Zensor R&D

2.1 Screen printed carbon electrode

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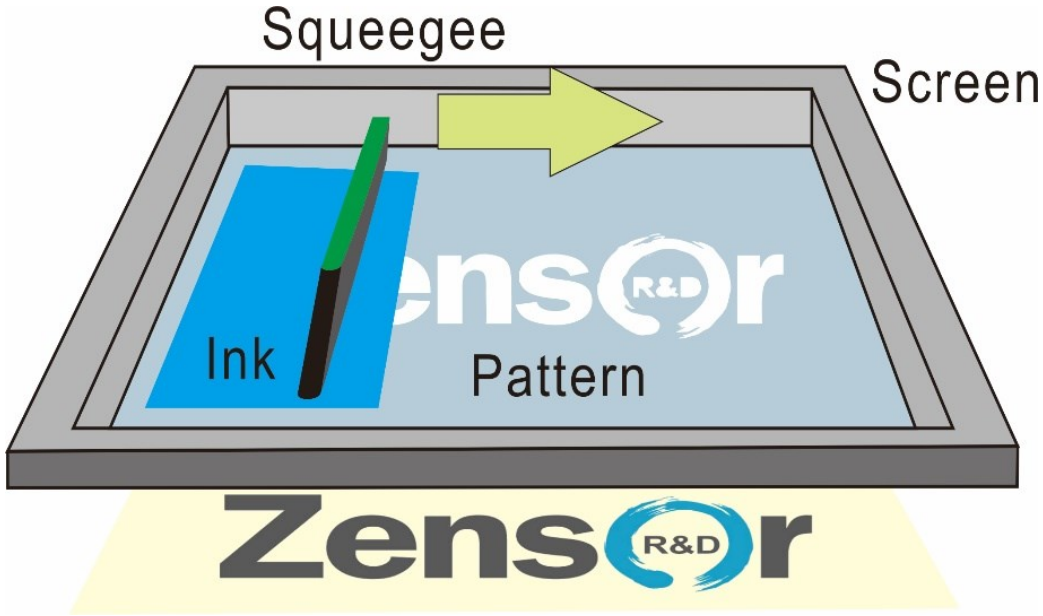
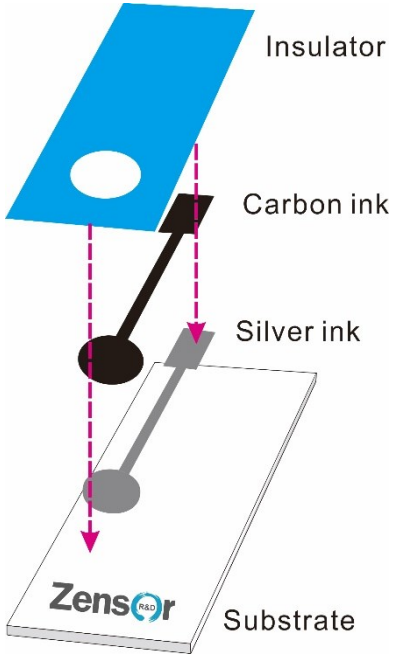
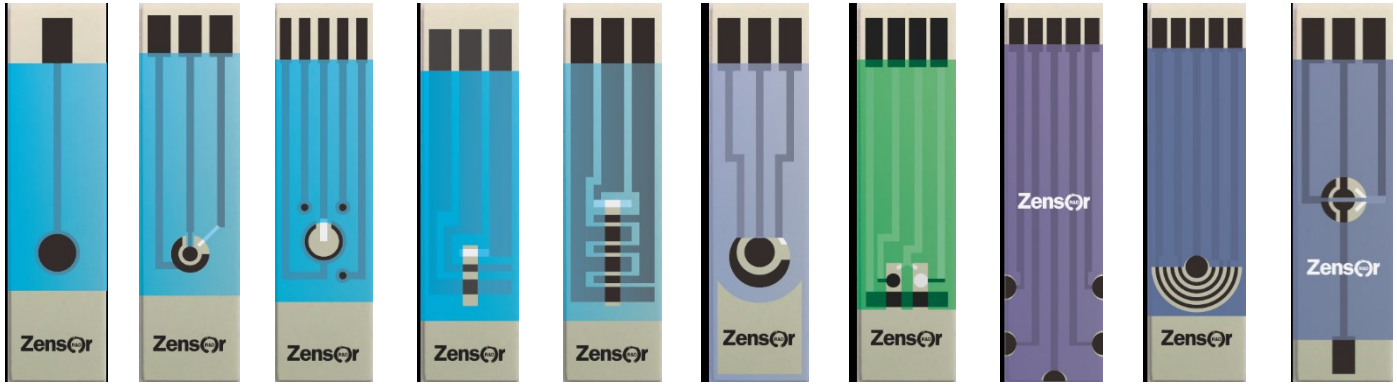
Screen printed electrode is one of greatest invention in the 20th century, which is the significant improvement of electrochemical three electrode from polished-based to polished-free and disposable. In general, the carbon ink can be printed on the surface of polypropylene with the linewidth around 100 µm to several millimeters and the thickness around 10 µm. And it has been the greatest platform to the development of point of care sensors such as glucose sensor for diabetes care which is the biggest health care market in the globe. Moreover, these kind of carbon electrodes have been widley employed in the field of biosensor, environment protection, food safety, immunoassay, medical issue and photoelectronics to fabricate numerous and novel sensors and devices.





