A Novel Modification Method of Stainless-steel Electrode for Sulfur Preparation by Reduction of Sulfur Dioxide
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ABSTRACT
A novel modification method of stainless-steel electrode for reduction of sulfur dioxide to prepare sulfur was reported. Sulfur dioxide can spontaneously react with modified stainless-steel electrode at a rate of 12.77 mA/cm² to produce sulfur under acidic conditions without additional energy. Evidence was found for the destruction of passive film on the stainless-steel surface in the process of modification which leads to the open circuit potential of stainless-steel electrode shift negatively to the reduction potential range of sulfur dioxide. When modified stainless steel was used as cathode in electrolysis, the contributions of impressed current and redox reaction made the sulfur yield up to 88% within 3 hours.

1. Introduction
Sulfur dioxide is known as one of the major air pollutants mainly produced in smelting and traffic tail gas. SO₂ can oxidize into sulfuric acid mist or sulfate aerosol, which is a major precursor of environmental acidification. SO₂ can be absorbed into the blood and has toxic effects on the whole body by destroying the activity of enzymes and respiratory system.¹

The electrochemical reduction method of SO₂ can convert SO₂ into sulfur or other low valence sulfur compounds. Researchers have done many works using different electrochemical reactors. The reactors with better mass transfer effects are conducive to the reaction. J. P. Fornés and J. M. Bisang used rotating cylinder intermittent electrochemical reactor and parallel plate reactor to study the reduction process of SO₂, respectively. They studied the effects of electrode materials, electrode rotation speed and sulfur attached to the electrode on SO₂ reduction process. They also established the theoretical mathematical model for the reactor.² ³

Various electrode materials have also been studied in the field of electrochemical reduction of SO₂, such as mercury, copper, carbon,⁴–⁶ and noble metal like gold and platinum,⁷–¹⁰ as well as various modified electrodes.¹¹,¹² The development of modified electrodes was mainly motivated by the determination of sulfites in food industry, where electrodes were modified mostly to improve selectivity and sensitivity to sulfite. Carbon paste electrode (CPE) modified with AuNP (CPE/Au-Si4Pıc5’Cl’−) (NP means nanoparticles) was established to explore SO₂ reduction.¹² Due to the larger active surface area of gold nanoparticles, the modified electrode shows low resistance and high selectivity, which makes it more sensitive to the detection of sulfur species in food. Glassy carbon electrode modified by RuOHCf (ruthenium-oxide hexacyano-ferrate) had been employed. R. H. O. Montes et al. found that the modified electrode has a catalytic effect on the reduction of sulfur dioxide and bisulfite compared with the unmodified glassy carbon electrode in the acid medium. They suggested that this may be due to the thin-layer diffusion effect in RuOHCf film.¹³ C. Quijada et al. studied the reaction characteristics of SO₂ on glassy carbon electrode cycling in the potential range of 0–2.2 V (vs. RHE) for several times, which had a catalytic effect on the electrochemical oxidation of SO₂.² In their further study on noble metal, the electrochemical oxidation of SO₂ was promoted when the moderate sulfur was deposited on the surface of the electrode.⁴ J. P. Fornés, et al. carried out a concise study in the impact of stainless steel electrode with the presence of colloidal sulfur on the electrochemical reduction of SO₂, and resulted in a negative consequence.¹⁵ They speculated that it was due to the poor conductivity of sulfur. Stainless steel material is of high practical value. However, the methods of stainless-steel electrode surface modification by sulfide were less reported.

This article reports on a novel modified 316L stainless steel electrode to conduct the reduction of SO₂ to prepare sulfur under the combination of two ways. The two sources of electrons for reducing SO₂ are external power supply and main metal elements in modified stainless-steel electrode, respectively. The mechanism of sulfur preparation by modified stainless steel electrode was discussed by polarization curve and AC impedance method in this paper.

2. Experimental
2.1 Chemicals
Deionized water (conductivity ca. 1.5 µS·cm⁻¹) was used to prepare solutions. All reagents were of analytical grade. Preparation of SO₂ acid stimulation solution: To a round-bottomed flask (1500 ml) containing a certain amount of NaHSO₃, 500 mL of deionized water was added with fully stirring, then diluted to 1000 ml, followed by adding concentrated sulfuric acid (98.3%) for pH regulation. Preparation of anode solution in ion-exchange membrane (IEM) electrolysis cell: To a round-bottomed flask (1500 ml) containing 30 g of Na₂SO₄, 500 mL of deionized water was added with fully stirring, then diluted to 1000 ml. If not specified, the experimental temperature was room temperature.

