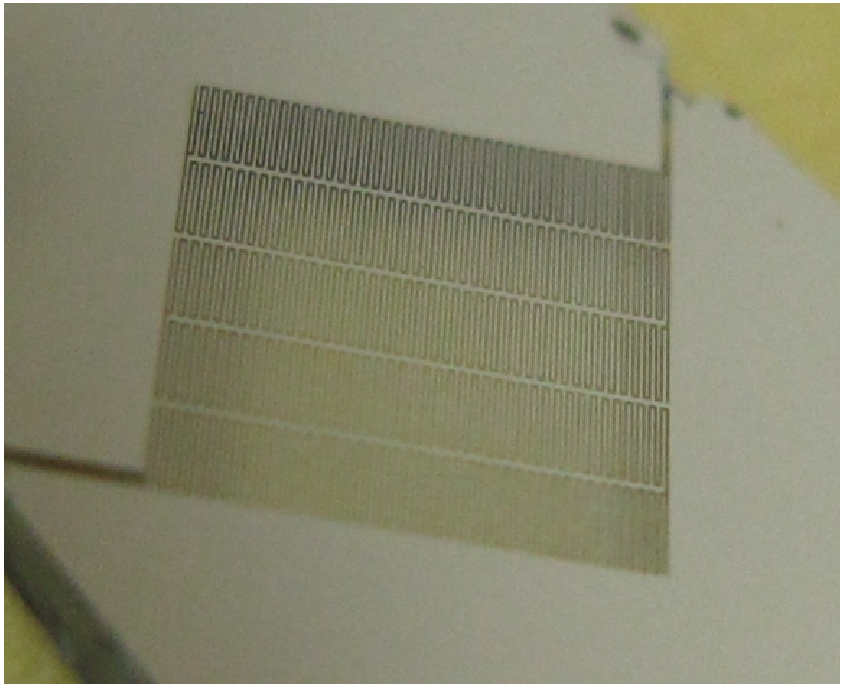

Fig. S4 Patterned Cr thin film on the glass. The pattern is produced using photolithography**.**

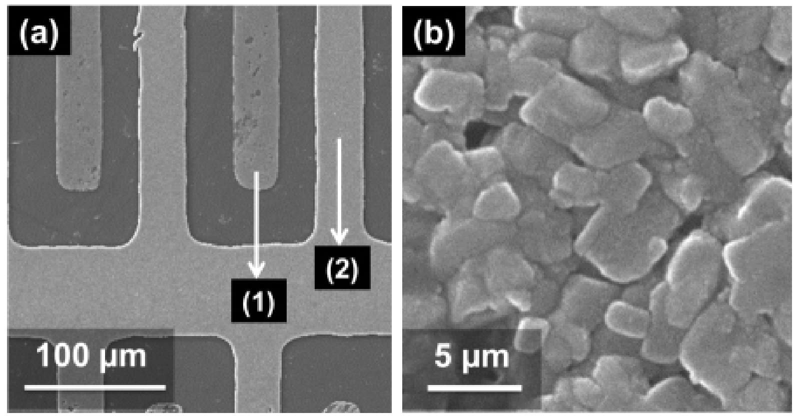

Fig.S5 The patterned Cr thin film on the glass which is thickened using electrodeposition of Cr on the pattern (a). (1) and (2) are Substrates of photo-anode and counter-electrode. The thickness is increased from about 200nm to about 1µm after Cr electrodeposition.

The morphology is shown in figure (b).

