Optical and structural properties of Cr and Ag thin films deposited on glass substrate

A. Rauf, K. Ahmed, F. Nasim, A. N. Khan and A. Gul
Institute of Industrial Control System, P. O. Box 1398, Rawalpindi, Pakistan
E-mail: abdulrauf3134@yahoo.com

Abstract. Most of the rotating or noting patterns are being developed by using silver plating through chemical coating. Silver layers deteriorate with the passage of time and become less reflective while undergo through cleaning process due to its softness and the results become unpredictable. In this paper an alternate method for development of above mentioned pattern has been demonstrated. Chromium (Cr) and Silver (Ag) thin films of 200nm and 160nm thick respectively have been realized using electron beam evaporation (PVD technique) on quartz substrate. Structural analysis has been carried out by XRD and SEM while optical transmission/reflection has been studied using spectrophotometer. XRD analysis shows that Ag coated thin films exhibit FCC structure while Cr coated thin films reveals a BCC structure. SEM analysis shows almost smooth and uniform surfaces in both cases. After passing through high and low temperature cycles it was found that the results of pattern structures developed by chromium coating were more reliable than obtained through silver plating process.

1. Introduction
Thin film chromium (Cr) and silver (Ag) coatings are used in photo masks, developing the desired reticules and pinhole on glass substrate integrated circuits, optical beam splitters etc. There are some other applications like thin film resistors, capacitor plates and antimagnetic shielding materials [1-2]. The chromium oxide (Cr2O3) thin films exhibit high hardness, high wear and high corrosion resistance which are important properties for protective coating applications [3-4].Hardness and wear resistance are important properties of chromium oxide for protective coating applications. In this regard by controlling the coating deposition parameters high hardness and good wear resistance can be obtained.

Chromium thin films are characterized either entirely on the electrical properties [5-10] or entirely on structural properties [11-14].

There are different techniques to deposit Cr/Cr2O3 coatings e.g., sputtering, electron beam evaporation, CVD process, electrochemical deposition, reactive pulsed laser ablation technique and chemical spray pyrolysis depending on different applications.

Optical applications of Cr2O3 / Cr thin films such as solar energy conversion and solar energy shielding films for windows have been made [3, 15-17] indicating an appreciable order of transmittance in the visible and near IR region where as the reflectance spectrum indicated a moderate value over the UV, visible and NIR wavelength region.

In this paper optical and structural properties of chromium (Cr) and silver (Ag) thin films deposited on glass substrate are explored for further optical applications.
2. Experimental
Chromium (Cr) and silver (Ag) thin films of thickness 200nm and 160nm respectively have been deposited through PVD technique on quartz substrates 25mm diameter and 2mm thickness. The samples (05 each) were properly cleaned with a mixture of either alcohol (80% x 20% by volume) in clean environment i.e., class 100 super clean table before placing them in an ultra-high vacuum system. Thin film coating technique was employed by using optical design software. Balzers vacuum coating machine was used for film deposition at the base pressure of 2.0 x 10^{-7} Torr. 99.99% pure chromium and silver grains of 50µm were used as source materials. Figure 1 shows the schematic diagram of thin film vacuum coating system. The detailed experimental technique is explained elsewhere [18].

During vacuum coating process, 50 ~ 55nm thick layer for both the cases was achieved in one routine process. The samples were again cleaned with the same mixture and the process is repeated for another 50 ~ 55nm thick layer in order to remove the pin holes from the coated surface. The process is repeated till the desired layer thickness and smooth surfaces for both cases were achieved.

The microstructure of coated samples were examined using X-ray diffractometer. The surface morphology of coated surfaces was characterized by SEM. The optical properties (Transmission/Reflection) of coated surfaces were measured using SHIMADZU UV-3100 photo-spectrometer in the spectral range 300 to 3200nm.

Figure 1. Schematic diagram of thin film coating system

3. Results and discussions
Cr and Ag thin films developed through e-beams evaporation on glass substrate were analyzed. Two methods i.e., XRD and SEM were used to study the structural behavior while the optical studies were carried out using the photo-spectrometer.

3.1. Structural analysis
Figures 2 & 3 show the X-ray diffraction (XRD) patterns and optical microscopy of e-beam deposited 200nm Cr thin films on quartz substrates. It can be seen from Figure 2 that only one peak with 20
about 43.8° is indicative with bcc (110) orientation structure as indicated elsewhere [1]. Due to efficient vacuum system, base pressure in the range of 2.0 x 10⁻⁷ Torr, almost no impurities are present at the surface of chrome coated thin films suggesting the preferred orientation of e-beam deposited Cr films on glass substrate is bcc (110). Figure 3 represents the optical micrograph of chromium coated thin films on quartz. It is clear from the figure that a smooth pattern is achieved which also supports the high purity chromium thin films.

The analysis of the elemental compositions for chromium thin films deposited on glass substrate has been carried out through SEM-EDS spectrum analysis. Figure 4 shows the EDS spectrum of Cr films. It is clear that Cr peaks are prominent on the spectrum. Only one Si peak is observed which may be due the quartz substrate material. This also indicates that a smooth and homogenous coating is achieved.