2.2 Surface preparation and modification
The cylindrical 316L stainless steel electrode (Φ = 6 mm) was ground with 1500-mesh and 2000-mesh sandpaper in sequence, then polished with 1.0 mm, 0.3 mm, 0.05 mm alumina slurry in sequence followed by rinsing with deionized water.
The simulated solution with SO\textsubscript{2} concentration of 8 g L\textsuperscript{-1} and supporting electrolyte of 0.5 mol/l H\textsubscript{2}SO\textsubscript{4} was prepared, which molecular oxygen was physically removed by purging with nitrogen previously. The prepared electrode above was used as working electrode for 20 seconds at a constant potential of −0.7 V (vs. SCE). The final electrode was coated with a layer of sulfur-containing adsorbate. During the experiment, the system was in inert atmosphere. After pretreatment, the modified stainless-steel electrode was removed and gently wiped with dust-free absorbent paper on the surface of the electrode. Then it was put into an inert atmosphere operating box for reserve.

2.3 Characterization

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, Perkin Elmer Optima 8000) was used to detect the kinds and contents of metal elements in electrolyte and solid products. Electron probe microanalysis (EPMA-1720 of Shimadzu, Japan) was used for qualitative and quantitative analysis of the elements on the electrode surface. X-ray diffraction (XRD, Ultima IV, Japan) was used to analyze the composition and crystal structure of the sulfur products. Scanning electron microscopy (SEM, FEI Quanta 600) was used to observe the surface morphology of sulfur products. The microregional component analysis was carried out with energy dispersive spectroscopy (EDAX Genesis 7000).

2.4 Apparatus

Three-electrode system is applied in the measurement of polarization curve and AC impedance spectroscopy, which were performed in a closed cell (100 ml). The electrochemical measurement techniques involved in this study were all based on the Gamry electrochemical workstation. The working, auxiliary, and reference electrodes were a cylindrical modified 316L stainless steel (Φ = 6 mm), a platinum wire (Φ = 1 mm), and a saturated calomel electrode (SCE), respectively. All the potential values of the electrodes were relative to the saturated calomel reference electrode, if not specified in this paper.

A laboratory-scale IEM electrolysis cell was employed to study the application of the modified electrode (see Fig. 1). The modified 316L stainless steel plate and lead plate were used as cathode and anode, respectively, all with an area of 110 cm\textsuperscript{2}, and the distance between them was 3 cm. Lead plate was polished with 1000 mesh sandpaper and then washed sufficiently with deionized water. The electrolysis cell halved into two parts of the same volume by a Nafion cationic membrane (N324) was 12 cm long, 9 cm wide and 18 cm high. The use of cationic membrane can separate the reduction products from the oxidation products, so that they do not affect each other and improve the current efficiency. The cathode and anode chambers were equipped with an external storage tank, each of which was equipped with a peristaltic pump for liquid circulation. The volume flow rate in the experiment is 800 ml/min. In order to prevent the loss of SO\textsubscript{2} and the influence of oxidation components on the cathode, the whole device was sealed.

After the experiment, the cathode solution was collected and placed in a constant temperature water bath (50°C) for 8 hours so that sulfur was fully settled. Then the solution was filtered, the product was dried in inert atmosphere for 3 h to obtain the prepared sulfur. The detection of sulfur purity was based on the method described in the literature\textsuperscript{14}.

The actual mass of sulfur from reduction of SO\textsubscript{2} in the experiment, Theoretical output based on 100% current efficiency of impressed current and Theoretical output based on total sulfur in solution was recorded as M\textsubscript{act}, M\textsubscript{eff}, M\textsubscript{theo}, respectively.

