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Publication date:
2010

Document version
Early version, also known as pre-print

Citation for published version (APA):
Amigo Rubio, J. M., Bro, R., Ostra, M., Ubide, C., & Vidal, M. (2010). *Flatbed scanner imaging for exploring the quality of nickel-electroplating deposits*. Paper presented at 7th Colloquium Chemiometricum Mediterraneum (CCM VII 2010 - Granada), Granada, Spain.

FLATBED SCANNER IMAGING FOR EXPLORING THE QUALITY OF NICKEL-ELECTROPLATING DEPOSITS

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Abstract

Desktop flatbed scanners are very well-known devices that can provide digitized information of flat surfaces. They are practically present in most laboratories as a part of the computer support. Several quality levels can be found in the market, but all of them can be considered as tools with a high performance and low cost. The present paper shows how the information obtained with a scanner, from a flat surface, can be used with fine results for exploratory purposes through image analysis. The samples used were steel sheets nickel-plated in an electrodeposition bath. The quality of the final deposit depends on the bath conditions and, especially, on the additives concentration in the bath. Some additives become degraded with the bath life and so is the quality of the sheet finish. Analysis of the scanner images can be used to follow the evolution of the metal deposit. Principal Component Analysis (PCA) is applied to find significant differences in the coating of sheets, to find out directions of maximum variability and to identify odd samples. The results found are compared with those obtained on the same plates by means of specular reflectance, which is here used as a reference technique.

Keywords - Image Analysis, Scanner, PCA, Nickel electrodeposition, Coating quality.

INTRODUCTION

Several techniques have been used to obtain digital images for different purposes; they include some types of spectroscopy, digital cameras, microscopy or scanners and they have been applied, for instance, in food [1] or pharmaceutical [2] industry. All this instrumentation is usually quite expensive but flat-bed scanners are relatively inexpensive and they can digitize images into a stored array of pixels within a computer. Flatbed scanners have not been used much for quality assurance, but some applications for quantification can be found in the literature [3,4]

An image is intrinsically a multivariate system as far as it is a wide collection of data, stored in pixels, each of them usually highly correlated to its neighbours [5]. The numeric information in each pixel can be decomposed into three channels corresponding to the red, green and blue light colours, which are added in various ways to reproduce a broad array of colours; this is known as the RGB model. Thus, a colour in the RGB model is described by indicating how much of each component (red, green, blue) is included and each component can vary from zero to a defined maximum value. When computing the component values they are often stored as integer numbers in the range 0 – 255; that is the range that a single 8-bit byte can offer. To handle such a great amount of data, proper tools are needed. One way to handle and analyse the results obtained is through Principal Component Analysis (PCA) as chemmometric tool. The fundamentals of PCA have been explained elsewhere [6].

In the present paper, sheets nickel-plated in an electrolytic bath are scanned and decomposed in the three channels of the RGB model; PCA is applied to the resulting image. This allows to follow the changes in the quality of deposits as the bath is being used. On the other hand, the value of scores and loadings of the PCA model can be used to evaluate the quality of future deposits. Similar results are obtained when compared with specular reflectance (SR) measurements. A critical evaluation of both techniques is made.

EXPERIMENTAL

An amount of 53 stainless steel sheets was electroplated using a commercial nickel bath (Supreme Plus Níquel Brillante, Atotech formulation). A Haake water bath thermostat controlled the temperature of the nickel bath (60±0.5)º C. A rectifier ± 20A/30A from HQ power (model no. PS 3020) was used for electrodeposition. SR was measured with an Ocean Optics USB 4000 spectrometer, an UV-VIS-IR DT-MINI—2 GS light source and an UV/Vis Premium 400 µm Reflection Probe (2 m long). The scanner was an Epson Stylus DX 7400. The UNSCRAMBLER 9.7 and Matlab 7.4.0 were used as software packages.

Image analysis. Scanning of the whole set of sheets was randomly carried out on both sides of the sheets and the result was treated as a bmp image. An amount of 51 x 276 pixels per sheet was acquired and transformed to the RGB model. This means a total amount of 42,228 colour data points per sample.

Specular reflectance. Spectra were registered at five points per side in every sheet with a template. Wavelengths between 237 and 568 nm (every 0.21 nm were acquired. As a result, each sheet was characterized by 15,762 data points (approximately). A mirror was used as a reference and spectra were corrected for dark current.