2.1.1 The screen printed carbon electrodes in Zensor

The shape, pattern of electrode and material of working electrode can be designed as much as we can and as our wish. The images of real products of Zensor are illustrated below. With the screen printed carbon electrode, its properties are fast fabrication, diversity, good reproducibility and disposable for researchers and end user to improve their research or technique development more efficiently and economically.
The carbon ink, the most important role regarded by the manufacturer are composed of graphite particles, polymer binders and additives, and strongly affect the analytical performance of resulting carbon sensors [(1)].

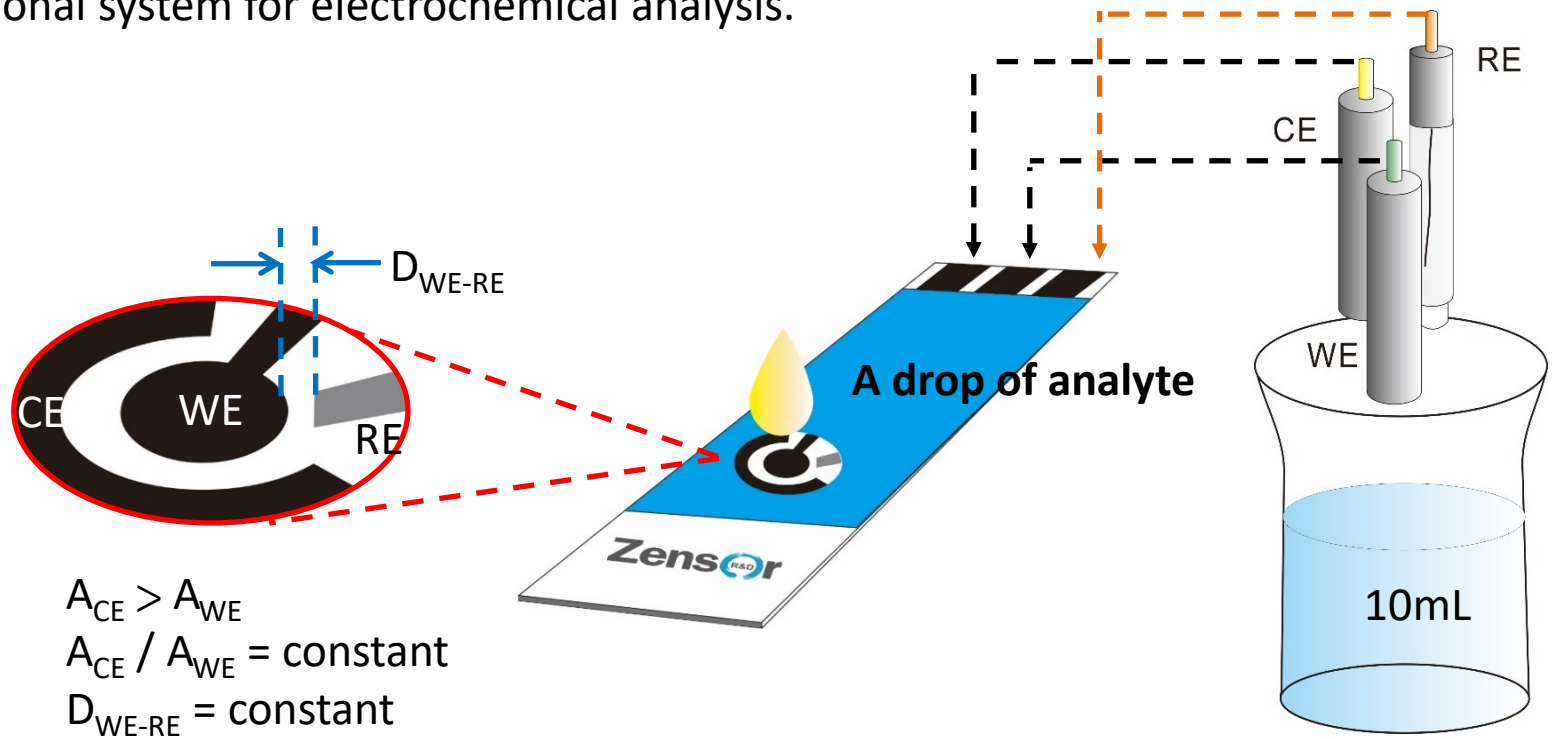


(1)Joseph Wang, Baomin Tian,a Valeberes. Nascimento and Lucio Angnes, Electrochimica Acta, Vol. 43, No. 23, pp. 3459-3465, 1998

