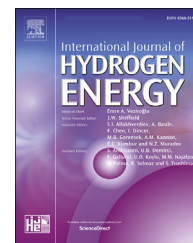


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Short Communication

Deep deoxidization from liquid iron by hydrogen plasma arc melting



Xiliang Guo ^{a,b}, Jianbo Yu ^{a,b,**}, Yujia Zhang ^{a,b}, Liang Liu ^{a,b}, Xia Li ^{a,b}, Hanlin Liao ^c, Zhongming Ren ^{a,b,*}

^a State Key Laboratory of Advanced Special Steel, Shanghai University, Shanghai 200072, China

^b School of Material Science and Engineering, Shanghai University, Shanghai 200072, China

^c ICB UMR 6303, CNRS, Univ. Bourgogne Franche-Comté, UTBM, F-90010 Belfort, France

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ABSTRACT

In the present study, removal of oxygen from liquid iron by Ar and (10%–40%) H₂ plasma arc melting have been investigated experimentally. It is shown that the reduction of oxygen content is slight when the plasma gas was argon only. However, the oxygen content of the iron melt decreases sharply when adding hydrogen in plasma gas, and the rate of deoxidization increases with the hydrogen content. The final oxygen content can be as low as 1 ppm after hydrogen plasma arc melting (HPAM) with 40% H₂ in plasma gas. The deoxidization from the iron melt by HPAM was a two-steps process: the fast 1st step and the slow 2nd step. From kinetic analysis, the oxygen removal by HPAM was found to obey a first-order rate law. In the 1st step, the reduction rate of oxygen increases proportionally to the approximately 0.44th power of the hydrogen volume proportion in plasma gas. The deoxidization process can be expressed as the following reaction: $[O] + 2H = H_2O$. The thermodynamic analysis indicates that deoxidization power of atomic H is higher than that of molecular H₂.

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Introduction

High purity iron is widely used as the most important material in the optoelectronic semiconductor, hard magnetic films [1] and biodegradable metallic stents [2], as it has excellent mechanical properties such as electro conductivity, good soft magnetic and corrosion resistance [3]. However, the oxide is negative to the mechanical properties and corrosion

resistance of iron. It is a significant task to eliminate the oxygen to a low concentration in iron.

Many techniques for metal purify in vacuum and inert gas atmosphere have been performed, such as strong deoxidizers [4,5], vacuum distillation [6], zone melting [7], electron beam melting [8,9] and hydrogen plasma arc melting (HPAM) [10,11]. For the sake of efficiency and cost during refining, HPAM is the reasonable one to eliminate impurities. HPAM has been studied to remove the metallic impurities from various active

* Corresponding author. State Key Laboratory of Advanced Special Steel, Shanghai University, Shanghai 200072, China.

** Corresponding author. State Key Laboratory of Advanced Special Steel, Shanghai University, Shanghai 200072, China.

E-mail addresses: jbyu@shu.edu.cn (J. Yu), renzm2201@163.com (Z. Ren).

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metals, such as Zr, Mo, Hf, Ti, Ta and Tb [10,12–18]. M. Isshiki et al. investigated the effect of hydrogen on the removal of nonmetallic impurity oxygen from liquid iron and cobalt using HPAM and they found that the rate of deoxidization rose remarkably as the increase of hydrogen content in plasma gas (from 0.5% to 20%) [19]. However, little attention has been paid to study the effect of much higher hydrogen content (above 20% H_2) in plasma gas on deep deoxidization from liquid iron during HPAM.

In this paper, the effect of hydrogen content (from 10% to 40%) in plasma gas on the removal of oxygen from iron by HPAM has been conducted. The oxygen content in iron was reduced to 1 ppm after HPAM. Furthermore, the kinetic and thermodynamic analyses were estimated to clarify the deoxidization mechanism of HPAM.

Experimental methods

The schematic diagram of the plasma arc furnace is shown in Fig. 1a. The pilot arc power source was used to obtain a stable non-transfer arc. Then, the transfer arc was generated by the D.C. power (transformed from a 3 phase A.C. power) after the power off of pilot arc power source. The power of plasma arc for melting was 6kw. The water-cooled Cu crucible was applied as an anode and the thoriated W cathode was placed in the plasma torch. Aim to eliminate the residual air, the plasma arc furnace was evacuated to 6×10^{-3} Pa and flushed

with high purity Ar gas immediately. The electrolytic iron specimen (containing approximately 100 ppm oxygen) about 30 g was loaded on the water-cooled Cu crucible of 40 mm in diameter and 6 mm in depth. The plasma gas with high purity Ar and H_2 were mixed and introduced into the plasma torch. The volume proportion of H_2 in the plasma gas was 10%, 20% and 40% respectively. The sample was melted again after being turned over for uniform refining. The total melting times for each specimen were 0.5, 1, 2, 4, 8, 15, 30, 60 and 120 min, respectively. The amount of oxygen was examined by LECO ONH-836.

