ATOMIC HYDROGEN PRODUCTION AND MODELLING REVISITED

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ABSTRACT. In this study the microwave discharge technique for atomic hydrogen production is reviewed starting with the earlier work of Wood in 1921 up till the extensive electrical discharge era of 1970’s. The evaluation is completed with the recent studies which concentrated on atomic hydrogen utilization in semiconductor manufacturing, thin film formation, surface treatment and modification, nano particle formation, sintering and hydropyrolysis of hydrocarbons.

A model reported in literature is modified and used to predict the production of atomic hydrogen in a 2.45 GHz MW system. The effect of MW power, hydrogen flow rate, moisture, ageing of reactor surface, surface coating and diameter of discharge tube are investigated experimentally and theoretically.

1.0 Introduction

The low pressure electrical discharge is universally recognized as an effective and convenient means for the production of radicals by dissociation of molecular gases. Highly active species formed through a suitable discharge medium have been considered by chemical engineers as a potential synthetic reagent. With the expectation of cheap electricity a big research programme was built in USA and Europe and voluminous literature has been accumulated on gas discharges. One branch of these attempts involved breaking of molecules into atoms for their chemical activity. Some examples of the dissociation studies were on oxygen, Mearns and Morris(1), and Bell and Kwong(2), on hydrogen, Mearns and Ekinci(3), on oxidation of hydrogen chloride, Cooper, Mickey and Baddour(4), on formation of hydrogen cyanide from methane and ammonia Juul-Dam and Brockmeier(5), and on oxidation of carbon monoxide Brown and Bell(6).

The reasons why this study on production of atomic hydrogen was carried out using a microwave (MW) discharge are:

a) Hydrogen being the simplest of all molecules, will serve as a good model for the understanding of discharge phenomena. Also data on many model parameters are available for hydrogen.
b) Hydrogen as a molecule plays a key role in chemical industries. Hydrogen atoms being more reactive is expected to open new horizons such as in reaction between salts of heavy metals.
c) Hydrogen discharge systems are finding upto date applications in semiconductor processing, especially in film formation and etching.
d) Chlorine industries are finding tighter controls due to environmental reasons.

Hydrogen discharge system may be an alternative compact chlorine production method from HCl or from iron chloride.

In this report experimental results, on effect of variation of different parameters on production of atomic hydrogen in a 2.45 GHz discharge is given. The experimental results are compared with a hydrogen dissociation model developed by Bell.

2.0 Historical Development of Atomic Hydrogen Production

2.1 EARLIER WORKS

In 1921 Wood produced atomic hydrogen by means of a glow discharge tube is known as a Wood's tube. Using a Wood's tube, Poole made a systematic study on hydrogen to determine the effect of power and flow rate on the yield, and investigated surface effects. Poole used both silica and pyrex discharge tubes. He found that the optimum pressure for dissociation of hydrogen was approximately 0.6 mm. The maximum value of the energy efficiency of hydrogen atom production obtained was $4.5 \times 10^{-2}$ molecules per electron volt. The Wood's tube was improved by Weinrich and Hughes in 1954, by the introduction of water cooled electrodes which made it more versatile for studies of hydrogen and oxygen dissociation.

Direct current or low frequency alternating current discharges was later replaced by radio-frequency or microwave techniques. Adoption of the high frequency discharge is attributed to a combination of factors such as ease of control, simplicity of construction of the discharge tube, improved purity and greater stability.

The development of microwave sources during the second world war led researchers to use microwave power for dissociation of gases. The early users of microwave power sources in discharge were Nagle, Julian, and Zacharias and Broida and Moyer. For a hydrogen discharge operated at 2.45 GHz, the highest yield of atomic hydrogen obtained by McCarthy was $1.0 \text{ g.atoms/kw-hr}$ or $3 \times 10^{-2}$ molecules per electron volt. Rose and Brown have measured