Selection of Materials and Techniques for Performance Coatings

G. Vergason and S. Gaur, Vergason Technology, Inc., Van Etten, NY

Key Words: Automotive, Arc vaporization, Sputter deposition, Physical properties

ABSTRACT

Designers of products to be metalized are constantly searching for new marketing advantages to enhance their products. Vacuum coaters can apply a variety of materials with numerous deposition processes to provide surface coatings that are environmentally safer, better performing and lower in cost than previously used coatings. This paper will focus on the use of sputtering and cathodic arc deposition techniques for the application of aluminum, stainless steel, nickel/chromium and chromium materials for decoration and reflectivity on ABS, PC and their blends. We will contrast the reflectivity and surface roughness results between the different materials and deposition techniques.

INTRODUCTION

For many years both vacuum metalization and wet plating techniques have been used to coat plastic substrates for automotive, decorative and reflective applications. Due to increased regulation of waste products and difficulties of masking with wet plating operations, vacuum processing has gained popularity with directional control of the coating deposition and higher accuracy masking using thermal-set and vacuum formed materials [1].

Automotive designers have a variety of materials that can be deposited with several techniques yielding different reflectivities, color and surface texture. Processing time for the coating application can be optimized by selecting the best-suited deposition technique and material.

Traditionally since aluminum rapidly oxidizes, forward lighting products were base coated, aluminum metalized and top coated using high-temperature paint products for the base and top coatings. This method of metalization protection can yield runs, drips, included dust and dry spray that will give the aluminum coating a less than desired quality often observed with modern clear lens headlights.

This has been greatly improved with the use of unbased coated substrates, aluminum metalization and HMDSO (hexamethyldisiloxane) top coatings [2]. Improving the quality of the molded substrate and eliminating the base coating has moved the metalization process upstream in the manufacturing model allowing for savings of both time and money.

Argent painted park and turn, rear and interior lighting substrates have virtually been eliminated with the introduction of chromium, nickel/chromium, stainless steel and titanium coatings. Today's lighting engineer can select the deposition technique and material to enhance the performance and appearance of clear lens products.

Thermal evaporation, a widely used process for the deposition of aluminum with subsequent topcoatings of paint or HMDSO, is limited in the variety of materials that can be deposited. Lower melting point materials are preferred as higher melting point materials often require a complete filament change with each coating cycle for consistent coating performance [3].

We will review sputtering and arc technologies and the materials that have been utilized in automotive and decorative industries.

PRODUCTION EQUIPMENT USED

Coating Equipment

Equipment used for all experiments conducted were production systems in their typical dirty, wet and full states (not clean, dry and empty). The VTI® Press-Side® 3000 was used for the sputtered coatings. VTI Press-Side 2000 was used for the arc deposited coatings. VTI Press-Side 1000 was used for the thermally deposited coatings. All systems utilized production fixtures and used source materials (sputter targets and arc cathodes).

Substrates and Analysis

1 X 3-inch glass slide substrates were masked and taped to fixturing discs for coating. Slides for sputtered depositions were rotated 3-inches from the sputtering targets. Slides for the arc depositions were rotated 6-inches from the arc source. Slides for the thermal depositions were statically arranged 12-inches from the tungsten filaments. The flat surface of the slides were positioned towards the deposition devices.

Thickness and roughness testing was performed with a Tencor P-10 Profilometer. Reflectivity measurements were performed at 514nm wavelength with an Ocean Optics SD-1000 Spectrometer. Microscopy was performed with a JOEL JSM-840 Scanning Electron Microscope.

42nd Annual Technical Conference Proceedings (1999) ISSN 0737-5921

EXPERIMENTS

Reflectance of Materials by Deposition Technique

Aluminum, 300 series stainless steel, nickel/chrome (80/20), chrome and titanium were deposited using sputtering, arc or Thermal deposition techniques. Table 1 shows the measured reflectance percentages from the glass slides, by the deposition technique and the material deposited.

Table I. Reflective percentages by deposition technique and material deposited.