2.1.2 The performance of screen printed carbon electrode

There are several factors to qualify the performance of screen printed carbon electrode (SPCE), which are electroactive surface area of working electrode, heterogeneous rate constant and peak to peak separation of redox system.

Typical screen three electrode system of Zensor is illustrated as the figure below, that consists of carbon working electrode, silver pseudo reference electrode and carbon counter electrode. With screen printed technique, it is easily to achieve precise surface area and accurate relative position of three electrode system. In addition, comparing with traditional three electrode system, the volume of analyte for SPCE is far less than the traditional system for electrochemical analysis.



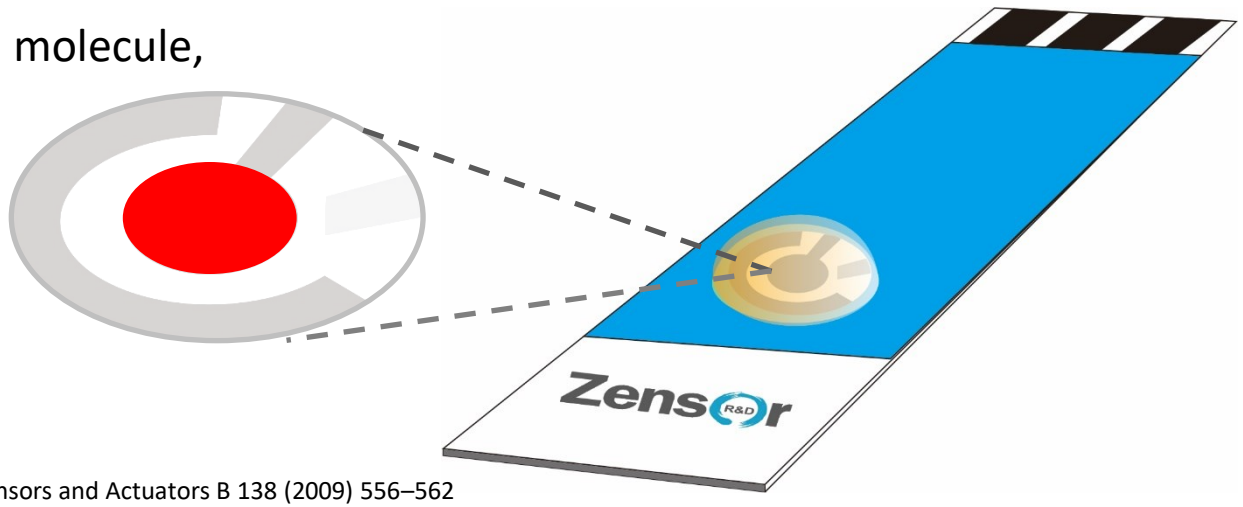
- $A_{CE} > A_{WE}$
- A_{CE} / A_{WE} = constant
- D_{WE-RE} = constant