Figures 5 & 6 show the X-ray diffraction (XRD) patterns and optical microscopy of e-beam deposited 160nm Ag thin films on quartz substrates. From figure 5 it is clear that four peaks with 2θ at 37.35°, 43.5°, 63.75° and 76.65° of silver coated films at different orientation with fcc structure have been found. The corresponding (h k l) values are (111), (200), (220) and (311). It is also clear from the Figure 5 that only silver peaks are present throughout the coated surface indicating the purity of the coated films. Figure 6 shows the optical micrograph of silver coated thin films showing a smooth, highly pure and homogenous structure of the silver plated films.
Figure 5. XRD pattern of Ag coated thin films on quartz

Figure 6. Optical Microscopy of Ag coated thin films on quartz

Figure 7 shows the SEM-EDS spectrographs of silver coated thin films deposited on quartz. It can be seen from the figure that only one element i.e., silver is present throughout the coated surface. This indicates the sustainability of vacuum coating system.

Figure 7. SEM-EDS spectrum of Ag coated thin films on quartz

Figure 8. Transmission Vs. wavelength for Cr and Ag coated samples

3.2. Optical analysis
Spectral transmittance/reflectance T/R of Cr and Ag thin films has been measured at wavelength 0.3<\lambda<3.2 \mu m using UV-Visible spectrophotometer. Figure 8 shows the transmission vs. wavelength spectra for 200nm and 160nm thick Cr and Ag coated thin films respectively.

The optical studies indicate that for Cr coated samples, there is no transmission in the visible range i.e., from 300 – 700 nm wavelength. The transmission increases from 1000 nm and reaches maximum value of about 4.26% at 2100 nm and then decreases drastically to minimum value (0%) at 2750 nm. The reason for such a low transmission is due to the high film thickness (200 nm). As the coated film thickness increases the components become mirror like and hence transmission decreases.
In case of Ag coated samples the transmission increases up to 18% in the visible range (from 300 ~ 700 nm wavelength). The transmission decreases to about 10% in the IR region (800 ~ 1800 nm wavelength) and then starts increasing beyond this region. It should be noted that the film thickness in this case is less (160 nm) as compared to Cr film thickness so the transmission in the visible region appears. In the IR region, the behavior of the spectrum is almost same instead that the magnitude of transmission is somewhat higher due to less film thickness.

4. Conclusions
Cr and Ag thin films of thickness 200 and 160 nm respectively have been prepared on glass substrate by e-beam evaporation at a pressure of 4.66 x 10^-5 Torr. XRD study shows that the thin films are amorphous in nature, while SEM study shows that the growth of thin films is uniform and smooth throughout the surface. The elemental composition has been studied through SEM-EDS analysis indicating the pure Cr and Ag elements are present throughout the coated surfaces. Optical studies in Cr coated samples indicate a very small transmission in IR region where as no transmission in visible spectrum showing the mirror like behavior. In case of Ag coated samples there is an appreciable transmission in visible region while the same behavior is observed in IR region due to the less film thickness as compared to Cr coated samples. After passing through the environmental tests it was found that the results of pattern structures developed by chromium coating were more reliable than obtained through silver plating process. It is due to the fact that the bonding of Cr with the glass is strong as compared to Ag and hence Cr coating with stands in severe environment conditions.

5. Acknowledgement
The authors acknowledge the structural analysis group in obtaining the XRD and SEM data and Mr. Sajid Mehmood (optical analysis group) for developing thin films and valuable contributions for providing the optical analysis data.

6. References
[1] Kulkerni A K and Chang L C1997 Thin Solid Films 301 17
[2] Holloway P H1980 Solid State Technology 23 109
[3] Julkarnain M D, Hossain J, Sharif K S and Khan K A 2011 J. of Optoelectronics and Advanced Materials,13(5) 485
[4] Pang X, Gao K, Lou F, Yang H, Qiao L, Wang Y and Volinsky A A 2008 Thin Solid Films 516 4685
[5] Gould P A 1965 Br. J. Appl. Phys. 16 1481
[6] Hara H and Sakata M 1977 J. Phys. Soc. Jpn. 43 468
[7] Udachan L A, Shivaprasad S M, Ashrit P V and Angadi M A 1980 Phys. Status Solidi 60 K191
[8] Mehanna E A, Araj S, Helbig H F, Aidun R and Kattan N A 1987 J. Appl. Phys. 61(8) 4273
[9] El-Hiti M A, Ahmed M A and El-Shabasy M 1989 J. Mater. Sci. 24 329
[10] Angadi M A and Udachan L A 1981 J. Mater. Sci. 16 1412
[11] Ravipati D P, Haines W G and Dockendorf J L 1987 J. Vac. Sci. Technol. A5 (4) 1968
[12] Duan S L, Artman J O, Wong B and Laughlin D E 1990 J. Appl. Phys. 67(9) 4913
[13] Wang D D and Oki T 1990 J. Vac. Sci. Technol. A8 (4) 3163
[14] Norenberg H and Neumann H G 1991 Thin Solid Films 198 241
[15] Hutchins M G 1983 Surf. Tech.20 301
[16] Geotti-Bianchini F, Guglielmi M, Polato P and Soraru G D 1984 J. Non-Crystal. Solids 63 251
[17] Xiaolu Pang, Kewei Gao, Fei Luo, Yusuf Emirov, Alexandr Levin A and Alex Volinsky A 2009 Thin Solid Films 517 1922
[18] Ahmed K, Khan A N, Rauf A and Gul A 2014 IOP Conf. Series: Materials Science and Engineering 60 012016