3. Results

The cyclic voltammetry was used to study the electrochemical behavior of SO\textsubscript{2} on modified stainless-steel electrode with supporting electrolyte of 0.5 mol/l H\textsubscript{2}SO\textsubscript{4}. The scanning speed was 50 mV/s. The two curves in Fig. 2 were in conditions with SO\textsubscript{2}-free and SO\textsubscript{2} concentration of 5 g L\textsuperscript{-1}, respectively. It can be seen from Fig. 2 that there were no other reduction peaks except hydrogen evolution reaction at −0.55 V, there was an obvious reduction peak A\textsubscript{1} at −0.71 V in the presence of SO\textsubscript{2} in contrast, which indicates that the reduction peak was caused by SO\textsubscript{2}. A yellowish insoluble substance can be observed around the modified stainless-steel electrode, so it can be inferred that the A\textsubscript{1} peak corresponds to the reduction of SO\textsubscript{2} to sulfur. Two oxidation peaks B\textsubscript{1} and C\textsubscript{1} appeared in the presence of SO\textsubscript{2} and a smaller oxidation peak B\textsubscript{2} appeared in the contrast curve without SO\textsubscript{2} when the potential was scanned from −1.0 V to 1.0 V. The B\textsubscript{2} peak was due to the anode passivation of modified stainless steel at the initiating passive potential of −0.17 V. The dissolution rate of the metal decreased rapidly due to the formation of a dense passivation film with semiconductor properties on the surface of the electrode. Corresponding to B\textsubscript{2}, B\textsubscript{1} peak should be the dissolution and passivation process of modified stainless steel. However, its peak current was higher than B\textsubscript{2}, and the initiating passive potential of B\textsubscript{1} was about 0.07 V, which was more difficult to passivate. It can be inferred that the reduction products of SO\textsubscript{2} made the modified stainless steel more difficult to passivate during negative scanning.

The effect of current density and temperature on sulfur yield when using modified stainless-steel electrode in the IEM electrolysis cell is shown in Fig. 3, which shows that the actual sulfur yield M\textsubscript{act}.

![Figure 1](image1.png)  
**Figure 1.** Schematic representation of the electrochemical reaction device for sulfur preparation.

![Figure 2](image2.png)  
**Figure 2.** Cyclic Voltammograms for modified stainless-steel electrodes in two different solutions. Red line: 5 g/l SO\textsubscript{2}; Blue line: without SO\textsubscript{2}. Supporting Electrolyte: 0.5 mol/l H\textsubscript{2}SO\textsubscript{4}, v = 50 mV/s, potential range: −1.0−1.0 V.
was greater than $M_{\text{eff}}$ under most conditions. The experiments were carried out under Galvanostatic conditions and the current density in the Fig. 3(b) is 126 A/m$^2$. In Fig. 3(a), the actual yield of sulfur increased with the negative shift of cathode potential, reaching its maximum at 126 A/m$^2$, but the ratio of $M_{\text{act}}$ to $M_{\text{eff}}$ shows a declining trend. In Fig. 3(b), the value of $M_{\text{act}}$ and the ratio of $M_{\text{act}}$ to $M_{\text{eff}}$ increased first and then decreased with the increase of temperature, reaching the maximum at 60°C, and the sulfur productivity ($M_{\text{act}}/M_{\text{tot}}$) reached 88%. The main reason is that the concentration of SO$_2$ in solution decreased, also, it should be noted that the colloidal sulfur can be oxidized by SO$_2$ or sulfit to thiosulfate at high temperature. This indicates that some redox reactions provided electrons besides the impressed current in the cathode chamber in electrolysis which were beneficial to the preparation of sulfur, their reaction rate decreased gradually with the negative shift of cathode potential and increased greatly with the increase of temperature.

It was found in experiments that when the pH value of solution was greater than 2.5, the output of sulfur was less. When the pH value was greater than 4.5, no sulfur was generated in the solution. But the reaction rate of sulfur formation was fast when the pH value was less than 2.5. According to the relationship between the equilibrium concentration of three sulfur species (H$_2$SO$_3$, HSO$_3^-$, SO$_3^{2-}$) and pH value in aqueous calculated by Ian Streeter et al. at 298 K, it can be obtained that when the pH value is less than 2.5, the elemental sulfur in the solution is mainly in the form of H$_2$SO$_3$, so it can be proved that SO$_2$ is an effective electrochemical active substance in the process of preparing sulfur.

### Table 1. Polarization curve data of stainless-steel electrodes with and without SO$_2$.

| Passive current $i_{\text{pas}}$ (A) | Breakdown potential $E_b$ (V) | Corrosion potential $E_{\text{cor,A}}$ (V) | Corrosion current $I_{\text{cor,A}}$ (A) |
|-----------------------------------|-------------------------------|-------------------------------------|----------------------------------------|
| None SO$_2$                       | $9.27 \times 10^{-5}$ | 0.901                               | $-0.452$                               | $1.4 \times 10^{-3}$               |
| SO$_2$ (5 g/L$^{-1}$)             | $5.47 \times 10^{-4}$ | 0.897                               | $-0.394$                               | $2.4 \times 10^{-2}$               |

SO$_2$ and pH value in aqueous calculated by Ian Streeter et al. at 298 K, it can be obtained that when the pH value is less than 2.5, the elemental sulfur in the solution is mainly in the form of H$_2$SO$_3$, so it can be proved that SO$_2$ is an effective electrochemical active substance in the process of preparing sulfur.

