Effect of temperature and electric field in hydrolysis of sodium borohydride for hydrogen generation in the presence of catalyst

Govindaraj Balakrishnan
Department of Electrical and Electronics Engineering
NPR College of Engineering and technology, Natham, Tamilnadu, India

Abstract- Hydrogen generation from chemical hydrides is one of the compact and safest methods for utilizing hydrogen in fuel cell. The hydrogen generation rate from sodium borohydride in the presence of various catalysts such as Pt/XC-72C, Pt /Al_2O_3, Co/γ-Al_2O_3, Co-B/C, and Co-B/MWCNT at 30 º C varies from each other. Application of an electrical field can be effectively used for increasing both the electrolysis of water and hydrolysis of sodium borohydride. In this paper hydrogen generation rate of sodium borohydride solution using Co-B/C Catalyst in the presence of 3Volt DC electric field at various temperature are discussed in detail. The major research and development needs, key benefits and critical challenges to improve this method were also discussed.

Keywords – Energy, Catalyst support, Hydrogen generation, Electric field, water electrolysis, sodium borohydride

I. INTRODUCTION

Among Hydrogen storage methods, chemical hydrides have been demonstrated to be promising hydrogen sources for portable applications [1, 2]. Sodium borohydride is one of the most promising metallic nonmetallic hydrides for hydrogen storage at ambient temperature and pressure, because this material is stable, non-flammable and non-toxic, together with the properties of high-energy density and easy control of hydrogen generation rate [3-5]. Sodium borohydride, $NaBH_4$, is stable until about 673K and is, therefore, not suitable for providing hydrogen through a thermal activation process. It does release hydrogen, however, on reaction with water as described below equation [6]

$$NaBH_4 + 2H_2O \rightarrow NaBO_2 + 4H_2$$

Although the self-hydrolysis of sodium borohydride at room temperature is quite slow, it can be completely suppressed by working in highly basic solution[7] Thus, the hydrolysis of sodium borohydride occurs only in the presence of a suitable catalyst [8]. Sodium borohydride ($NaBH_4$) reacts with water to produce 4 mol of hydrogen per mol of compound at room temperature. Under certain conditions, it was found that 6 mol of hydrogen per mol of sodium borohydride was produced in the presence of electrical field created by DC voltages, whereas 4 mol of hydrogen was produced in the presence of catalyst per mole of sodium borohydride. It was found that hydrogen produced from sodium borohydride by applying an electrical field can be effectively used for both increasing the electrolysis of water and hydrolysis of sodium borohydride [9].

II.EFFECT SOLUTION TEMPERATURE AND ELECTRIC FIELD

A. Experimental setup –

The water column arrangement is used to measure the hydrogen generation rate as indicated in the Figure (1). The experimental apparatus used for hydrolysis reaction of sodium borohydride enabled the measurement of the volume of gas produced through the displacement of water in an inverted burette. The reaction solution 20 wt.% $NaBH_4$+3 wt. % NaOH solution containing 10.0 mg of 17.33 wt. % Co-B/C (Co-B on Carbon) Catalyst. The gas is produced in a reactor (test tube) immersed in a thermostatic bath, where the liquid phase occupies a fraction of the volume. It then leaves the reactor through the top, continues through the rubber tube and enters an inverted burette, initially filled with water. While the hydrogen accumulates at the top of the water column, pressure rises, and the water level decreases. The initial temperature of the solution is 30ºC. The hydrolysis of sodium borohydride using

Co-B/C as catalyst is carried out in the presence of 3 Volt DC electric field. When we increase the temperature then hydrogen generation rate also increases as indicated in the Figure (3).

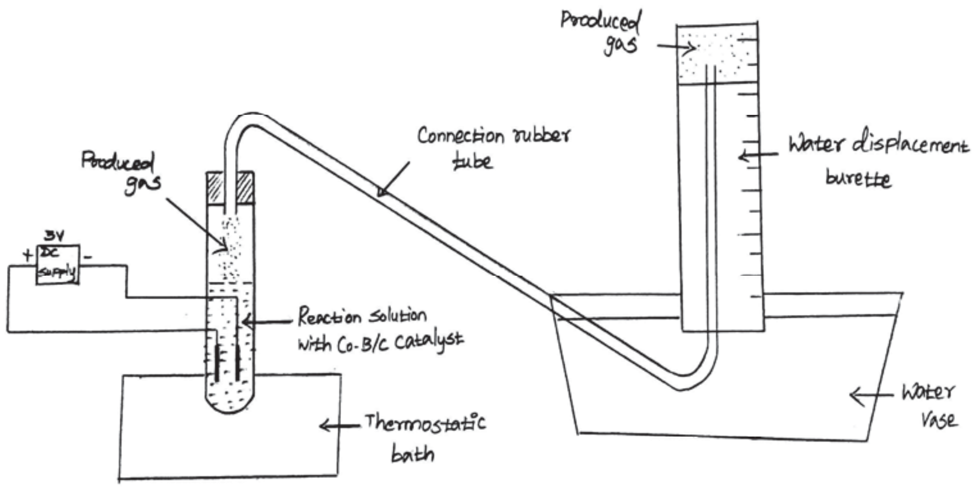

Figure (1) Schematic representation of the experimental apparatus used to measure the hydrogen gas volume produced

