CHAPTER 5 CONCLUSION

5.1 Summary

The growth and characterizations of the $AlTi_3N$ deposited on unheated substrates by the unbalance magnetron co-sputtering system were conducted on films deposited on suitable substrates according to the analysis techniques involving. The results on the characteristics of the films such as crystalline structure, surface morphology, thickness and microstructure are concluded as following:

The crystallinity and the structure of $AlTi_3N$ thin films deposited on silicon wafers were investigated by XRD measurements. The resulted XRD patterns of $AlTi_3N$ thin films deposited for 15, 30, 45 and 60 min at Ti sputtering currents of 0.6, 0.7, 0.8, 1.0 and 1.2 A are shown in figure 4.6– 4.10. The deposition parameters will directly influence the crystal structure evolution. The peaks observed can be identified that the thin films have polycrystalline orthorhombic structure for all deposition parameters of coatings. The increasing of the deposition time results in an increase in the crystallinity and phase transition of the films. The narrower X-ray diffractions pattern with higher XRD intensity were investigated as increased Ti sputtering current to 1.0 A with fixed deposition time of 60 min. It can conclude that the $AlTi_3N$ thin films deposited at Ti sputtering currents of 1.0 A are highest crystallinity.

The crystal size was determined from Scherrer equation with using full width at half maximum of the x-ray diffraction peaks of (112), (004) and (153) planes. The result from table 4.6 indicate that the crystal size depended on the titanium sputtering current and deposition time which was calculated and varied from 22.9 to 53.4 nm. Moreover, the crystal size were change with the crystallinity of prefer orientation peak in each sputtering current.

Besides the XRD investigation of the crystallinity and structure of $AlTi_3N$ thin films, HRTEM are also employed for the studies. The lattice planes shown for all sputtering currents and deposition times indicating a crystalline structure. The d-spacing indexed in the figure 4.12-4.14 corresponds to the (112), (004), (200), (153) and (243) planes of the crystalline orthorhombic phase of $AlTi_3N$ in the JCPDS-ICDD card no. 51-0724 for all the Ti sputtering currents and deposition times. The crystallinity of $AlTi_3N$ thin films are confirmed by the spotty rings appearing in the electron diffraction patterns and are in good agreement with the XRD results. The diffraction rings from films deposited with Ti sputtering current of 0.6 A for 15, 30, 45 and 60 min correspond to the (112), (004), (200), (153) and (243) planes of the orthorhombic $AlTi_3N$. The same spotty rings patterns were also observed for the films deposited at others currents and deposition times. Moreover, the higher crystallinity of $AlTi_3N$ thin films are appear by the more spotty pattern of the electron diffraction pattern as increase Ti sputtering current and deposition time.

The overall results from the investigation of the surface morphology and thickness of $AiTi_3N$ thin films with AFM are summarized as shown in Table 4.17-4.18. From the AFM analysis, the results from the table explore variations of surface roughness, the grain size, rms roughness value and thickness of $AlTi_3N$ thin films deposited with different sputtering currents of 0.6, 0.7, 0.8, 1.0 and 1.2 A by varying deposition times from 15 to 60 min. The surface roughness were directly depended on sputtering parameters by increase and decreased of rms value as a function of Ti sputtering current with fixed deposition time for all experiment. The effect of deposition time on surface roughness is that for the film deposited with the same sputtering current, its surfaces became smoother over the longer deposition time. For the films deposited with the same sputtering current, the effect of deposition time on the surface roughness was that at longer deposition yields rougher surfaces for sputtering current of 0.6 – 0.8 A. However, the surface are smoother when increase deposition time more than 45 min for the sputtering current of 1.0 A and 1.2 A. The influence of deposition time and sputtering current on the grain size can be concluded that at each sputtering current, the grain size increased with longer deposition times, while it was also increased with higher sputtering currents for all deposition times from 25-45 min.

The thickness of $AlTi_3N$ thin films can be measured from section analysis of 2D-AFM images over across the line region. The study of how Ti sputtering current and deposition time effect to the thickness of $AlTi_3N$ thin films on glass slides were investigated and was concluded as shown in table 4.19. The effect of deposition time on the thickness of the films is straight forward; longer deposition times yield thicker $AlTi_3N$ thin films. The increment of sputtering currents affecting the deposition rates which results thicker films for the same deposition time.

The cross-sectional observations from Figure 4.20 indicate that the films have columnar structure. The changing of cross-section microstructure change from columnar pattern and individual of each grain to columnar with more open pores or void through the surface between columns were observed by longer deposition time.

For comparison purpose the thickness of $AlTi_3N$ thin films were analyzed by two methods; AFM and SEM, the thickness of the films obtained from all the methods were a little bit different to another one.

The crystal structure still exhibit a stable $AlTi_3N$ structure when reduce the Al sputtering current from 0.6 to 0.2 A.

This research can be concluded that $AlTi_3N$ thin films deposited on unheated substrates no substrate bias, long distance target-substrate and low sputtering current by the DC unbalanced magnetron co-sputtering method with sputtering currents of 0.6, 0.7, 0.8, 1.0, and 1.2 A for deposition times of 15, 30 45 and 60 min and particularly having a long target-substrate distant of 130 mm are in nanostructure $AlTi_3N$. It was found that the crystalline structure is strongly depends on the Ti sputtering current and the deposition time for the studied range. The crystallinity of the $AlTi_3N$ thin films increases as the sputtering current increases. The grain size of $AlTi_3N$ thin films is in the range of 13.7-125.1 nm. In addition, the grain size depend the sputtering current and the deposition time increases. Moreover, the stable $AlTi_3N$ structure was observed by varying the Al sputtering current.

5.2 Future Works

Although the results of $AlTi_3N$ thin films from the processes are in nanocrystal structure for all deposition conditions and having properties depend on the different in deposition parameters, thus the quality of the film can be further improved by adjusting the processes. The following works are recommended as a follow-up to this study:

1. Study the different parameters for prepare the (Ti,Al)N thin films.
2. Effect of deposition parameter on the chemical composition of thin film deposited by unbalanced magnetron sputtering co-sputtering method.
3. More measurements on the mechanical and tribology properties of the films deposited under different parameters as studied in this experiment.