### 4. Discussion

In order to investigate the changes of stainless-steel electrode during modification, polarization curves of stainless-steel electrode in two different solutions were measured and shown in Fig. 4. The electrode is not pretreated in these two experiments. According to the definition of Tafel curve, various electrochemical parameters can be obtained from Fig. 4. Relevant corrosion parameters were shown in Table 1. In comparing with none-SO$_2$ solution, the existence of SO$_2$ enlarged the passive current $i_{\text{pas}}$ by 1–2 magnitude order, the breakdown potential of the two cases was approximately the same. The existence of SO$_2$ also increased the self-corrosive current of stainless steel, which means that the rate of corrosion kinetics increased. These results indicate that the existence of SO$_2$ or its electrolytic products reduced the corrosion resistance of stainless steel and narrowed the passivation zone.

There were three corrosion potentials (A, B, C) and cathode current loops in Fig. 4 when the potential was scanned from the negative to the positive direction in the electrolytic system in which SO$_2$ exists, and which corrosion potential will remain in the actual system depends on the initial state. In the process of cathode polarization which is more negative than $E_{\text{cor,A}}$, it was observed that pale yellow colloid was continuously formed near the electrode, XRD results show that the product was sulfur, and no bubbles were observed, indicating that the hydrogen evolution reaction was inhibited. So the cathodic reaction of corrosion under $E_{\text{cor,A}}$ should...
be the reduction of SO$_2$ to sulfur. From the point of view of sulfur
preparation, the corrosion reaction of stainless steel cathode under $E_{\text{cor,A}}$ potential was beneficial to sulfur production.

In order to find out what initial state can make the corrosion potential of stainless steel electrode be $E_{\text{cor,A}}$ with the following corrosion reactions:

$$4\text{SO}_2 + 4\text{H}^+ + 4e^- \rightarrow \text{S} + 2\text{H}_2\text{O} \quad (1)$$

$$\text{Fe} \rightarrow \text{Fe}^{2+} + 2e^- \quad (2)$$

Two groups of electrodes were investigated in the experiment by changing the initial state of the electrode surface. Different electrodes were placed in the same solution (5 g L$^{-1}$ SO$_2$, 0.5 mol/L H$_2$SO$_4$) for 1 h respectively without additional energy and the open-circuit potential and the composition and content of the metal elements in the solution after corrosion were measured. In the first group, 316L stainless steel electrode without any electrochemical treatment was used, and the open circuit potential of it was $\approx 0.08$ V ($E_{\text{cor,A}}$). In the second group, 316L stainless steel electrode was modified according to the method described in the second section, and then placed in the target solution. The open circuit potential of it was $\approx 0.39$ V ($E_{\text{cor,A}}$). During the static process, pale yellow colloidal was continuously formed around the modified electrode. The change of corrosion equilibrium potential indicates that the stainless-steel electrodes had different corrosion characteristics after modification. From Table 1, it can be concluded that the corrosion current under the two equilibrium potentials differed by about one order of magnitude, which indicates that the corrosion resistance of the stainless-steel electrode decreased and the corrosion rate accelerated.

After the modified electrode was put in the solution for 1 hour, it became turbid, which was caused by sulfur from cathode corrosion product.

The spontaneous reaction of modified electrode should be related to the destruction of passive film of stainless steel. A lot of research has been done on passive film of stainless steel,$^{15-17}$ the composition of passive film is mainly chromium oxide (hydroxide), followed by iron oxide and nickel oxide.$^{18}$ Sato et al. considered that the thickness of passive film of Fe increased with the electrode potential and the pH value in acidic solution, generally in the range of 1.5–3 nm. The passive film thickness of stainless steel is 1–2 nm thinner than that of Fe.$^{19}$ So the passive film thickness of stainless steel surface was very thin under modification conditions (pH = 1.0, E = $\approx 0.7$ V).