B.Hydrogen generation rate -

The following table indicates comparison of hydrogen generation rates on various catalysts on the same temperature 30ºC.[12]

Catalyst	Initial temperature of solution (ºC)	$NaBH_4$ concentration (wt.%)	NaOH concentration (wt.%)	Average hydrogen generation rate/l $min^{-1}g^{-1}$	Reference
Pt/XC-72C	30	5	5	3.7	[10]
Pt/Al_2O_3	30	5	5	3	[11]
$Co/\gamma\text{-}Al_2O_3$	30	5	5	0.15	[11]
Co-B/C	30	20	3	3.1	[12]
Co-B/MWCNT	30	20	3	5.1	[12]
Co-B/C (in the presence of 3Volt DC Electric field)	30	20	3	3.6	This paper

Figure (2) Hydrogen generation rate on various catalysts

From the Figure (3) we may clearly understand that when we increase the temperature the hydrogen generation rate also increases rapidly in the presence of electric field. As indicated in the figure (4) in the absence of electric field the hydrogen generation rate reduces when we compare it with the presence of electric field. The main reason for this increase in hydrogen generation rate is the applied electric field which increases both electrolysis of water and hydrolysis of sodium borohydride.

C.Hydrogen generation rate in the presence of DC electric field -

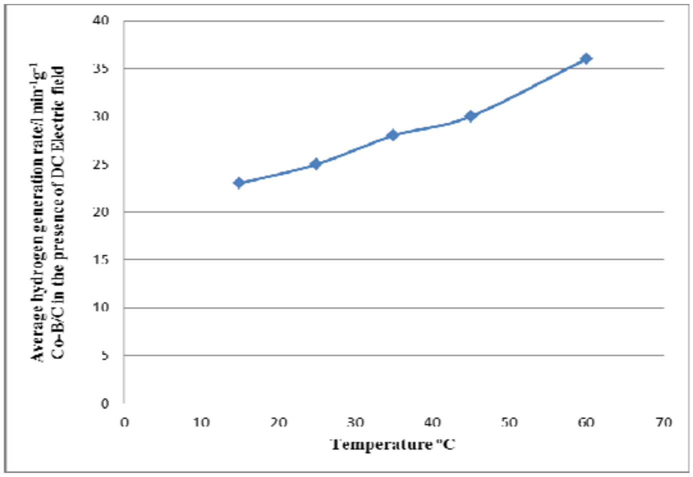

Figure (3) Effect of solution temperature on the average hydrogen generation rate measured after 20 min in 20 wt.% $NaBH_4$+3 wt. % NaOH solution containing 10.0 mg of 17.33 wt. % Co–B/C in the presence of 3Volt DC Electric field

D.Hydrogen generation rate in the absence of DC electric field -

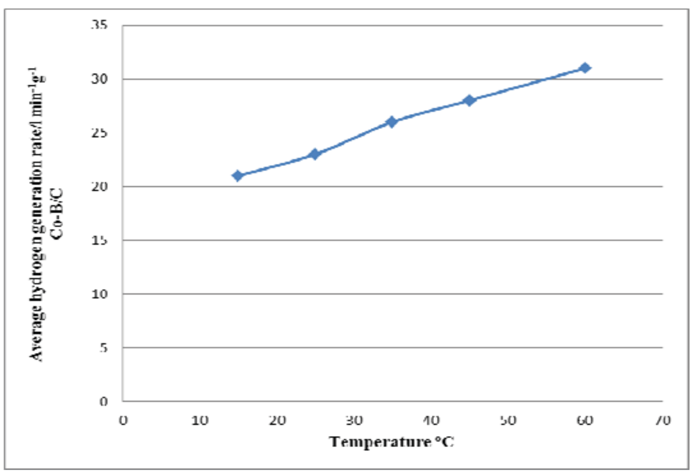

Figure (4) Effect of solution temperature on the average Hydrogen generation rate measured after 20 min in 20 wt.% $NaBH_4$+3 wt. % NaOH solution containing 10.0 mg of 17.33 wt. % Co–B/C in the absence of DC electric field