Fig. 1b illustrates the raw material and specimens after HPAM for 120 min. It can be seen obviously that the button samples with metallic luster are very smooth.

Results and discussion

As shown in Fig. 2a, the oxygen content reduces slowly from 100 ppm to 30 ppm after 120 min melting by the argon plasma only. As shown, the deoxidization by HPAM is primarily a two-steps process. In the 1st step, the oxygen content decreases rapidly with melting time. In the 2nd step, the oxygen content reduces slightly and tends to reach the minimum gradually. In addition, the rate of deoxidization increases extremely as the increase of hydrogen content in the plasma gas. The final oxygen content after HPAM with 40% H_2 was reduced to

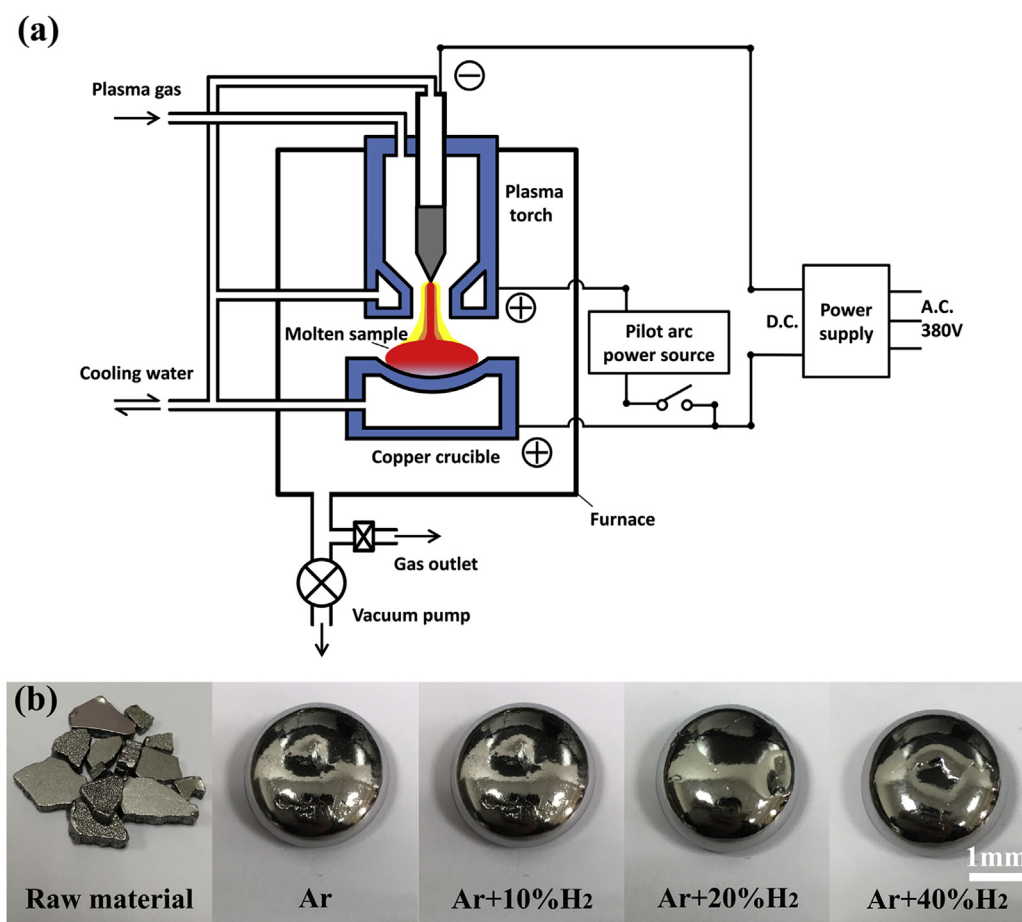


Fig. 1 – (a) Schematic diagram of plasma arc furnace; (b) Raw material and specimens after 120 min HPAM.

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