2.2.3 Electroactive surface area of the working electrode

The active electrode area is determined using the Randles-Sevčik equation for quasi-reversible electron transfer process. The electroactive surface area of Zensor SPCE had been estimated by Professor Banks [(1)] and the value is around 0.035 cm^2. In general, it is said that the higher the electroactive surface area, the higher signal of redox analyte. Therefore, producing a high electroactive surface area of electrode is more favorable to the researchers.

$$I_p = (2.65 \times 10^5)\, n^{3/2}\, A\, C\, D^{1/2}\, \upsilon^{1/2}$$

n is the number of electrons participating in the redox process,
A is the working electrode area,
D is the diffusion coefficient,
C is the concentration of probe molecule,
υ is the scan rate.



Reference
(1) Rashid O. Kadara, Norman Jenkinson, Craig E. Banks, Sensors and Actuators B 138 (2009) 556–562
(2) P. Zanello, Inorganic electrochemistry, theory, practice and application, RSC (2003).

2.1.4 Heterogeneous rate constant (k^0)

Heterogeneous rate constant is determined using the Nicholson method and the equation is shown below. The standard rate constant for electron transfer is determined from the peak potential separation and frequency [1-4]. As the Professor Banks calculated, the K^0 for Zensor electrode is around 2.5 X 10^{-4} which is the higher K^0, resulting the faster the electron transfer rate. [4]

$$k^0 = \Psi \left[D_0 \pi \nu \left(\frac{nF}{RT} \right)^{\frac{1}{2}} \right] \left(\frac{D_R}{D^0} \right)^{\frac{\alpha}{2}}$$

where Ψ refers to a kinetic parameter,
D_O is the diffusion coefficient for the potassium ferricyanide (7.6×10^{-6} cm^2 s^{-1}),
D_R is the diffusion coefficient for potassium ferrocyanide (6.3×10^{-6} cm^2 s^{-1}),
α is the transfer coefficient (0.5),
R is the universal gas constant,
T is the absolute temperature (K),
n is the number of electrons transferred,
F is the Faraday constant.

Reference
(1)Morrin, A.J. Killard, M.R. Symth, Anal. Lett. 36 (2003) 2021.,
(2)Nicholson, R. S. Anal. Chem. 1965, 37(11), 1351.
(3)R.N. Adams, Electrochemistry at Solid Electrodes, Marcel-Dekker, New York, 1969.
(4) Rashid O. Kadara, Norman Jenkinson, Craig E. Banks, Sensors and Actuators B 138 (2009) 556–562

2.1.5 Peak to peak separation ($\triangle E_p$)

Theoretically, it can be used to determine the number of electron transferred, in which an electron transfer process exhibits the $\triangle E_p$ of about 59 mV. The $\triangle E_p$ of Zensor electrode is around 116 mV, that is a good reversible system. However, it is sometimes influenced by the binder, curing condition, and storage condition etc. to be larger than the value of 59 mV. The more close to value of 59 mV, the better the reversibility. And hence it can be used to measure the quality of screen printed electrode is good or bad. [1,2]

$$\triangle E_p = E_{pa} - E_{pc} = 59 / n \text{ (mV)}$$

E_{pa} is anodic potential
E_{pc} is cathodic potential
n is number of electron transferred

