PRINCIPAL COMPONENTS ANALYSIS OF PRINTED CIRCUIT BOARD LIBS DATA

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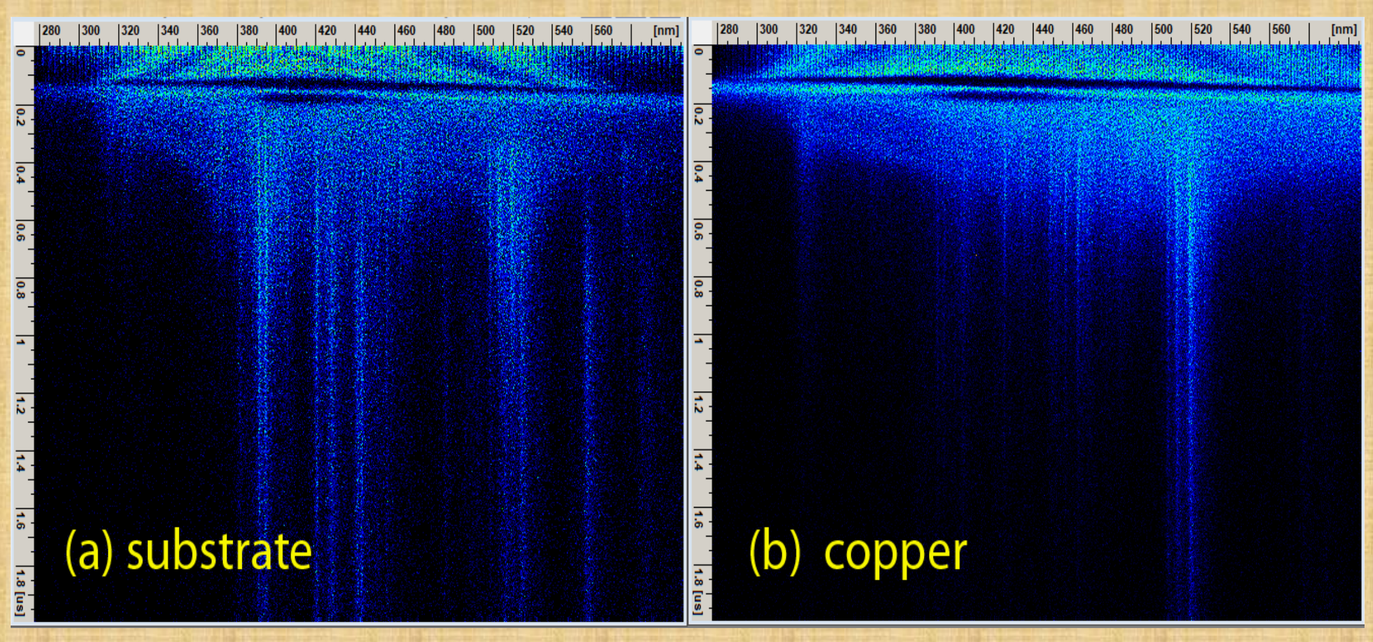
Laser ablation has many applications. Main aim of our research presented in Rabasovic et al. 2016. was rapid prototyping of printed circuit board. We have used the laser-induced breakdown spectroscopy (LIBS) as a convenient method both for ablation and for monitoring the selective removal of thin layers by laser. In Rabasovic et al. 2016 the LIBS data were analyzed by using correlation coefficients. Nowadays, availability of more and more fast computers, capable of machine learning, moves the analysis algorithms from simple numerical calculation towards the more sophisticated artificial intelligence methods. Here, we study the spectral data obtained in Rabasovic et al. 2016. by using the Principal Component Analysis (PCA).



Streak images of plasma breakdown optical spectra of printed circuit board at the start, when only copper is ablated; and when the substrate is fully exposed, are shown above. Their differences could be seen by a naked eye.

If X is a data matrix with m rows and n columns, each variable being a column and each sample a row, PCA decomposes X as the sum of r t_i and p_i, where r is the rank of the matrix X:

$$X = t_1 p_1^T + t_2 p_2^T + ... + t_k p_k^T + ... + t_r p_r^T \qquad r \leq min\{m, n\} \tag{1}$$