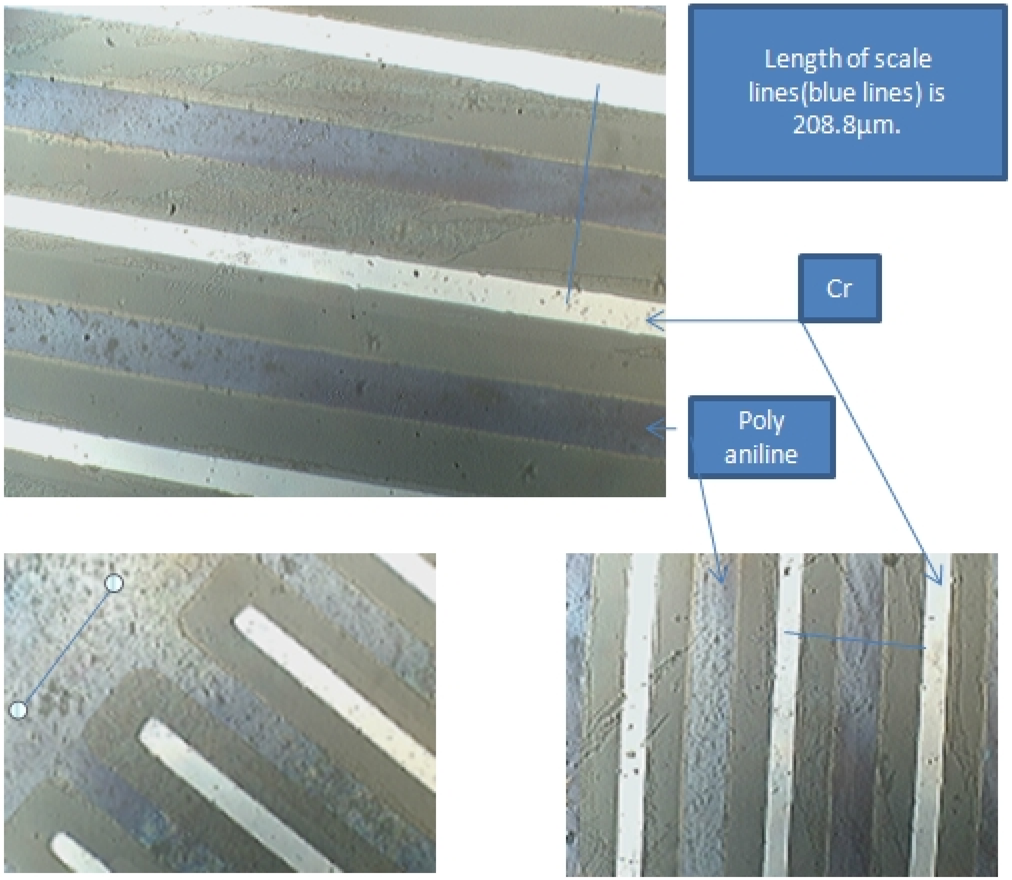

Fig.S6 Electrodeposition of poly-aniline on patterned Cr layer. As shown, poly-aniline covers Cr lines continuously.

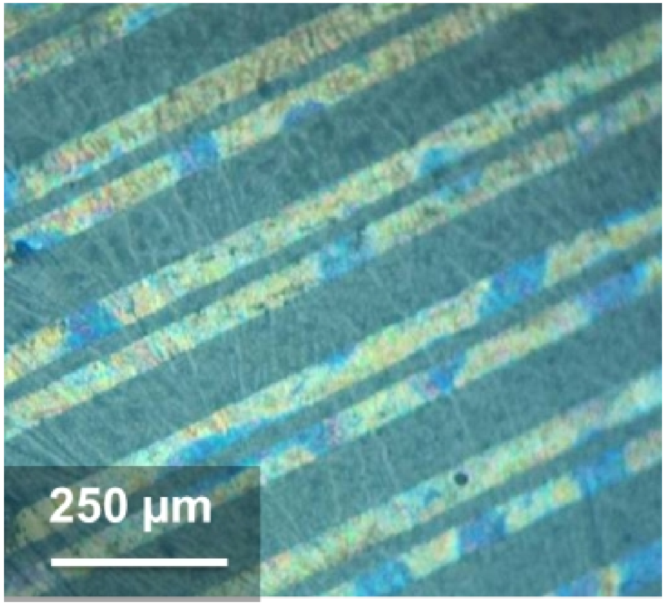

Fig.S7 Patterned Cr thin film on the glass after heating at 500 °C for 30 min. The color is related to chromium oxide layer production on the surface of Cr layer.