References
(1)Rashid O. Kadara, Norman Jenkinson, Craig E. Banks, Sensors and Actuators B 138 (2009) 556–562
(2)Joseph Wang, Analytical Electrochemistry 2nd ed., 2000

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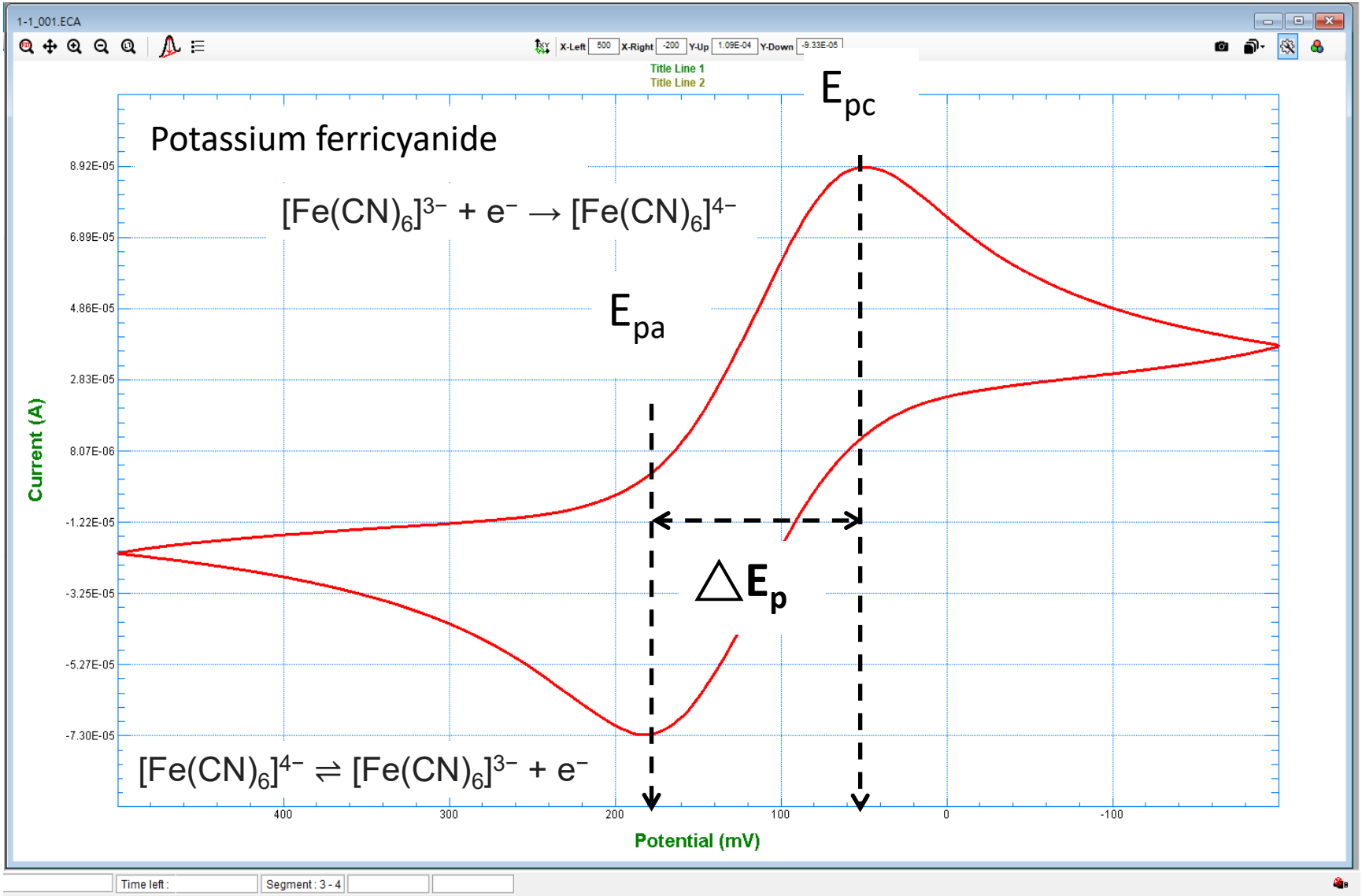
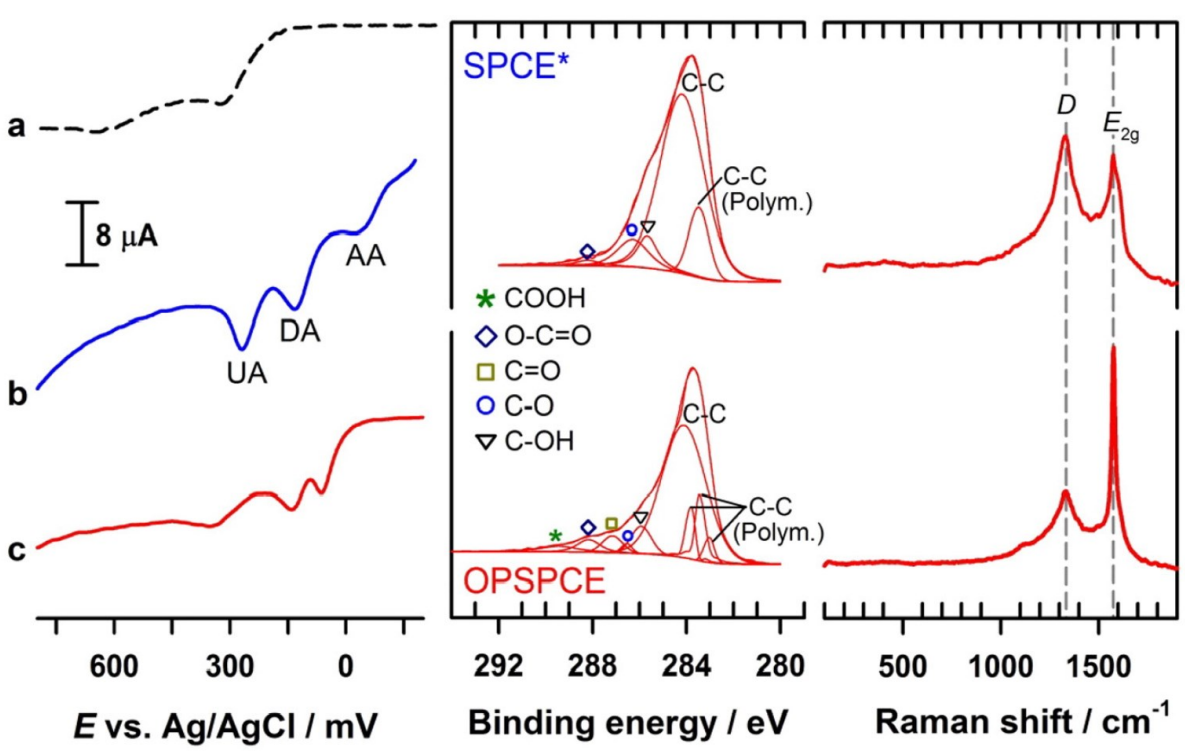


2.1.6 Functional group on the surface of electrode

The oxygen functionalities are common existed on the surface of carbon electrode after either electrochemically pre-anodized or oxygen plasma pretreated. It is true that the electrochemical response can be enhanced by these kinds of functional groups. There are, in addition to the surface with the most C-H groups, the carboxylic groups, the carbonyl groups, the hydroxyl groups and the aldehyde groups. [1-3]