RESULTS AND DISCUSSION

Scanner stability. There is a need to assure that changes in the sheet image do come only from the nickel coating and not from the scanner or its associated processing. This is the way to assure that lighting conditions are maintained. In this case a home-made inner standard with 10 patches was used (Fig.1). Black, grey and white colours were included because colours in scanned images evolves along a grey scale. Dark green was used as a bottom and top colour in order to see if lighting conditions keep stable along the sheet length. It was proved that lighting conditions were stable for, at least, one week. Otherwise, a colour correction should have been accomplished [7].

Fig.1. Scanned image of the inner standard close to an electroplated nickel sheet

Sheets scanning. Fig. 2(a) shows the scanned images of 5 out of the 53 measured sheets. The evolution along the electroplating process can clearly be seen. The first sheets, highly-bright, look mainly black, whereas the last electroplated sheets are mainly grey. This evolution could also be appreciated at first glance, with no need of scanning, but it would be helpful to establish an objective technique capable of measuring the plating evolution by a colour scale. If the images in Fig. 2(a) are decomposed into the RGB channels, the evolution can more clearly be appreciated (Fig. 2(b), red channel). The blue colour dominates in the first sheets, whereas orange dominates in the last ones.

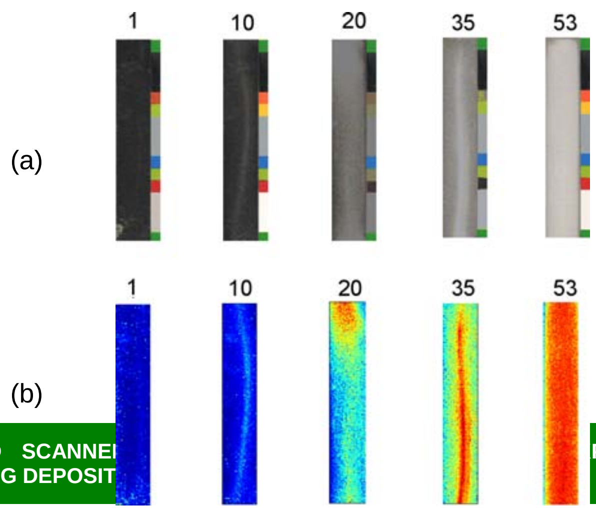

Fig. 2. (a) Scanner images for the sheet number 1, 10, 20, 35 and 53 of the electroplating nickel bath. (b) Red channel image for the same sheets.

The colour evolution is first appreciated in the centre of each sheet as it can be seen from the figure. This is due to the apparition of a dull-stripe that grows up from the centre to the corners and it is indicative of the loss of brightness. The stripe size can be related to the sheet quality because samples with a wide and white stripe would not be industrially accepted. The reason for this effect is that the nickel electrodeposition is not a homogeneous process. The loss of quality is firstly appreciated in the centre of the sheets since the density of current is, in general, lower in the centre than in the corners.

PCA of sheets images. PCA analysis of the images unfolded as a pixels x RGB matrix was carried out in order to see if there are significant differences between the two faces of the sheets and to find out the directions of maximum variability or possibly to identify odd samples. PC1 accounts for a data variability of 96.46%, whereas PC2 explains 0.75% and PC3 only a residual 0.09%. No significant differences seem to exist between the two faces, indicating that stirring during electrodeposition was efficient. PC1 explains most of the information, and is the main indicator of the sheets quality evolution. Fig 3(a) shows how the PC1 score increases with the sample number and this is related to the fact that deposits go from being totally glossy-bright to completely grey. The values of PC2 scores are shown in Fig 3(b). There is a "*W*" shape that seems to be related to the non-uniformity of the deposit and the appearance of a dull-centre-stripe in the sheets as the bath is consumed. Highly-bright, medium-bright or totally light-grey sheets (homogenous aspect) are characterized by a high-score value and are distributed at the top of the graph. Sheets that are medium-bright in its central part and highly-bright in the corners or grey in its central part and medium-bright in the corners (non-homogeneous) are distributed at the bottom of the graph because of their low score value.