	Al	**SST**	**NiCr**	**Cr**	**Ti**
Sputtering	92	60	59	63	
Arc		45		40	50
Thermal	93		45		

It can be noted that the reflectivities measured from the sputtered coatings closely follows reported percentages at 500 nm [4]:

Aluminum	92%
Stainless Steel	60%
Nickel	62%
Chrome	65%
Titanium	50%

Arc deposited materials measured lower than normal reflectivities due to included nitrogen which contaminated the films and microparticles on the surface. The roughness differences of sputtered and arc SST can be observed in Figure 1a and 1b. All micrographs were taken at 3,500X, 65 degree tilt.

The thermal aluminum coatings and the sputtered aluminum coatings had similar reflectivities with slightly different surface profiles. This is shown in Figure 2a and 2b. Thermal NiCr coatings were slightly less reflective than the sputtered coatings. This could be due to alloying of the tungsten filament with the evaporant at the required higher melting temperatures. Figures 3a and 3b show the comparisons between thermal and sputtered nickel/chrome coatings.

Thickness vs Reflectance and Roughness - Sputtering

For all materials deposited, the reflectance increases with thickness at first and then levels out as shown in Figure 4. Aluminum coatings were the most reflective, followed by chrome, stainless steel, and nickel/chrome, respectively. The similarity of the chemical composition of the last three coatings should be noted as the reflectance values for these are close to each other. When using this information for practical applications, coating thickness and required reflectance should be weighed against the cost of the material and the designers color requirements.