References

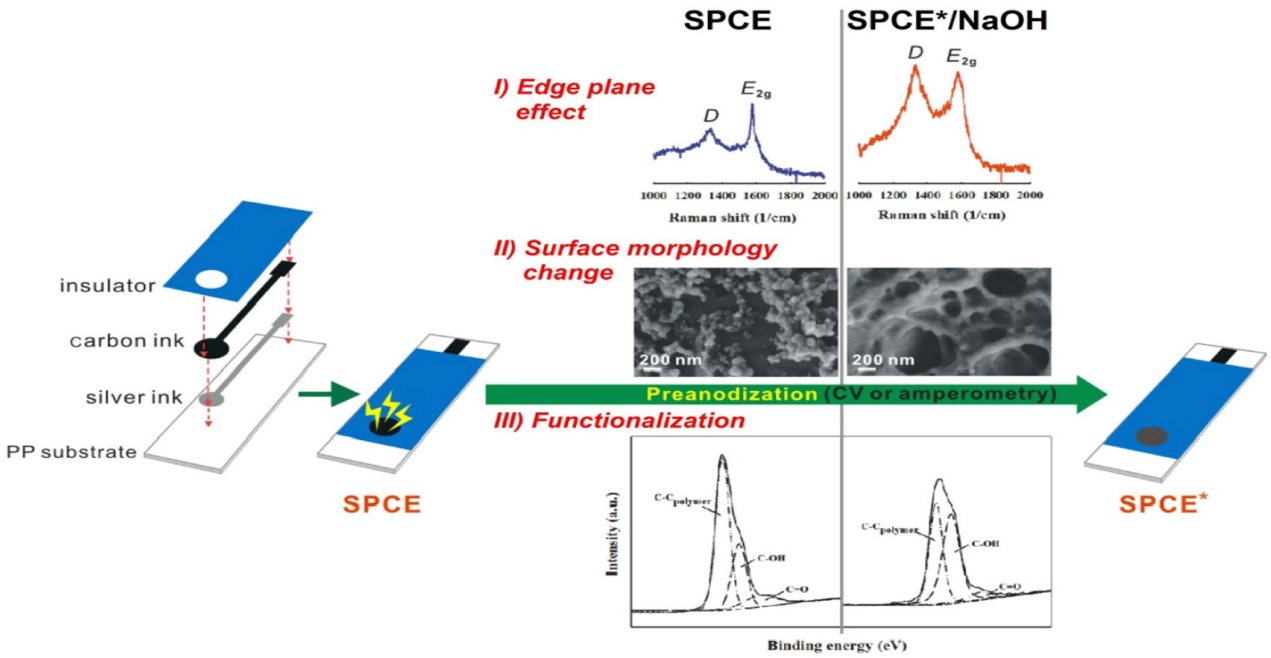
(1)Craig E. Banks, Trevor J. Davies, Gregory G. Wildgoose and Richard G. Compton, Chem. Commun., 2005, 829–841

(2)K. Sudhakara Prasad, Govindan Muthuraman, Jyh-Myng Zen, Electrochemistry Communications 10 (2008) 559–563

(3)Natarajan Thiyagarajan, Jen-Lin Chang, Krishnan Senthilkumar, Jyh-Myng Zen, Electrochemistry Communications 38 (2014) 86–90

2.1.7 Edge plane on the surface of electrode

As the Professor Compton said, the highly ordered pyrolytic graphite (HOPG) consists of two kinds of graphitic planes, which are the basal plane and the edge plane perpendicular to the basal plane. And its electrochemical properties are far apart in the description of redox reaction. Moreover, as the Professor Zen published, with the Raman experiment, a D band attributed to the edge plane was dramatically increased by pre-anodizing the screen printed carbon electrode which is the product of Zensor. And resulting in simultaneous detection of DA, UA and AA at neutral pH. [1-3]



References

(1)Craig E. Banks, Trevor J. Davies, Gregory G. Wildgoose and Richard G. Compton, Chem. Commun., 2005, 829–841

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