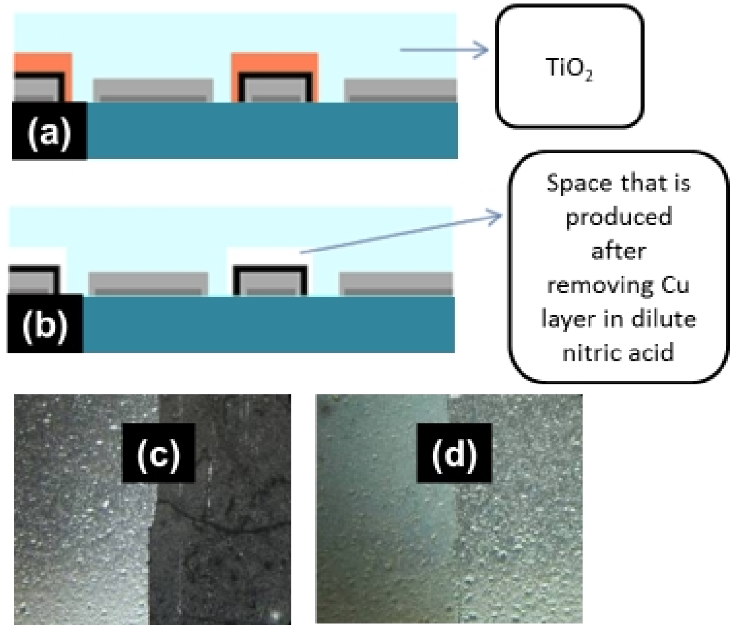

Fig.S8 Schematic of bracken like monolithic device with Cu layer as a spacer layer (a), removing Cu layer to produce a free space between them (b), and their corresponding optical microscopy image (c&d). The black layer in Fig(c) is the copper oxide and as shown in Fig (d) it is removed completely after immersing in dilute nitric acid.

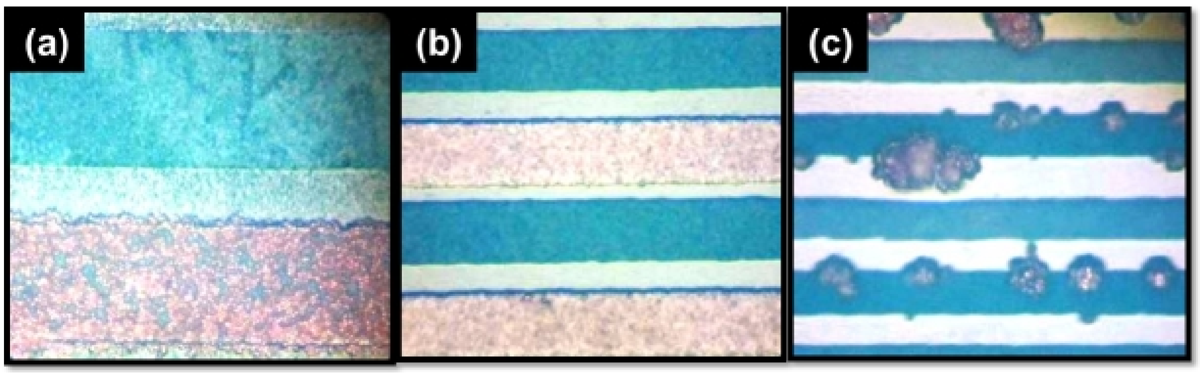

Fig.S9 Cu layer that is deposited on the patterned Cr layer. There is some non-uniformity due to the fast growth of Cu particles, which hinders successful use of Cu as a sacrificial spacer layer.

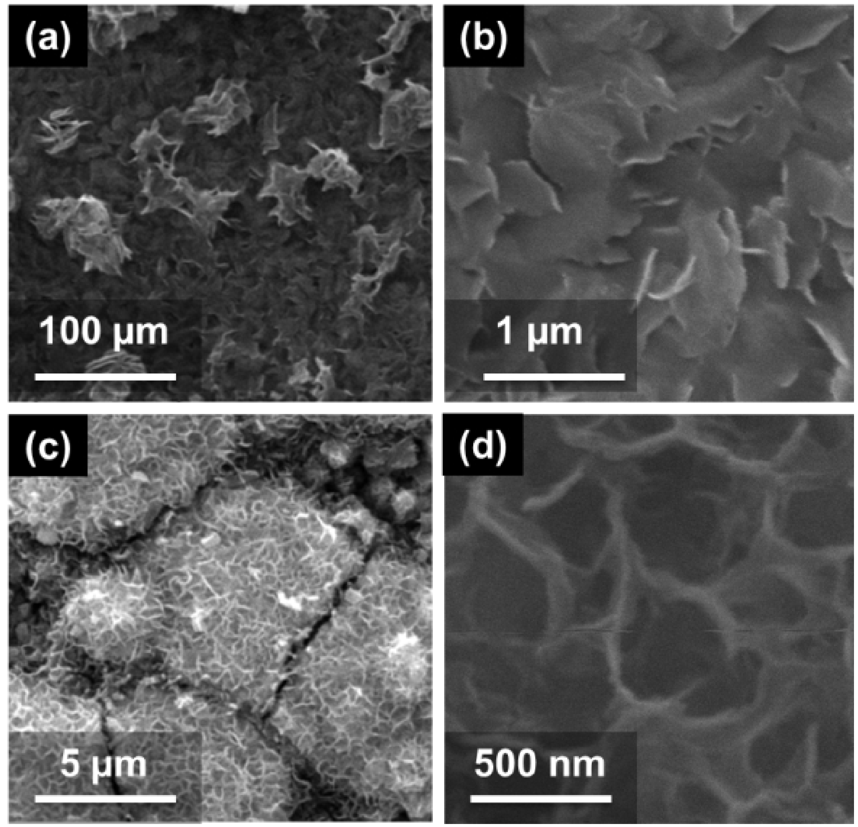

Fig. S10 SEM image of ZnO electrodeposited layer (a & b) on a nonpatterned Cr layer for 3600s (a & b in different scales) and patterned Cr layer for 1500s (c & d in different scales) by using constant voltage deposition. In the case of patterned Cr layer, Pt nanoparticles were already deposited under the zinc oxide layer.

