Molten salt-enhanced production of hydrogen by using skimmed hot dross from aluminum remelting at high temperature

P. Li[1*], M. Zhang[2], X.M. Hou[2], B.J. Yan[1], H.W. Guo[1], S. Seetharaman[3]

[1]Shagang School of Iron and Steel, Soochow University, Suzhou 215021, PR. China
[2]State key Laboratory of Advanced Metallurgy, University of Science and Technology Beijing, Beijing 100083, PR. China
[3]Department of Materials Science and Engineering, Royal Institute of Technology, SE-10044 Stockholm, Sweden

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Presenting author email: lipeng@suda.edu.cn

Introduction: The demand for hydrogen as clean and regenerative energy is urgent, considering the minimization of the use of fossil fuel and consequently, the carbon footprint. Among variety of hydrogen generation technologies, the splitting water reaction (Shkolnikov et al., 2011) at high temperature using cheap and abundant aluminum metal has been received serious attentions.

$$2Al(s) + 3H_2O(g) \rightarrow Al_2O_3(s) + 3H_2(g) - 954.8kJ/mol \qquad (1)$$

It has been shown that the use of secondary aluminum or aluminum scrap provides a more energy efficient way of utilizing energy compared with primary aluminum (Wang et al., 2012). During the secondary production of aluminum, the byproduct "skimming" dross from regular slagging is generated in enormous amount through aluminum remelting process which presents high abundance in metallic aluminum and salt flux sources. The present work was started with a view to produce hydrogen based on Al/water vapor reaction at high temperature from skimmed hot dross. The influence of inherent impurities salt flux in the dross on the hydrogen generation was investigated.

Materials and methods: The experimental assembly consists of gas cleaning system, a steam generator, and reaction system. For each set of experiments, skimmed dross sample containing 25 mg of metallic aluminum was placed in the reaction zone of the furnace at room temperature. The chamber was then purged with purified argon for 6 hours. Non-isothermal studies were carried out from 500 ^oC to 1000 ^oC with a ramping rate of 5 ^oC min^{-1}. After attaining of 500 ^oC, water was fed at a flow rate of 0.035 ml min^{-1} using a peristaltic pump (60 ml min^{-1} in form of steam), together with purified argon (200 ml min^{-1}) into the furnace from the same port to allow the Al/water reaction happen. Isothermal studies were carried out at 600 ^oC, 700 ^oC, 800 ^oC, 900 ^oC, for 1h. The off gas after purification by cleaning system was passed through a gas analyzer(Testo Pro350, Testo) and the variation of hydrogen produced during the reaction was measured.

Results and Discussions: As shown in Fig.1, it was confirmed that the inherent salt flux in the dross could be used as catalyst to enhance the hydrogen production in a relatively lower temperature region of 600-850^oC by dissolving the product layer containing amorphous and γ-Al_2O_3. More relative amount of salt flux will bring more aggressive reaction. Once the molten salt flux was supersaturated, the precipitation of α-Al_2O_3 occurred. Healing of α-Al_2O_3 crystallites afterwards would bring better resistant against salt fluxes corrosion, and the densification of production layer. As a consequence, the hydrogen evolution rate will drop dramatically at high temperature region of 900-1000 ^oC. The maximum aluminum conversion degree was found to be more than 60%, and the maximum hydrogen evolution rate was over 60 $cm^3g^{-1}min^{-1}$ when skimmed dross with 30 wt% Al used under non-isothermal mode.

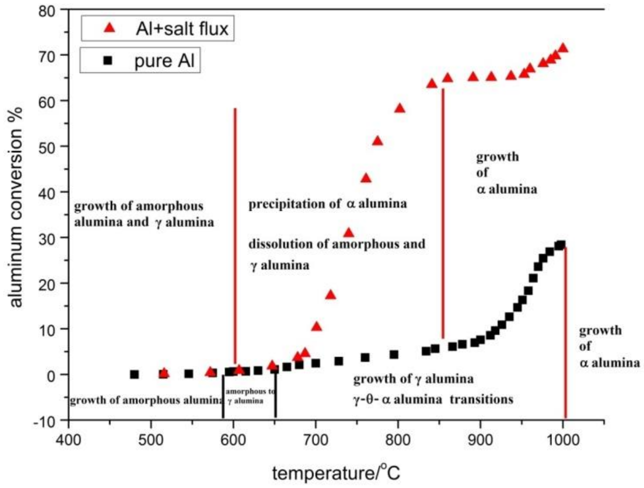

Fig.1.A schematic diagram showing different reaction behavior of Al/water steam at high temperature with or without salt flux.

Conclusions: The skimmed hot dross generated in secondary production of aluminum contains high amount of metallic aluminum and also the potential heat. An innovative process for hydrogen generation using skimmed hot dross from aluminum remelting industry is proposed in this work. During the slagging in the real plant, considering the skimmed hot dross has a temperature around 750-800 ^oC, in the presence of salt flux, the shift of Al/water reaction zone to lower temperature region of 600-850 ^oC provides a possibility for further utilizing the potential heat preserved in the skimmed hot dross and the Al/water reaction enthalpy. The hydrogen and water vapor with high temperature could be utilized for power generation. An added advantage of this approach is that the solid product from the process can be a suitable raw material for alumina production due to its large content of alumina formed during the Al/water reaction.

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