Use of compact spectrometer for plasma emission qualitative analysis

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Abstract. Usage of compact optical spectrometer for plasma emission analysis is considered. Capabilities of specially developed personal computer software to identify specific emission spectral lines are shown. Difficulties of analysis of complex plasma compositions emission spectrums are described.

Plasma analysis by means of spectral methods is widely and successfully used since years [1-5]. To determine plasma gas composition, both qualitatively and quantitatively, plasma emission spectrum is to be analyzed. If the technological process to be analyzed is not yet well-elaborated, good choice of equipment for spectral analysis is some compact general-purpose optical spectrometer such as ISM3600 developed by St. Petersburg Electrotechnical University [6].

PC software used to control the spectrometer and to visualize and analyze the spectral data obtained from ISM3600 is called Aspect2010 [7]. One of main functions of this software is plasma emission spectrum analysis. For plasma composition manual analysis it is useful to display some spectral lines of certain periodic table element on chart (figure 1).

Figure 1. Periodic table element selection.
Spectral lines corresponding to selected periodic table elements are displayed on the same chart together with measured spectrum that allows detecting of such elements presence in plasma composition [8]. Figure 2 shows Aspect2010 chart containing measured spectrum and spectral lines of Ar which was selected from periodic table window.

Figure 2. Plasma spectrum with spectral lines markers.

Usually technological chamber contains more than one periodic table element so software can display few elements spectral lines simultaneously. Resolution of ISM3600 spectrometer is approximately 1.5 nm so lines located close to each other on wavelength axis can visually join on chart. Such lines can belong to different periodic table elements that create additional difficulties for analysis of plasma composition. Figure 3 depicts fragment of spectrum containing oxygen and argon spectral lines. 798-802 nm wavelength range contains superposition of not resolved by spectrometer lines of the two elements.

Figure 3. Spectrum with oxygen and argon spectral lines

Components utilized in technological processes typically have complex spectrums with many spectral lines and usually it is possible to find wavelength band where absence or presents of certain element can be easily detected. Example of such condition is shown in figure 4: spectrum (1) contains no tantalum while spectrum (2) with tantalum present is obviously different.

Software also allows comparison of two spectral lines energies that handy for simple emission analysis. Parameters for this function entered by user are two wavelength bands. User defines these bands manually in such a way so line of interest suits its band. Software integrates spectrum data within both specified bands. Each band must not be narrower that spectral resolution of ISM3600 (1-2 nm) and estimated width of real spectral line. When set up, this software function integrates data
within both bands (Σ1, Σ2) and calculates ratio of these values (Σ1/Σ2). Results of calculations are displayed on top of main spectrum plot as set of values and small time chart of (Σ1/Σ2). This chart represents the plasma composition dynamics in a descriptive visual way. Chart window is fixed to display last 190 measured and calculated data points.

Figure 4. Plasma spectrums with and without tantalum present

Special analytic module of software can be used to process the experimental spectral data. Interface of this module is shown in figure 5.

Figure 5. Spectrums calculator user interface

Buttons S0-S3 shown in figure 5 correspond to four spectrums on the chart. Mouse pointer move over certain button highlights its curve on chart that allows easy selection of proper spectrum. When some spectrum is selected it is possible to process it using some function (see “Unary spectrum operations” group in figure 5).

List of available operations applied to one spectrum:
- reverse-clamping to the specified level (values below level are zeroed);
- normalization to 100%;
- shift of spectrum down (negative values are zeroed);
- spectrum spline filtration;
- the spectral line half-width calculation in specified spectrum band;
- maximal value calculation in the specified spectrum band;
- minimal value calculation in the specified spectrum band;
- calculation of the area under spectral curve in specified spectrum band;
- peak weight calculation in specified spectrum band (peak is automatically detected, then area under peak is calculated).
There is possibility to use some binary operation such as subtraction or multiplication in case two spectrums have been selected. Set of available options allows creation of quite complex formulas. For instance, comparison of energies of two spectral peaks requires not only simple comparison of their magnitudes. First of all it is necessary to calculate areas covered by these peaks and then – ratio of these areas. Result of each operation can become a part of more complex formula.

Set of features for spectral emission analysis offered by Aspect2010 software is quite reach but of course these features are suitable for some manual analysis for technology tuning and not intended to be used in any kind of automatic process control.

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