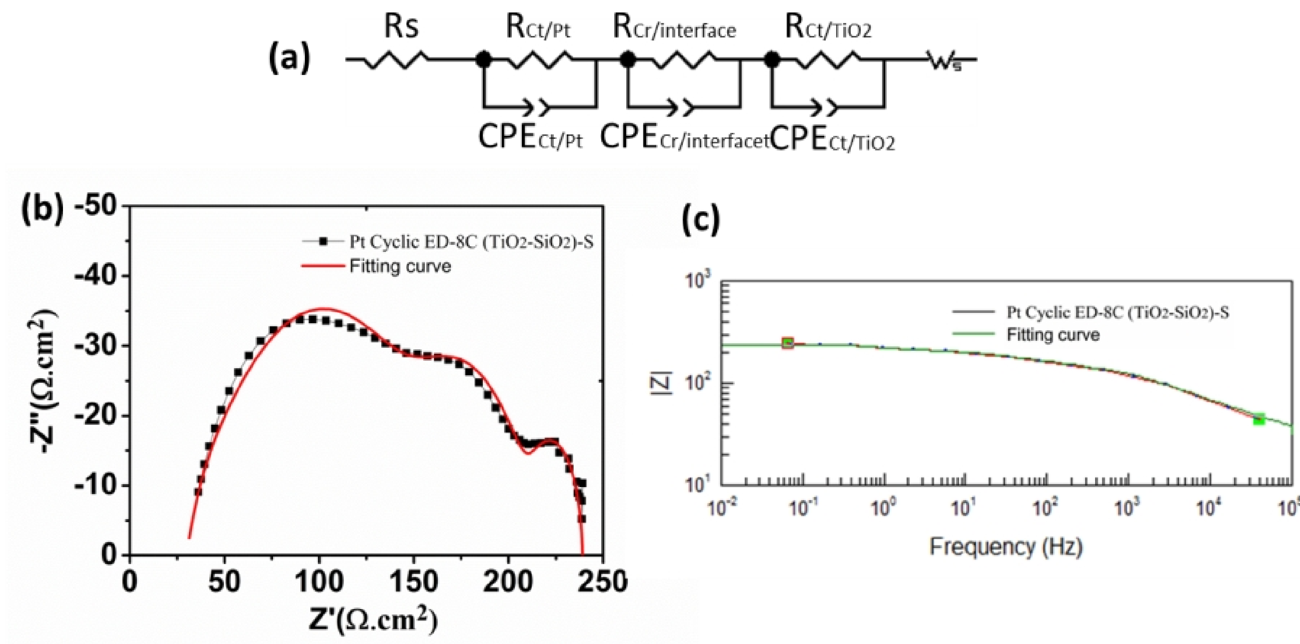

Fig. S11 a) Equivalent circuit for the Nyquist plot for bracken-like monolithic device with counter-electrodes prepared by electrodepositing Pt nanoparticles using cyclic electrodeposition. TiO_2/SiO_2 particulate layer is used as the spacer layer and TiO_2 compact layer is deposited by spin coating 1wt% TiO_2 sol spin coating. The external resistance related to conductivity of substrates is indicated by R_s, the charge transfer resistance and constant phase element (CPE) at the interface of Pt nanoparticles and electrolyte, are shown by a parallel configuration of $R_{ct/Pt}$ and $CPE_{Ct/Pt}$. The charge transfer resistance at the interface of TiO_2,dye and electrolyte and related constant phase element are shown by $R_{ct/TiO2}$ and $CPE_{Ct/TiO2}$. There is also an interfacial resistance parallel with a CPE between Cr substrate and TiO_2 orPt layer, therefore we can consider an equivalent resistance and CPE for them ($R_{cr/interface}$ and $CPE_{cr/interface}$). A finite-length Warburg element is also added to the equivalent circuit due to ion diffusion. Details of Fitting results are shown in table S1.

