EIS Detection of MUC1 with Two Symmetric Aptamer/Au Electrodes

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Electrochemical impedance spectroscopy (EIS) has been proven as an effective method for ultrasensitive protein and cell detection. Typically, an EIS biosensor is constructed on the basis of a conventional three-electrode system, and an antibody is immobilized on the working electrode for specific affinity binding of the target protein or cell to generate detectable R_{ct} and C_{dl} changes. Although there have been a number of works demonstrating promising integration of EIS biosensors in microfluidic biochips, the tedious three-electrode fabrication and lack of an efficient method for selective deposition of antibodies on the working electrode have hindered EIS biosensors for realistic microscale and multiplex bioanalysis. In this work, we investigated a novel fabrication-favorable EIS approach for detection of mucin 1 (MUC1) using simply two symmetric aptamer-modified Au electrodes (ϕ = 2mm). (Note: MUC1 is an important surface glycoprotein over-expressed in several types of cancer cells.) For EIS detection of MUC1, anti-MUC1 aptamers with 5'-thiol linkers were coated to the two Au electrodes in the same way and ferricyanide was employed as a redox reporter. A symmetric duplex Randles circuit (Fig. 1(a)) and a self-defined error mathematical model (Fig. 1(b)) were developed for data fitting and determination of R_{ct}, CPE, and Z_W. Cyclic voltammogram (CV) and EIS responses of two symmetric bare Au electrodes in contact with $[Fe(CN)_6]^{3-}$ were analyzed to identify the operating sensing voltage (0.70V) that yielded the lowest background R_{ct} (Fig. 1(c)-(e)). With this condition, specific EIS detection of MUC1 (3-200 nM) was successfully performed (Fig. 1(f) and (g)) and a K_D value of 15.92nM for the aptamer-MUC1 binding could be evaluated from the R_{ct}-protein concentration fitting analysis. The above findings can be further extended to symmetric aptamer microelectrodes for both microfluidic applications and K_D measurements.

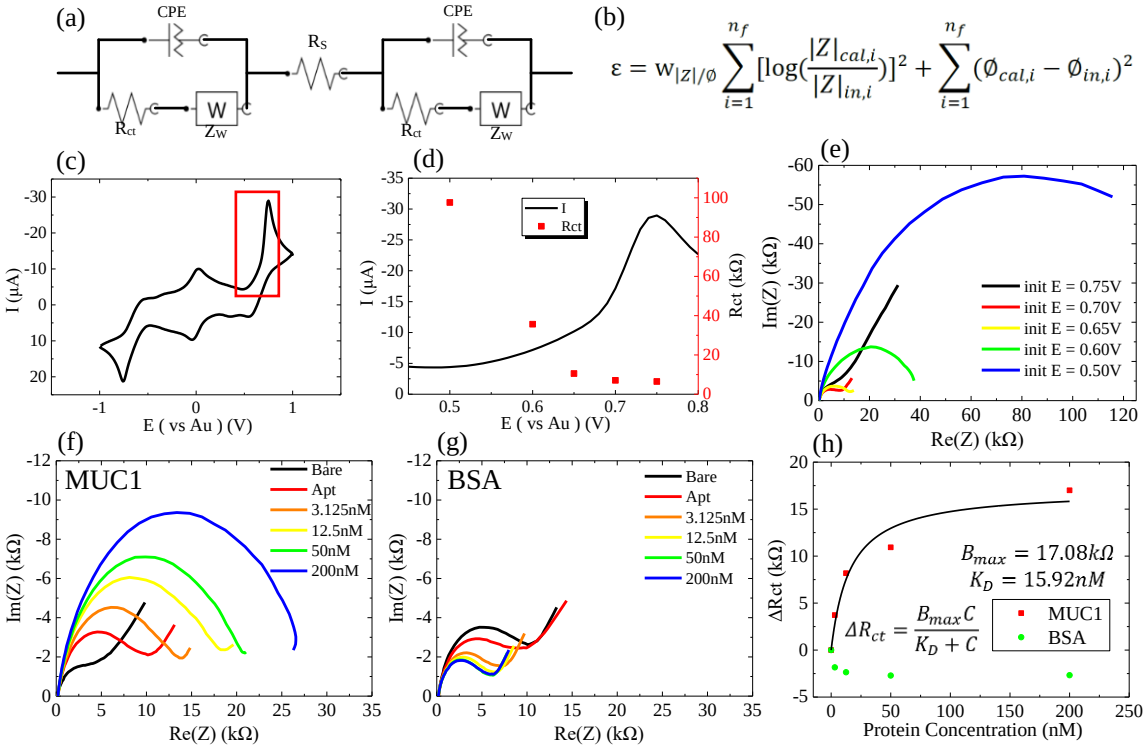

Figure 1. (a) The symmetric Au electrode equivalent circuit. (b) Self-defined error (ε) impedance-fitting model. (c) Cyclic voltammogram, (d) magnified area of (c) with R_{ct} data and (e) Nyquist plots obtained at different voltage biases for two bare Au electrodes in contact with $[Fe(CN)_6]^{3-}$. EIS detection of (f) MUC1 and (g) BSA using the symmetric aptamer/Au electrodes with $[Fe(CN)_6]^{3-}$. (h) Binding data analysis for MUC1 and BSA detection. Data in (c)~(h) were all obtained with the electrodes immersed in a sample solution of 10mM $[Fe(CN)_6]^{3-}$ in PBS buffer (0.1M KCl).