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) was used to determine the content of metal elements in the solution after the above two groups of reaction, and the results are shown in Table 2. It was found that the content of metal elements in the first group of solution was lower than the detection limit, and that in the second, except Fe, Cr and Ni, other metal elements were lower than the detection limit. Fe, Cr and Ni are the main elements in the passive film of stainless steel, which indicates that the corrosion rate of stainless-steel electrode was much lower than that after modification, and the passive film of stainless steel was destroyed after modification.

It can be inferred that in the second group of experiments, the passive film was destroyed after modification, and the corrosion potential was transferred to $E_{\text{cor,A}}$. The passive film on the surface of stainless steel became unstable, so it would dissolve quickly.

**Table 2.** Composition and content of metals in solutions after reacting with modified and unmodified electrodes, respectively.

|        | Fe (g L$^{-1}$) | Cr (g L$^{-1}$) | Ni (g L$^{-1}$) |
|--------|---------------|---------------|---------------|
| The first group | <0.05         | <0.05         | <0.05         |
| The second group | 0.47          | 0.12          | 0.05          |

In order to investigate what factors lead to the destruction of passive film on stainless steel surface in the process of modification, the surface substances of the electrode after modification were analyzed by EPMA (Electron Microprobe). The outermost of the electrode was covered with a layer of yellow sulfur. After removing the sulfur layer, we can see a black surface on the electrode, and the main components of this film were Fe, Cr, Ni and S elements by means of EPMA as shown in Table 3. From the comparison experiment results in Table 3, we can see that the presence of SO$_2$ increased the content of sulfur element in the surface film significantly, which proved that sulfide was formed on the electrode surface during electrolysis. C. Quijada et al. proved that the chemical adsorption layer closest to the electrode substrate produced sulfide (mainly H$_2$S) during the reduction of SO$_2$.$^{10}$ Therefore, it can be inferred that H$_2$S produced by reduction of SO$_2$ in modification participated in the destruction of passive film on stainless steel. When H$_2$S was adsorbed on stainless steel surface, it could react with passive film to form sulfide metal film (Fe(Cr)S)$_2$. This sulfide film is far less dense than oxide film, which leads to pitting corrosion of metal.$^{21}$ At the same time, it can hinder the repair of passive film, so the corrosion activity of the electrode increased after modification. We can obtain the corrosion current density from Table 1, which was 12.77 mA/cm$^2$, and it represented the rate of anodic dissolution and cathodic reduction in the open circuit potential $E_{\text{cor,A}}$. The rate of spontaneous reaction decreased with the negative shift of electrode potential and the decrease of temperature, so the trend shown in Fig. 3 appeared when the impressed current was combined with spontaneous reaction.

The AC impedance spectroscopy of modified stainless-steel electrode system was measured at the open circuit potential of $\approx 0.39$ V and the amplitude of 5 mV. The frequency range was 0.01–10000 Hz. A series of electrochemical impedance data at different frequencies were measured and plotted into a complex plane diagram (Nyquist diagram) as shown in Fig. 5. It shows...
approximately a half circle above real axis, which was the relaxation process of charge and discharge of electric double layer capacitor $C_d$ on the electrode surface after disturbed by small amplitude sinusoidal alternating current. There was only one peak in the Bode diagram (not shown) with a unique time constant, which indicates that the control step of the corrosion process was electrochemical reaction process. As can be seen from the Fig. 5, the curve deviates from the semicircle track to some extent. This was due to the continuous adsorption and desorption of sulfur on the electrode surface and the increase of surface roughness during the corrosion process, which resulted in the deviation from the ideal capacitance of the electric double layer. The equivalent circuit fitting by Zview software that best accord with the experimental data was given in the inset of Fig. 5. The $R_1$ includes all ohmic resistances in the system. $R_2$ represents the Faraday impedance, which is the parallel connection of the corresponding anode and cathode process impedance. CPE represents the constant phase element, which is used to describe the degree of electric double layer deviating from pure capacitance. The $R_1$ was 1.11 k$\Omega$, it mainly included the ohmic resistance of electrolyte and the high resistance sulfur film on the electrode surface which contributed most to $R_1$. The $R_2$ was 0.33 k$\Omega$, which mainly referred to the charge transfer resistance in this system.