III. RESULT AND DISCUSSION

Based on the results the temperature and application of DC electric field increases the hydrogen production rate. It can be used effectively in various fuel cell applications. Average hydrogen generation rate of Co-B/C in the presence of 3Volt DC Electric field is 3.6 l $min^{-1}g^{-1}$ .We have a hydrogen generation rate of Co-B/C in the absence of DC Electric field is 3.1 l $min^{-1}g^{-1}$.So,the application of DC electric field increases both hydrolysis of sodium borohydride and electrolysis of water. Both the test was carried out at the same concentration. However the major drawback of using DC electric field to increase the hydrogen generation rate is it will decrease the system efficiency. Integration with renewable energy sources is also one of the critical challenges in this method. The key benefits are we may use existing infrastructure. It produces virtually no pollution with renewable energy sources. In order to increase the efficiency we should do research and development of durable, low cost and active catalysts. Certainly, hydrogen generation rates are closely affected by DC electric field and temperature.

IV.CONCLUSION

In this paper average hydrogen generation rate of Co-B/C in the presence of 3Volt DC Electric field is determined as 3.6 l $min^{-1}g^{-1}$.The combined effect of electric field and temperature in hydrolysis of sodium borohydride using varying catalysts such as Pt/XC-72C, Pt /Al_2O_3, Co/γ-Al_2O_3 and Co-B/MWCNT may differ from each other. In addition, these results will give better understanding. Research is under progress to characterize the effect of temperature and electric field in hydrolysis of sodium borohydride for various other catalysts. Instead of using DC electric field when we use AC electric field with different waveform the hydrogen production rate may differ. However for largely varying hydrogen demand system these methods will satisfy it needs depending upon the hydrogen requirement of the fuel cell application.

REFERENCES

[1] Kojima Y, Suzuki K, Fukumoto K, Sasaki M, Yamamoto T, Kawai Y, et al. Hydrogen generation using sodium borohydride solution and metal catalyst coated on metal catalyst coated on metal oxide. Int J Hydrogen Energy 2002;27:1029–34.

[2] Amendola SC, Sharp-Goldman SL, Janjua MS, Spencer NC, Kelly MT, Petillo PJ, et al. A safe, portable, hydrogen gas generator using aqueous borohydride solution and Ru catalyst. Int J Hydrogen Energy 2000;25:969–75.

[3] Wee JH, Lee KY, Kim SH. Sodium borohydride as the hydrogen supplier for proton exchange membrane fuel cell systems. Fuel Process Technology 2006;87(9):811-9.

[4] Zhang JS, Zheng Y, Gore JP, Fisher TS. 1 kWe sodium borohydride hydrogen generation system: part I: experimental study. Journal of Power Sources 2007;165(2): 844-53.

[5] Krishnan P, Hsueh KL, Yim SD. Catalysts for the hydrolysis of aqueous borohydride solutions to produce hydrogen for PEM fuel cells. Applied Catalyst B: Environmental 2007;77(1e2): 206-14.

[6] Sodium borohydride as a fuel for the future D.M.F. Santos*, C.A.C. Sequeira Institute of Materials and Surfaces Science and Engineering, Department of Chemical and Biological Engineering, Instituto Superior Técnico, TU Lisbon, 1049-001 Lisboa, Portugal 21 August 2011

[7] M.M. Kreevoy, R.W. Jacobson, Ventron Alembic 15 (1979) 2–3.

[8] S.C. Amendola, J.M. Janjua, N.C. Spencer, M.T. Kelly, P.J. Petillo, S.L. Sharp-Goldman, M. Binder, Int. J. Hydrogen Energy 25 (2000) 969–975.

[9] hydrogen production from sodium borohydride for fuel cells in presence of electrical field ömer sahin1,*, hacer dolas2, mustafa kaya1, mehmet sait izgi1, halil demir article first published online: 27 jul 2009 doi: 10.1002/er.1563 international journal of energy research volume 34, issue 7, pages 557–567, 10 june 2010

[10] Xu DY, Zhang HM, Ye W. Hydrogen generation from hydrolysis of alkaline sodium borohydride solution using Pt/ C catalyst. Catal Commun 2007;8:1767–71.

[11] Ye W, Zhang HM, Xu DY, Ma L, Yi BL. Hydrogen generation utilizing alkaline sodium borohydride solution and supported cobalt catalyst. J Power Sources 2007;164: 544–8.

[12] Accurately measuring the hydrogen generation rate for hydrolysis of sodium borohydride on multiwalled carbon nanotubes/Co–B catalysts

[13] Yueqiang Huanga, Yi Wanga, Ruixiong Zhaoa, Pei Kang Shena,*, Zidong Weib,* aState Key Laboratory of Optoelectronic Materials and Technologies, School of Physics and Engineering, Sun Yat-Sen University, Guangzhou 510275, China bThe State Key Laboratory of Power Transmission Equipment & System Security and New Technology, Chongqing University, Chongqing 400044, China Accepted 19 September 2008