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RESEARCH

Influence of Gas Flow Rate on the Deposition Rate on Stainless Steel 202 Substrates

M.A. Chowdhury[a], D.M. Nuruzzaman[b]

[a] *Department of Mechanical Engineering, Dhaka University of Engineering and Technology, Gazipur-1700, Bangladesh*
[b] *Faculty of Manufacturing Engineering, University Malaysia Pahang, Malaysia*

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Corresponding author:

Mohammad Asaduzzaman Chowdhury
Professor
Department of Mechanical Engineering
Dhaka University of Engineering and Technology, Gazipur
Gazipur-1700, Bangladesh
E-mail: asadzmn2003@yahoo.com

A B S T R A C T

Solid thin films have been deposited on stainless steel 202 (SS 202) substrates at different flow rates of natural gas using a hot filament thermal chemical vapor deposition (CVD) reactor. In the experiments, the variations of thin film deposition rate with the variation of gas flow rate have been investigated. The effects of gap between activation heater and substrate on the deposition rate have also been observed. Results show that deposition rate on SS 202 increases with the increase in gas flow rate within the observed range. It is also found that deposition rate increases with the decrease in gap between activation heater and substrate. In addition, friction coefficient and wear rate of SS 202 sliding against SS 304 under different sliding velocities are also investigated before and after deposition. The experimental results reveal that improved friction coefficient and wear rate is obtained after deposition than that of before deposition.

1. INTRODUCTION

Chemical vapor deposition (CVD) is a process in which a solid material formed from a vapor phase by chemical reaction, is deposited on a heated substrate. The controlling parameters in CVD process are surface kinetics, mass transport in the vapor, thermodynamics of the system, chemistry of the reaction and processing parameters like temperature, pressure etc. The deposition rate which is the prime limiting factor in a CVD process is mainly controlled by the formation of required species to be deposited and its transportation in the vapor and surface kinetics [1-3]. Thin film synthesis via chemical vapor deposition (CVD) has been the subject of active research over the last two decades. Numerous studies have been carried out to examine the effects of the process parameters, such as temperature of the substrate and filament, gas flow rate, gas composition, chamber pressure etc. on different types of materials [4-9]. Experimental results and numerical calculations of thermal conduction and diffusion have shown that the mass transport in the gas phase plays an important role during thin film growth, and growth of thin films are mainly controlled by the mass transport rate rather than by the surface reaction rate at substrate temperatures [10,11]. Gas flow rate is an important parameter for CVD

thin film growth because the gas flow rate is closely related to the gas transport in the CVD reactor [10]. To date, efforts have been made to investigate the effects of the gas flow rate on thin film growth and conflicting results have been reported by different groups. Celii et al. [12,13] reported that varying the gas flow rate could change markedly the resultant microcrystalline diamond (MCD) crystal texture and surface morphology but has little effect on the growth rate. Yu et al. [14] have found that CVD thin film growth by hot filament CVD depends on a mass transfer controlled process and the growth rate was increased by increasing the gas flow rate, while other groups have reported that the gas flow rate does not appear to have a significant influence on thin film growth [15,16]. One of the conditions required for high deposition rate is that the diffusion of gas toward the substrate is the rate-determining stage. It was considered that the high flow rate made the mechanism of thin film growth possible [17]. The effect of gas flow rate and the gap between activation heater and substrates on the deposition rate on carbon steel was investigated [18,19]. Several researches [20-29] were carried out under different coating systems for ensuring the tribological behaviour of coated materials, even though more researches are necessary for the implication of past and future results to be clearly understood.

From the aforementioned research works, it can be concluded that several experiments were conducted at different gas flow rate conditions and the effects on thin film growth differ significantly. Even now a day, the effects of gas flow rate on thin film deposition for different materials, especially, at varying gap between activation heater and substrate are less understood. In the present research, an attempt is made to investigate the effect of gas flow rate and gap between activation heater and substrate on the thin film deposition rate on SS 202. Friction coefficient and wear rate of SS 202 before and after deposition are also investigated in this study. It is expected that the application of these results will contribute to the different concerned mechanical processes.