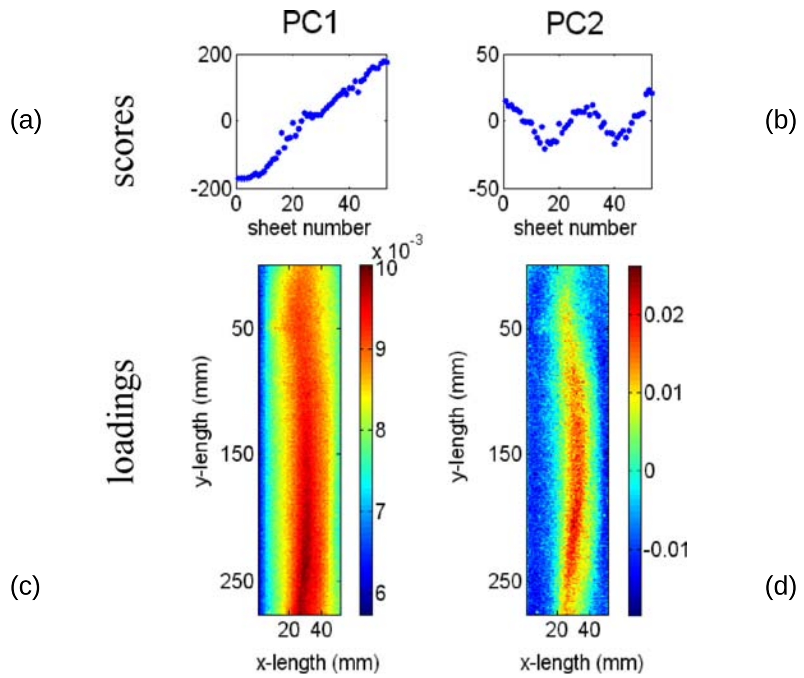

Fig. 3 (a) PC1 scores and (b) PC2 scores as a function of the sample (sheet) number. (c) and (d) are loadings of the corresponding scores.

These results are confirmed when the loadings from the two first PC are taken into account. Fig. 3(c) and (d) show the loadings of PC1 and PC2 respectively, rearranged into images. That is, the colour intensity in every pixel (represented in the colour scale attached) is zenithally projected onto the plane where the different pixels are represented. Red colour is assigned to high values of the loading and it means that the pixel bears relevant information; blue colour indicates low values of loading, which means pixels with irrelevant information. The loadings from PC1 and PC2 confirm the conclusions of Fig. 2; that is, the central part of the sheet is the most sensible to the loss of quality and the numerical value of the loadings is higher in that region.

Specular reflectance. Fig. 4 shows the reflectance spectra for several sheets along the bath live. When PC1 scores of image are compared to those obtained when PCA is applied to specular reflectance spectra (90º), a high correlation (R^2=0.993) is found. PC2 scores from specular reflectance spectra show the same "*W*" shape as scores in Fig 2 (b). It can be stated that the information obtained when the proposed image technique is used is similar in some aspects to the one obtained with the more usual specular reflectance (SR). However, some critical evaluation can be made.

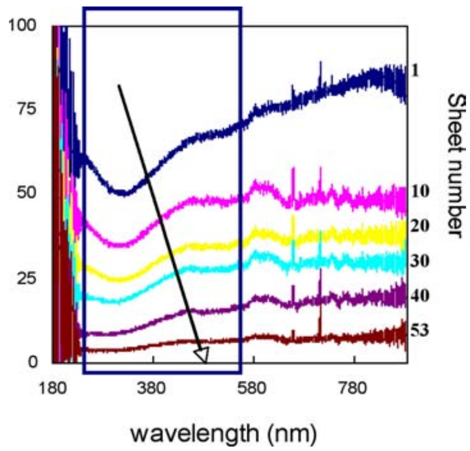

Fig. 4 Specular reflectance spectra for different sheets measured at the central point.

Critical evaluation. Both image analysis and specular reflectance provide similar information on quality of the plating process. The interpretation of SR data are easier, but image analysis with flatbed scanners provides a great amount of data of the whole entire sheet surface, whereas SR only provides information on a few points of the sheet; consequently, irregularities on the surface are easier to discover by the scanning process. Measurements are more easily taken with a scanner and a much better reproducibility is obtained. Finally, a general purpose scanner can amount to about 50€, but RS measurements need instrumentation for at least 100 fold.

CONCLUSSIONS

Image analysis of nickel-plated sheets with a flatbed scanner is an easy and cheap way to collect a great amount of data to implement a robust methodology for evaluation of plating quality. The colour decomposition in the RGB model allows a fast identification of different finishes on the same sheet. It avoids some problems that arise in SR measurements from the stability of the light source and the critical alignment between signals. It constitutes, therefore, a simple and affordable way of providing valuable qualitative knowledge about the obtained final nickel deposits through easy multivariate PCA analysis. This can help industries to take decisions on the suitability of nickel bath conditions. The quantitative power of the technique for analysis of the bath will have to be considered in the future.

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Acknowledgements: Financial support from MICINN (CTQ2008—06751-C02-02/BQU) and from UPV/EHU (Project GIU07/58) is here acknowledged. M. V. acknowledges financial support to GV in the form of a scholar fellowship.