Therefore, the destruction of passive film on the surface of stainless-steel electrode made its corrosion reactivity enhanced in acidic solution containing SO$_2$ after modification and the cathodic corrosion product was sulfur. Moreover, the corrosion reaction was spontaneous. Figure 4 shows that when the cathodic polarization current was applied to the modified stainless-steel electrode, the electrode potential will shift to a direction more negative than E$_{\text{cor,}}$A. The speed of the target reaction (1) will accelerate and the speed of the reaction (2) will decrease. So, when the modified stainless steel was used as cathode, the electrons needed for the reduction of SO$_2$ came from two ways. One was the current supplied by the DC power ($I_j$), the other was the current ($I_k$) provided by electrochemical corrosion reaction. The total current used for SO$_2$ reduction reaction was $I = I_j + I_k$. The cathode polarization current will increase the rate of SO$_2$ reduction reaction, but it does not mean that $I_k$ will be greatly reduced. If the impressed cathode current is not significantly greater than the self-corrosive current $I_{\text{cor,A}}$, the cathode protection cannot effectively reduce the dissolution rate of metal in highly acidic solutions. As can be seen from Fig. 2, the reduction potential of SO$_2$ ranges from $-0.7$ V to $-0.3$ V, and the hydrogen evolution reaction increases when exceeding $-0.7$ V. The value of $E_{\text{cor,A}}$ is $-0.39$ V, which were close to each other. Therefore, the contribution of corrosion reaction to sulfur yield cannot be neglected within the potential range of SO$_2$ reduction, which has been verified in Fig. 3.

In the IEM electrochemical experiment, the conversion rate of SO$_2$ to sulfur was 88% when the current density was 126.98 A/$m^2$ and the temperature was 60°C. Under these conditions, the current $I_j$ supplied by DC power was assumed to be 100% current efficiency, and the theoretical output of sulfur $M_{\text{eff}}$ was 1.79 g, while the actual output $M_{\text{act}}$ was 2.2 g. This indicates that the contribution rate of corrosion reaction to products should be at least 18.64% ((2.2 g − 1.79 g)/2.2 g × 100%). So, the impressed current and corrosion reaction contribute to the sulfur production together when modified stainless steel was used as cathode for electrochemical reduction of SO$_2$ as shown in Fig. 1. The role of cathodic protection is limited when the cathodic polarization current is not very large and the contribution of corrosion reaction is still considerable.

It should be pointed out that hydrogen sulfide is inevitable in the initial stage of the SO$_2$ reduction reaction even if unpretreated stainless steel electrode is used for electrolysis in IEM reactor. This is due to the formation of a high resistance film on the surface of the electrode when the sulfur begins to form and adhere to the electrode. The internal and external potential of the high resistance film is different, which leads to electrochemical polarization. It makes the potential of the inner layer of sulfur adsorbed more negative, so the inner sulfur will be reduced to hydrogen sulfide preferentially under the polarization potential. Therefore, from the perspective of corrosion protection, it should be avoided to use stainless steel electrodes to reduce SO$_2$ in acidic solution to prepare sulfur. However, from the perspective of sulfur preparation, the corrosion reaction of stainless steel can make the preparation process more efficient.

After sedimentation, filtration, drying and other steps, the electrolytic products were obtained with a pale-yellow appearance. Figure 6 was a scanning electron microscopic picture of the product. The shape of the sulfur crystal was regular and diamond-shaped. The length of the long axis of the crystal particles was between 3–12 microns. Combining with the XRD image in Fig. 7, it can be seen that the product was mainly α-S. The inset of Fig. 6 was an energy spectrum obtained by EDAX, and the characteristic peaks of sulfur in the inset were obvious, which indicated that the purity of sulfur was high.
5. Conclusions

The modified 316L stainless steel can spontaneously react with SO2 to produce sulfur in acidic solution without external energy. The destruction of passivation film on stainless steel surface during modification was identified as the main mechanism that leads to enhanced dissolution of iron in stainless steel and reduction of SO2 under the conditions used in this work. Results of substance detection provide evidence for that the passive film on stainless steel surface was destroyed greatly by the by-product of SO2 reduction (mainly hydrogen sulfide) during modification. In laboratory-scale experiment, the application of modified stainless-steel electrode strongly accelerates the reduction process of the SO2 under the combination of impressed current and electrochemical corrosion reaction, which contribute to increased sulfur yield per unit time together.

This modification steps do not even need to be done in advance, and the unpretreated stainless steel electrode can easily be modified in the initial stage of electrolysis in the IEM reactor. Therefore, the use of stainless-steel electrodes in the sulfur preparation process has advantages and disadvantages, which should depend on the situation.

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