2. EXPERIMENTAL DETAILS

A thermo-chemical vapor deposition (hot filament) setup was designed and fabricated which is shown in Fig. 1. The substrate as shown in Fig.1 was placed on the substrate holder in between substrate heater and activation heater. During CVD process, the temperature of the substrate heater and the temperature of the activation tungsten heater are measured by optical pyrometer (Brand: Foster, England, Model: AJ/ON/19.5).

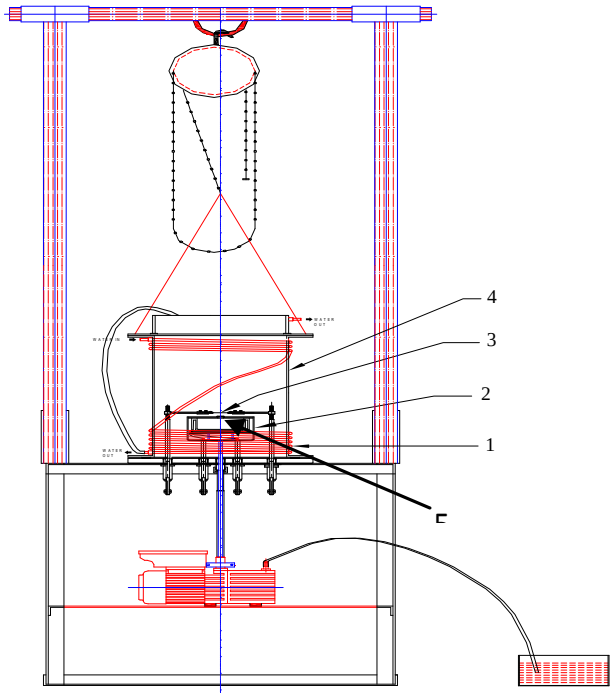

Fig. 1. Schematic diagram of chemical vapor deposition (hot filament) setup [1. Cooling tube, 2. Substrate heater, 3. Activation heater, 4. Reactor chamber, 5. Substrate].

The process pressure during CVD process is continuously measured by a digital vacuum gauge meter (Brand: vacuubrand, German, Model: VAP 5). During experiment, pressure: 0.085 MPa, substrate heater temperature: 800 ^{0}C, activation heater temperature: 1200 ^{0}C, deposition duration: 1 hr is maintained. The weight of the deposited substrate was measured on a high-resolution weighing scale. Gas flow inside the reactor chamber during CVD process is measured by a gas flow meter whose range is 0 to 2.0 liter per minute. This flow meter is connected to the supply line of the gas inside the reactor chamber. Natural gas is used as reactant gas for CVD process. The test sample used in this investigation is stainless steel 202. During tests, each experiment was repeated five times and their average results are presented. Frictional tests were carried out using a pin-on-disc machine. Friction coefficient and wear rate of SS 202 sliding against SS 304 are investigated

before and after deposition. Each test was conducted for 20 minutes of rubbing time with new pin and test sample. Furthermore, to ensure the reliability of the test results, each test was repeated five times and the scatter in results was small, therefore the average values of these tests were taken into consideration.

3. RESULTS AND DISCUSSION

Figure 2 shows the variation of deposition rate (mg/min) on SS 202 with the variation of gas flow rate. Curves 1, 2, 3 and 4 are drawn for gap between activation heater and substrate 10.0, 8.5, 7.0 and 5.5 mm respectively.

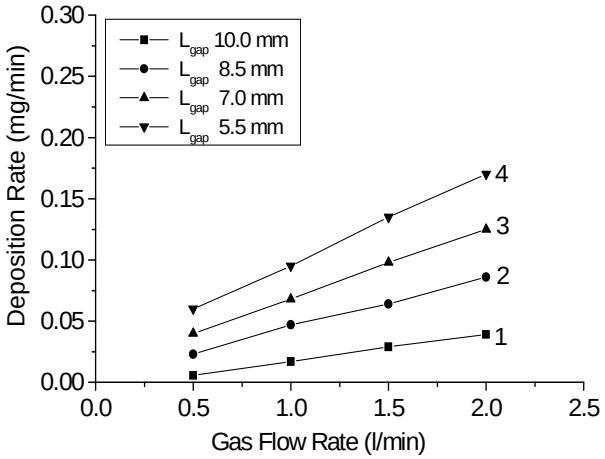

Fig. 2. Variation of deposition rate (mg/min) with the variation of gas flow rate at different gaps between activation heater and substrate for SS 202.