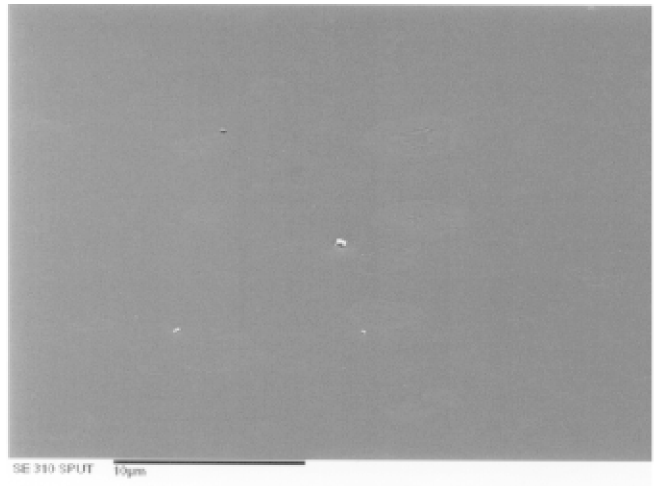

Figure 1a. Sputtered SST

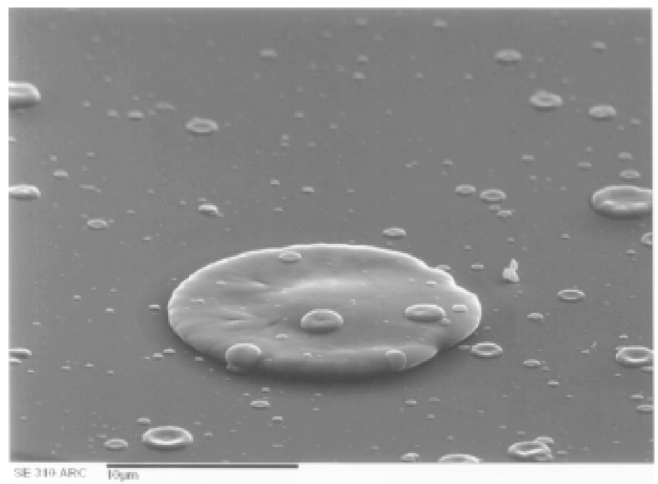

Figure 1b. Arc SST

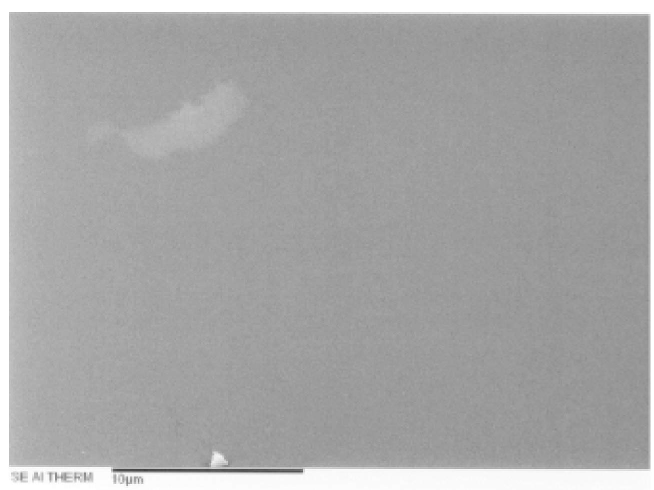

Figure 2a. Thermal Al

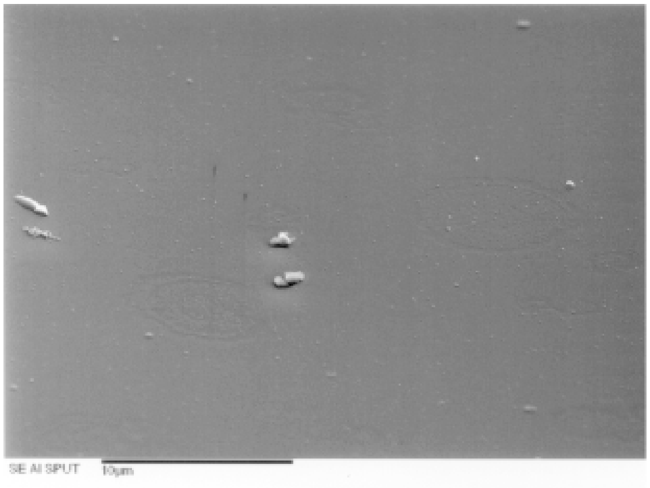

Figure 2b. Sputtered Al

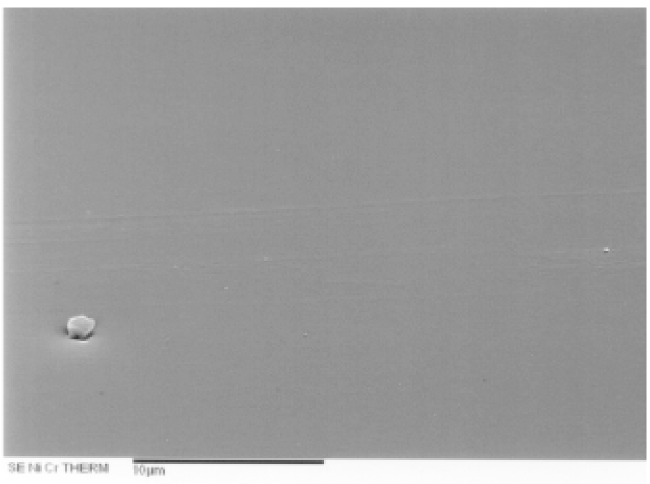

Figure 3a. Thermal NiCr

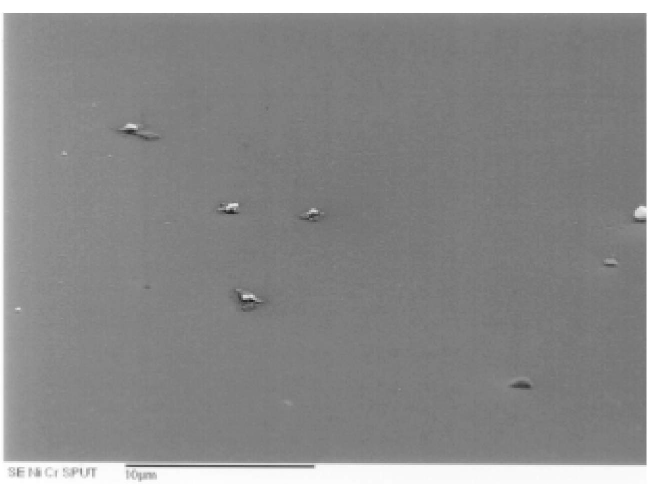

Figure 3b. Sputtered NiCr

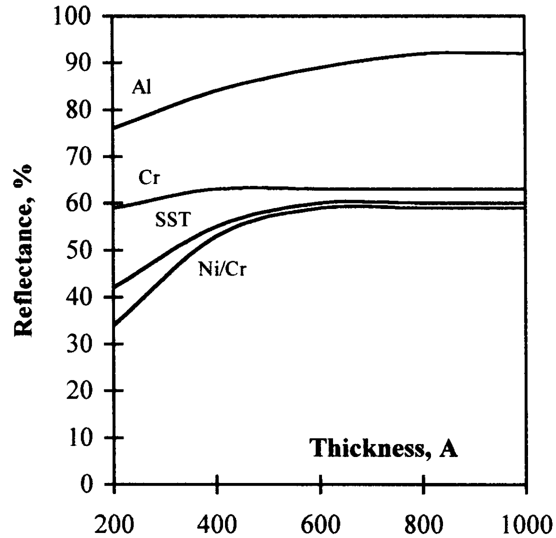

Figure 4. Thickness vs Reflectance - Sputtering

Total roughness (Ra), measured in angstroms (Å) is the average deviation in roughness from the center line of the scanned measurement using profilometer. As shown in Figure 5 the roughness in most cases, increases with coating thickness. For chrome, the roughness increases minimally with thicker coatings. Nickel/chrome, aluminum, and stainless steel increase respectively with coating thickness, with stainless steel being the roughest deposited films.

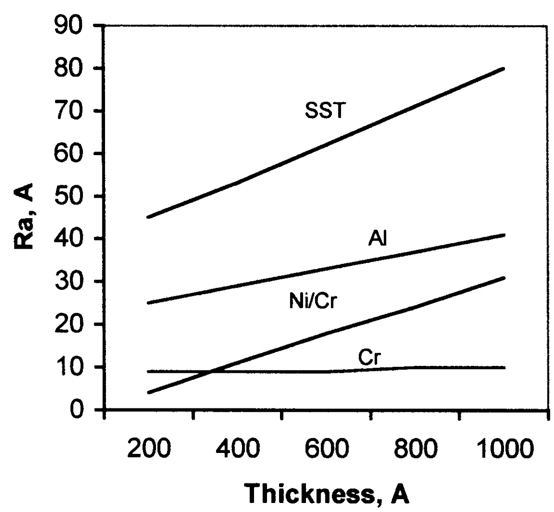

Figure 5. Thickness vs Total Roughness (Ra) -Sputtering

