CHAPTER 5

CONCLUSIONS AND SUGGESTIONS

5.1 Conclusions

5.1.1 Nitridation and Carburization by Direct Metal-Gas Reaction

The nitrides, carbides and carbonitrides can be deposited on the surface of MJ12 and MJ47 by nitridation and carburization at 1100-1300 K. After nitridation and carburization at 1000 K, neither nitrides nor carbides were detected. Nitride and carbide concentrations seem to be too low or the film may be too thin to be detected. The concentration of nitrides, carbides and carbonitrides were increased with the increasing temperature. The detection of N, C and O using EDX are in agreement with the XRD. The SEM micrographs show that surface morphology of the alloys were effected by the processing temperature and C_2H_2 potential. The Knoop hardness values of the alloys increased with increase in the temperature and C_2H_2 potential. The Knoop hardness values of MJ12 and MJ47 with 1300 K nitridation in 10 $cm^3.s^{-1}$ ammonia and carburization in 0.05 $cm^3.s^{-1}$ acetylene balanced with argon are maximum at 962.2 ± 87.8 and 992.4 ± 79.6 $kg.mm^{-2}$, respectively. The irregular wear rates is controlled by the nitride, carbide and carbonitride phases and their concentrations in the films.

5.1.2 Nitridation by Direct Metal-Gas Reaction

The nitrides can be deposited on the surface of MJ12 and MJ47 by nitridation in NH_3 at 1100-1300 K. Ti and Al were detected using RBS. There were no detection of B and N due to their low scattering cross-section. This leads to the cover of their peaks with background. Film thickness, mass increase, density increase and diffusion coefficient were increase with increasing temperature. Calculated diffusion coefficients of N in MJ12 and MJ47 at 1000-1300 K are 7.89×10^{-18} - 4.06×10^{-17} $m^2.s^{-1}$

and 7.19×10^{-18} - 3.22×10^{-17} $m^2.s^{-1}$, respectively. The EDX spectra reveal the dissolution of nitrogen in the alloy matrices during nitridation. At high temperature nitridation, the particles on the surface of the alloys agglomerated into large grains and can influence the film density. Knoop hardness values and wear resistance of the alloys are increased with the increase in temperature. Knoop hardness values of MJ12 and MJ47 with 1300 K nitridation are maximum at 549.6 ± 66.0 and 553.1 ± 60.9 $kg.mm^{-2}$, respectively. The wear rates of MJ12 and MJ47 with 1,300 K nitridation are minimum at $1.811 \pm 0.683 \times 10^{-8}$ and $1.595 \pm 0.280 \times 10^{-8}$ $mm^3.mm^{-1}$, respectively. The wear rates decreased with an increase in nitridation temperature.

5.1.3 Carburization by Directly Applying Voltages

The carbides could be deposited on the surface of MJ12 and MJ47 by directly applying voltages. After carburization, Ti and C were detected on both alloys using RBS. Although C is a light element, its signal coming from C-riched region was strong enough to be detected. The solid C deposited on the alloy surfaces. MJ47 has higher penetration depth, mass increase and density increase in comparison with MJ12 due to its higher carburization temperature. The EDX spectra reveal the dissolution of carbon in the alloy matrices during carburization process. The analyses show that RBS, XRD and EDX results are in agreement. SEM micrographs show the different surface morphologies of MJ12 and MJ47 which reflect the different surface properties. After carburization, the Knoop hardness values of MJ12 and MJ47 are 360.9 ± 38.0 and 547.3 ± 34.5 $kg.mm^{-2}$, respectively. The Knoop hardness value of MJ47 is higher than that of MJ12 due to its higher penetration depth and film density. The wear rates of MJ12 and MJ47 with carburization are $4.165 \pm 1.472 \times 10^{-8}$ and $3.025 \pm 0.691 \times 10^{-8}$ $mm^3.mm^{-1}$, respectively.

5.2 Suggestions

It is suggested that there are three ways for impure oxygen to diffuse into the chamber during surface modification by direct metal-gas reaction. There were oxygen containing in the gases used in the experiment, the oxygen coming from the

atmosphere when the seal rubber of the cap was soften by heat and the oxygen from the reduction of silica in the porcelain chamber by NH_3. The first one could be improved by using the high purity gases. The second one could be improved by using high temperature materials which have low thermal expansion. The third one could be improved by using high temperature materials which have low thermal expansion and have high resistance to the reduction reaction, for example, quartz. In case of the carburization by directly applying voltages, the impure oxygen was diffuse into the chamber due to the poor contact between the stainless steel caps and the cylindrical glass. It could be improved by the use of the rubber to seal the contact.

The intensity of TiC peak of the alloys with carburization by direct metal-gas reaction and directly applying voltages analysed by XRD were quite low due to low TiC concentration. In the former case, the carbide concentration could be increased by the increase in C_2H_2 potential and carburization time. However, C_2H_2 flow rate would not be exeed 0.1 $cm^3.s^{-1}$, as it balance with Ar for the total flow rate of the gas mixture to be 10 $cm^3.s^{-1}$. In the latter case, the carbide concentration could be increased by the increase in carburization time.

The effect of C_2H_2 potential and temperature on the wear resistance of the alloys were not much evident. It is suggest to increase the carburization time in order to let C_2H_2 potential and temperature to take more effect on the wear resistance. In case of carburization process by directly applying voltages, it is suggest to study on the effect of time and applying voltages on the surface properties of the alloys.

Comparing between direct metal-gas reaction and directly applying voltages, the input powers for the first and second methods are 672.5 W and 274.3-293.4 W, respectively. The power for the first method is more than that for the second. The exposure time for the first is longer than that for the second; especially, during heating up the alloys. Mechanical properties of the alloys treated by directly applying voltages would be better than that of the alloys treated by direct metal-gas reaction.