From the curves of this figure it is found that deposition rate increases with the increase in gas flow rate. Results also show that the lower the gap between activation heater and substrate, the higher the values of deposition rate (mg/min) are obtained. Several experiments are conducted to investigate the effects of gas flow rate on deposition rate (μm/min) and these results are presented in Fig. 3. Curves 1, 2, 3, and 4 of this figure are drawn for gap between activation heater and substrate 10.0, 8.5, 7.0 and 5.5 mm respectively. Curve 1 shows that deposition rate increases with the increase in gas flow rate. Similar trends of results are observed for curves 2, 3 and 4. Results also indicate that the lower the gap between activation heater and substrate, the higher the values of deposition rate are obtained. The average surface roughness of SS 202 before deposition was 0.45 μm. After deposition the average value of roughness becomes 0.30 μm. From the obtained results, it is concluded that smoother surface is obtained after deposition than that of before deposition.

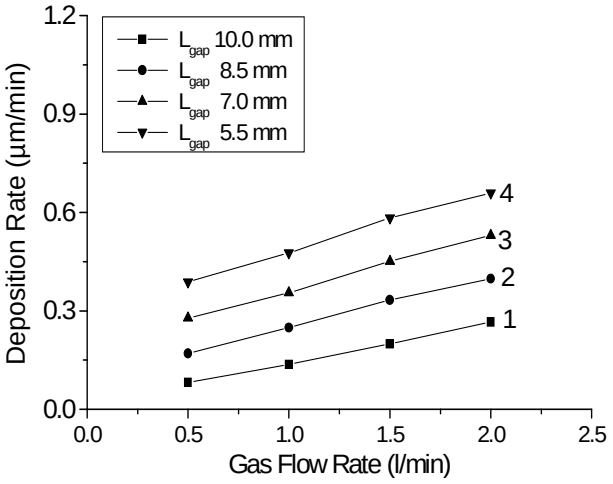

Fig. 3. Variation of deposition rate (μm/min) with the variation of gas flow rate at different gaps between activation heater and substrate for SS 202.

Figure 4 shows the variation of friction coefficient with the variation of duration of rubbing for SS 202. This figure is drawn for sliding velocity 1.0, 1.5 and 2.0 m/s and normal load 15 N and relative humidity 70 %.

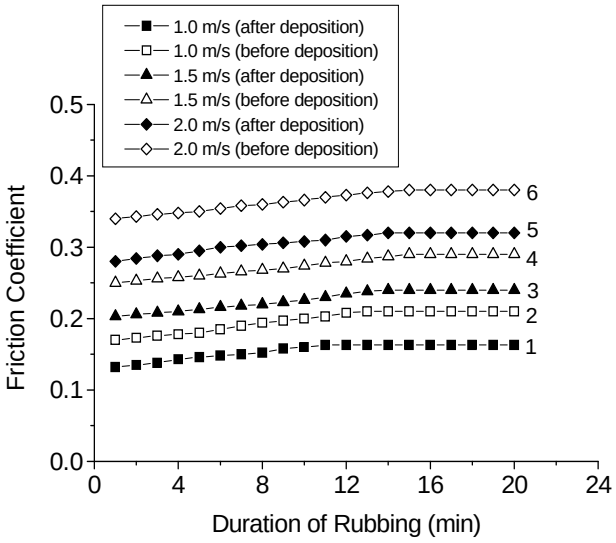

Fig. 4. Variation of friction coefficient with the variation of duration of rubbing at different sliding velocities [Normal load 15 N, Relative humidity 70 %, Surface roughness before deposition 0.45 microns, Surface roughness after deposition 0.30 microns, Substrate: SS 202].