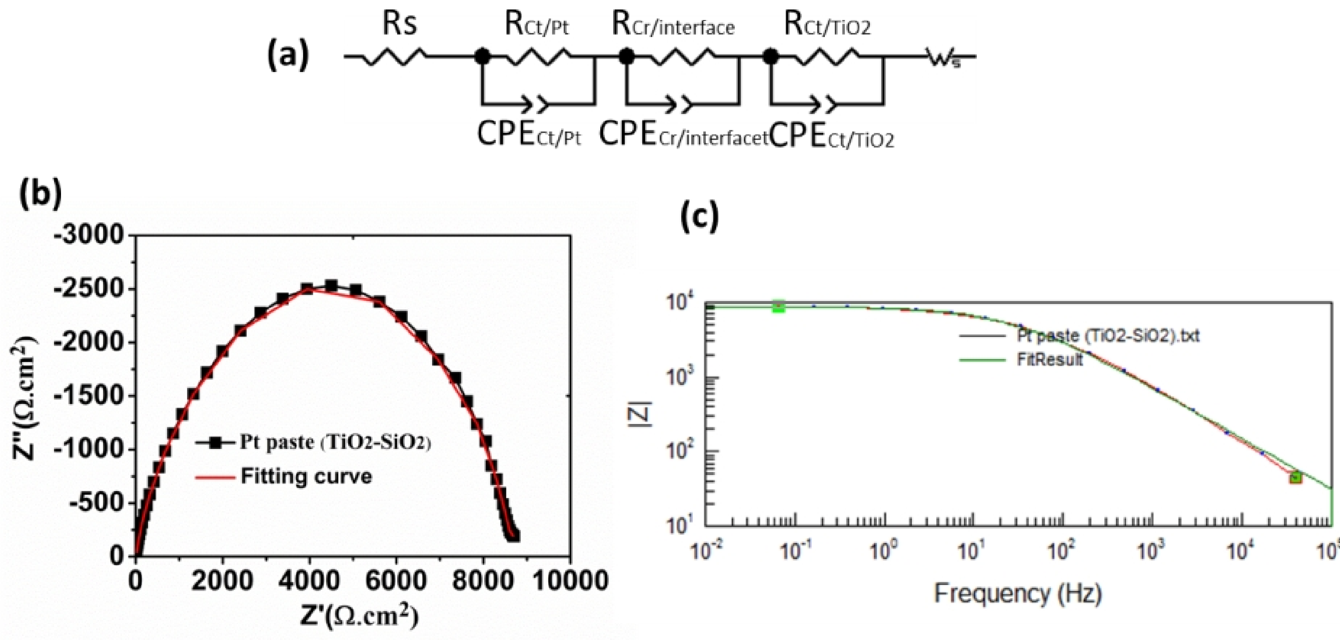

Fig. S12 a) Equivalent circuit for the Nyquist plot for bracken-like monolithic device with counter-electrodes prepared by doctor blading a Pt paste and heating in 400 °C. TiO_2/SiO_2 particulate layer is used as the spacer layer without any compact layer at the interface of Cr substrate and TiO_2 meso-porous layer. The external resistance related to conductivity of substrates is indicated by R_s, the charge transfer resistance and constant phase element (CPE) at the interface of Pt nanoparticles and electrolyte, are shown by a parallel configuration of $R_{ct/Pt}$ and $CPE_{Ct/Pt}$. The charge transfer resistance at the interface of TiO_2, dye and electrolyte and related constant phase element are shown by $R_{ct/TiO2}$ and $CPE_{Ct/TiO2}$. There is also an interfacial resistance parallel with a CPE between Cr substrate and TiO_2 or Pt layer, therefore we can consider an equivalent resistance and CPE for them ($R_{cr/interface}$ and $CPE_{cr/interface}$). A finite-length Warburg element is also added to the equivalent circuit due to ion diffusion. Details of Fitting results are shown in table S1. Details of Fitting results are shown in table S1.

Table S1 Resistances, constant phase elements and Warburg element values related to the fitting results of Nyquist plots that are reported in Fig. S11 and Fig. S12.

WD			**$CPE_{Ct/TiO2}$**		**$R_{Ct/TiO2}$ (Ω)**	**$CPE_{cr/TiO2}$**		**$R_{Cr/interface}$ (Ω)**	**$CPE_{ct/Pt}$**		**Rct/Pt (Ω)**	**Rs(Ω)**	**Sample name**
W1-P	W1-T	W1-R **(Ω)**	CPE-P	CPE-T (F)		CPE-P	CPE-T (F)		CPE-P	CPE-T (F)			
0.5	0.5	33	0.8	0.00022	52	0.66	1.75E-5	110	0.77	6E-6	14	30	Pt cyclic ED-8CV
0.5	0.5	33	0.8	0.00022	52	0.66	1.75E-5	3000	0.70	4E-6	5700	3	Pt paste