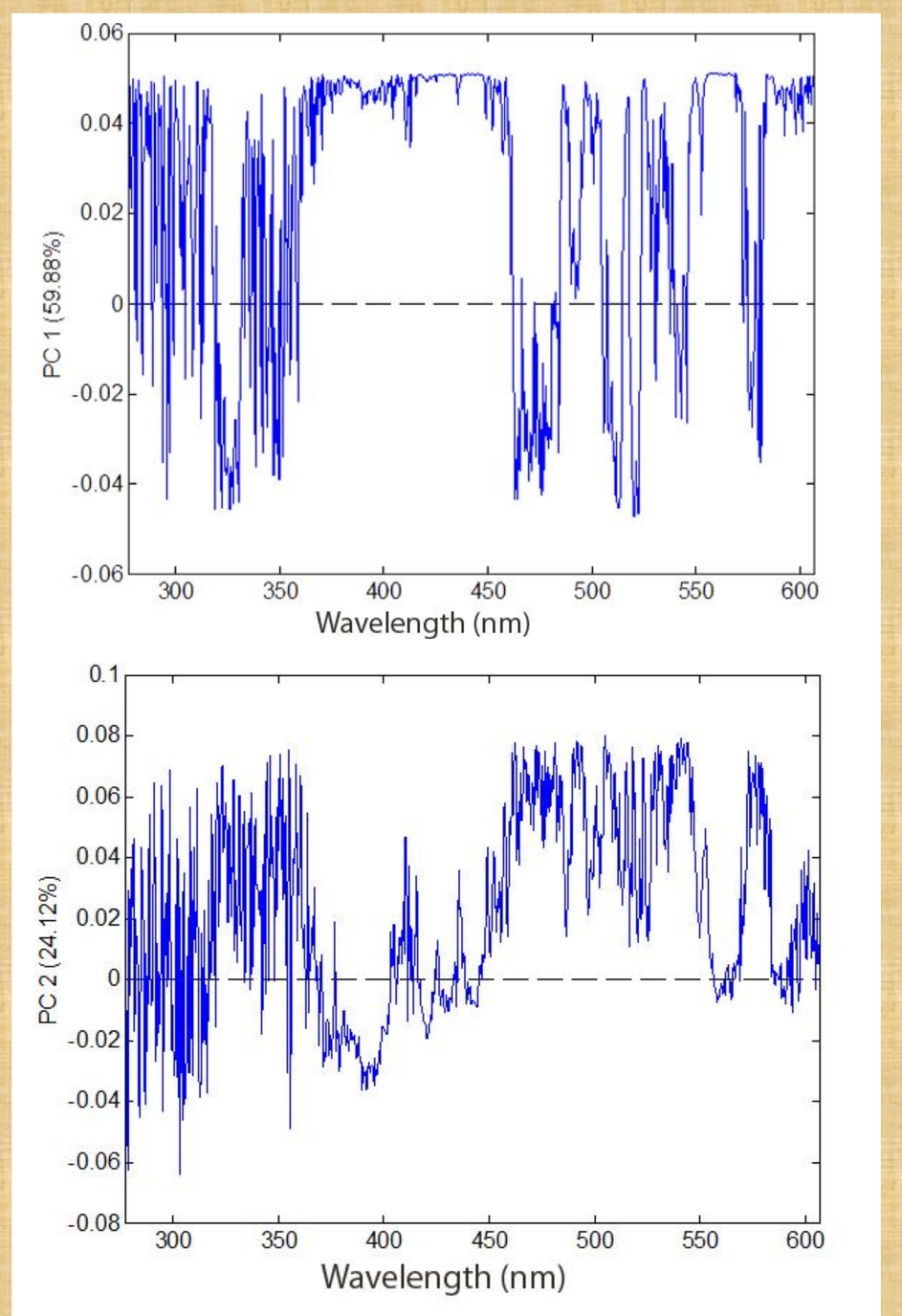
In the PCA decomposition, the p_i vectors are eigenvectors of the covariance matrix; it holds:

$$cov(X) = \lambda_i p_i \tag{2}$$

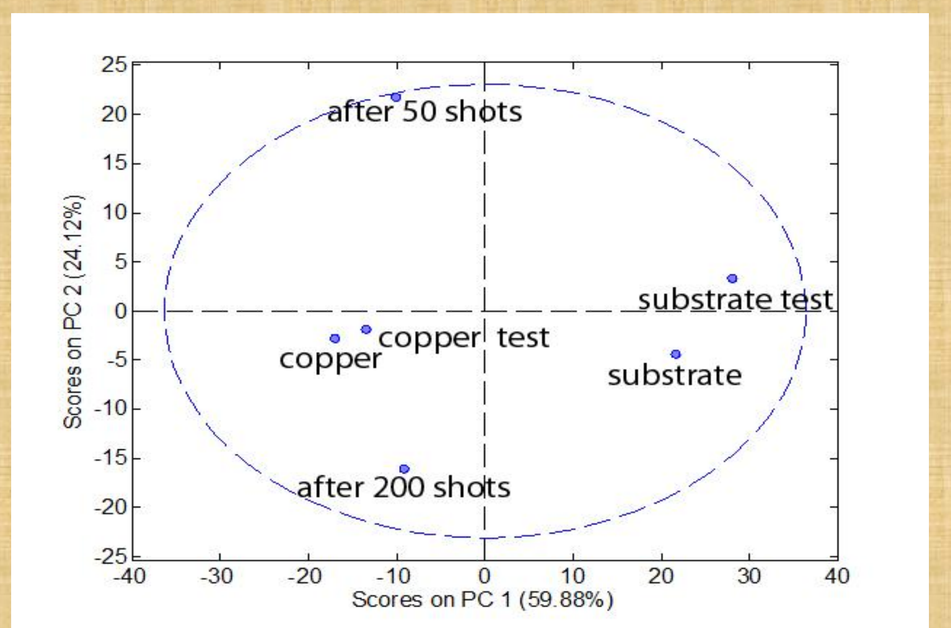
where λ_i is the eigenvalue associated with the eigenvector p_i.

The t_i, p_i pairs are ordered by the amount of variance captured. The t_i vectors are known as scores and contain information on how the samples relate to each other. The p_i vectors are known as loadings and contain information on how the variables relate to each other. Generally, the PCA model is truncated after k components.

Scores plot of first two principal components is shown on the right. As expected, the scores corresponding to spectra at the start of ablation and at the end of ablation are spaced widely apart, enabling automatic recognition of the moment when the useful ablation ends. The spectra corresponding to partial ablation are somewhere in between on PC1 axis, and widely apart on PC2 axis.



First two principal components of substrate LIBS data are shown above.



We have analyzed the LIBS data of printed circuit board by using machine learning algorithm. In our previous analyses we have used the correlation coefficients to identify the moment when laser ablation reaches the composite substrate of printed circuit board. Now, we have proved that it is possible to automatically detect the instant when the copper layer is fully ablated by Principal Component Analysis.

Rabasovic M.S., Sevic D., Lukac N., Jezersek M., Mozina J., Gregorcic P. : “Evaluation of laser-induced thin-layer removal by using shadowgraphy and laser-induced breakdown spectroscopy”, 2016 Appl. Phys. A 122, 186.

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