At sliding velocity 1.0 m/s, curve 1 is drawn for after deposition and curve 2 is drawn for before deposition. From curve 1 it is observed that at initial stage of rubbing, friction coefficient is low

(0.132) and then increases almost linearly up to 0.163 and after that it remains constant for the rest of the experimental time. Similarly curve 2 drawn for before deposition a show that at the starting friction coefficient is 0.16 and then increases very steadily up to 0.2 and after that the values of friction coefficient remain almost constant. At starting of experiment the friction force is low due to contact between superficial layer of pin and disc. Then the friction coefficient increases due to ploughing effect and because of roughening of the disc surface. After certain duration of rubbing, the increase of roughness and other parameters may reach to a certain steady value and for this reason the values of friction coefficient remain constant for the rest of the time. Similar results are obtained for sliding velocity 1.5 and 2.0 m/s i.e. the coefficient of friction is lower for after deposition than that for before deposition. Moreover, the higher the sliding velocity, higher the values of friction coefficient are obtained for before and after deposition. These results are in agreement with the results of Chowdhury, Nuruzzaman, Mia and Rahaman for copper-copper, copper-brass, brass-brass, brass-copper pairs [30].

The steady values of friction coefficient at different sliding velocities for before and after deposition are shown in Fig. 5. The value of friction coefficient varies from 0.21 to 0.38 and 0.163 to 0.32 for before and after deposition respectively. This means that the values of friction coefficient after deposition are lower than that of before deposition.

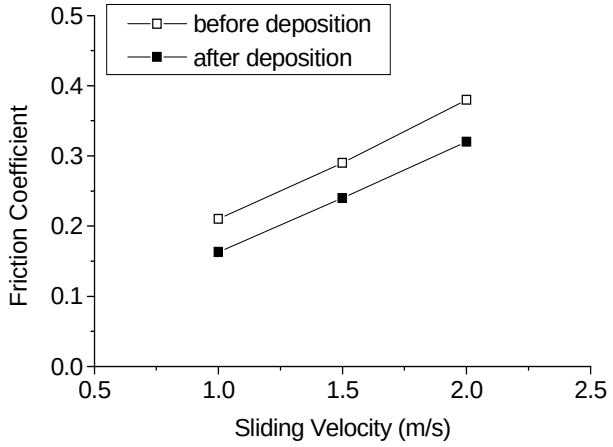

Fig. 5. Variation of Friction Coefficient with the Variation of Sliding velocity [Normal load 15 N, Relative humidity 70 %, Surface roughness before coating 0.45 microns, Surface roughness after coating 0.30 microns, Substrate: SS 202]

Figure 6 shows the variation of wear rate with the variation of sliding velocity before and after deposition. Curve drawn for before deposition indicates that wear rate varies from 1.8 mg/min to 3.05 mg/min while for after deposition, it varies from 0.85 mg/min to 2.1 mg/min with the variation of sliding velocity from 1.0 to 2.0 m/s.

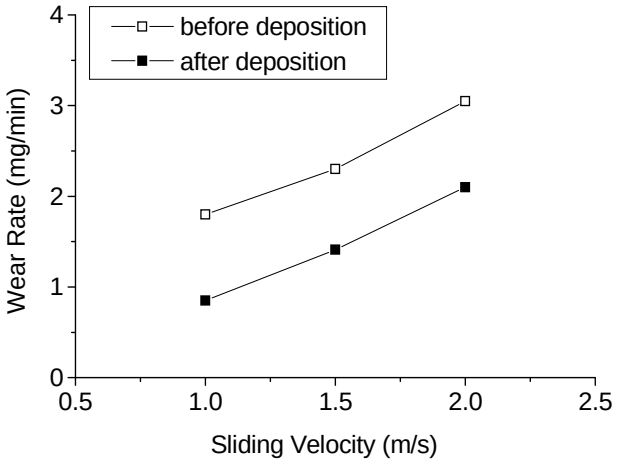

Fig. 6. Variation of Wear Rate with the Variation of Sliding velocity [Normal load 15 N, Relative humidity 70%, Surface roughness before coating 0.45 microns, Surface roughness after coating 0.30 microns, Substrate: SS 202].

That is, the wear rate after deposition is less compared to that for before deposition.

4. CONCLUSIONS AND REMARKS

Deposition rates on SS 202 substrates are significantly influenced by the gas flow rate. Moreover, deposition rates are greatly affected by the gap between activation heater and substrate. Within the observed range, deposition rate increases with the increase in gas flow rate whereas it decreases with the increase in gap between activation heater and substrate. Lower friction coefficient, lower wear rate and better surface finish are obtained after deposition than that of before deposition. It is expected that maintaining an appropriate level of gas flow rate and gap between activation heater and substrate, deposition rate may be kept to some optimum value.

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