Revolutions vs Roughness - Sputtered Chrome

Tests were performed to investigate the influences of different rotational speeds with the same total coating times.

As it shows in Figure 6, the surface roughness increases with number of revolutions even if the total coating time is the same.

It means greater number of passes in front of sputtering gun introduce undesirable surface roughness in the coating. A single pass deposition is favored by Cambey et al [5] in their studies on sputtering.

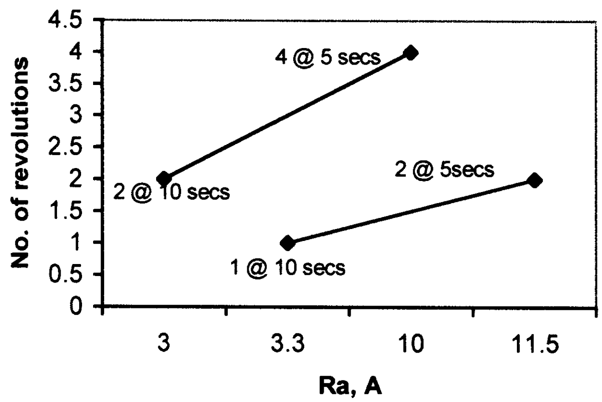

Figure 6. Number of Revolutions vs Ra for Sputtered Chrome

Thickness vs Reflectance and Roughness - Arc

Thickness vs roughness results of stainless steel, chrome and titanium are shown in Figure 7. As noted, the roughness of the stainless steel coating is considerably higher than the chrome and titanium coatings. Roughness of the chrome and titanium coatings are comparable. Chrome arc coatings were equal in roughness to the chrome sputtered coatings with a Ra of 10 to 15Å.

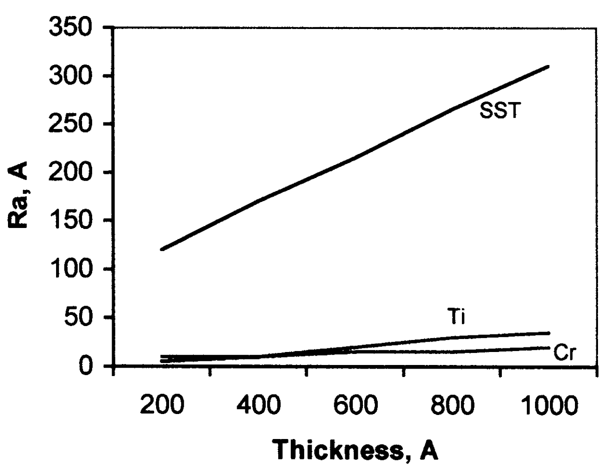

Figure 7. Thickness vs Total Roughness (Ra) - Arc

Table II compares the Ra of sputtered, arc and thermal depositions of the materials reported. Arc produces a rougher coating using cathodes of lower melting point materials.

Table II. Comparative Ra (Å) of sputtered, arc and thermal coatings

	Al	SST	NiCr	Cr	Ti
Sputtering	24-38	44-78	4-30	10	
Arc		120-300		10-18	5-35
Thermal	2-5		3-6		

The reflectance results of titanium, chrome and stainless steel are shown in Figure 8. The reflectance for titanium increases with thickness at first and then levels out to about 50%. The coatings of chrome and steel, on the other hand, decrease slightly with thickness.

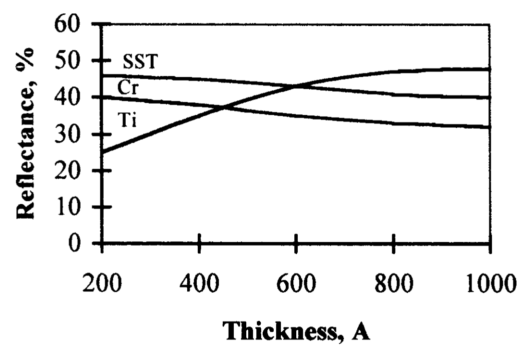

Figure 8. Thickness vs Reflectance - Arc

CONCLUSION

With thermal evaporation, cathodic arc and sputter depositions, today's designer can select from aluminum, stainless steel, nickel/chrome, chrome, titanium and other materials for direct replacement of VOC containing paint products for decorative and reflective applications. These technologies and materials bring tailored solutions, flexibility, cost savings and improved quality yields to a variety of markets.

Of the three deposition techniques, sputtering offers the widest range of coatings with a high degree of process control and production repeatability.

REFERENCES

1. G. Vergason and A. Papa, "Rapid Cycle Coating Techniques for Cell Manufacturing," SVC, 40th Ann. Tech. Conf. Proc. (1997)

2. H. Grunwald, J. Henrich, J. Krempel-Hesse, W. Dicken, S. Kunkel and G. Ickes, "Rapid, High-Quality Metallization of Plastic Parts," SVC, 40th Ann. Tech. Conf. Proc. (1997)

3. D.V. Rigney in Metals Handbook Ninth Edition, W.G.Wood, Coordinator, American Society for Metals, Ohio, p.387, 1982.

4. Handbook of Chemistry and Physics,79th Edition, D.R.Lide, Ed.-in-Chief, CRC press, NY, 1998.

5. L.A.Cambey and S.Weinig, "Sputtering and its Applications - the Present Status," Advances in Surface Coating Technology-an International Conference (1978).