Detection of Trace Impurities Based on Stroboscope Measurement

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Abstract. Stroboscope method is a non-contact detecting technique through analyzing objects luminous radiation characteristic when the objects are excited by external source such as visible light, X-ray, γ-ray and electron beam etc. By analyzing the excited parameters, we can obtain the trace elements characteristics plot. The experimental results indicate that the measurement has more accuracy and sensitivity.

Keywords: Stroboscope, Trace impurities.

1. Introduction

Regular trace element measuring includes many ways , such as mass spectrograph measurement , purifying trace element elements measurement , resin extraction chromatography, temporal resolution fluorophotometry, inductive coupling high frequency plasma-atomic emission spectrometry , atomic absorption spectrography and isotopic spectrometry etc.[1] There are some disadvantages in above methods, for example , some method need expensive apparatuses to work on some method take long time to analyses elements because special chemistry operating, some measured objects maybe connect the apparatuses and influence the final measuring result.

Based on above reasons, we will introduce a new measurement method – objects trace element measurement method based on stroboscope method. Stroboscope method is an observation measurement that detects and identifies trace elements content in some objects or on the objects' surface through analyzes objects luminous radiation characteristic

When objects is excited by external visible light, X-ray, γ-ray and electron beam etc. [2]

The method is also a non-contact detecting technique, so we can get acceptable measuring results because the pollution to measured elements is at minimum degree.

In the meantime, couple amplifier circuit and sensitive electronic device is also a guarantee for continuous measuring. And its structure is simple and cost is cheaper.

2. Structural design and working principle

Depending on the application requirements, we'll introduce the adapted decay of luminescence time parameter τ in larger time range.

For constructing arithmetic, we'll assume two elements radiation included in the decay of luminescence, and the intensity of radiation with time changing is written as followed equation.

$$I_1(t) = I_{01}\exp(-\frac{t}{\tau_1})$$

$$I_2(t) = I_{02}\exp(-\frac{t}{\tau_2})$$

The luminous radiation of two elements in the object will reduce according to the above equation when the luminescence impulse is ceased, so the single value of light impulse average duration time will determinate decay of luminescence by τ_1 and τ_2. The light impulse will be converted current impulse. The output luminescence impulse to the light detector must undisturbance when we analysis the current. We can assume the luminescence impulse is rectangle pulse and its duration time is τ_0 for short-cut calculation. [3]

The typical current impulse output from opto-electronic receiver is shown in followed Fig.1.

The interval time is -τ_0 to zero (0). The excitation by external is visible light, X-ray, γ-ray and electron beam etc. The decay of radiation is zero(0) to infinity (∞) .

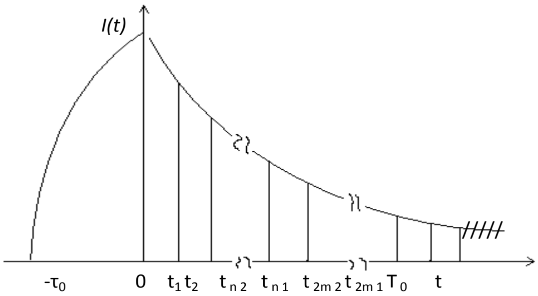

Fig.1 Amplitude value and time output plot from opto-electronic receiver

The output impulse current from opto-electronic receiver may be expressed to (1) when the time interval is 0≤t<∞ .

$$I_{(t)} = I_{01}\exp(-\frac{t}{\tau_1}) + I_{02}\exp(-\frac{t}{\tau_2}) \tag{1}$$

and t≥0 , I_{01} and I_{02} represent the current impulse amplitude value. We can get integral equation (2) from (1) equation.

$$P_{(t)} = \int_t^{\infty} I_{(t)} \cdot dt = \tau_1 I_{01}\exp(-\frac{t}{\tau_1}) + \tau_2 I_{02}\exp(-\frac{t}{\tau_2}) \tag{2}$$

$P_{(t)}$ represents below area of current impulse decrement curve when it's time interval in [t, ∞] . It's denomination is electric charge (A S) that can be measured directly.

The time interval in [tn-1,∞] should be divided integral multiple of △ t

Thus tn-1=(n-1)△ t.

There are four unknown number

(τ_1, I_{01}, τ_2, I_{02})according to (2) ,

So we get four equations and n=1,2,3,4. (3)

$$\tau_1 I_{01} + \tau_2 I_{02} = P_1$$

$$\tau_1 I_{01}\exp(-\frac{\Delta t}{\tau_1}) + \tau_2 I_{02}\exp(-\frac{\Delta t}{\tau_2}) = P_2$$

$$\tau_1 I_{01}\exp(-\frac{3\Delta t}{\tau_1}) + \tau_2 I_{02}\exp(-\frac{3\Delta t}{\tau_2}) = P_4$$

Where: $\tau_1 I_{01} = S_1, \tau_2 I_{02} = S_2$,

$$\exp(-\frac{\Delta t}{\tau_1}) = X_1,$$

$$\exp(-\frac{\Delta t}{\tau_2}) = X_2$$

That all equations are (3)

The (3) becomes (4)

$$\left.\begin{aligned} S_1 + S_2 &= P_1 \\ S_1 X_1 + S_2 X_2 &= P_2 \\ S_1 X_1^2 + S_2 X_2^2 &= P_3 \\ S_1 X_1^3 + S_2 X_2^3 &= P_4 \end{aligned}\right\} \tag{4}$$

From equation (4), we can get (5) two linear equations about ($X_1 \cdot X_2$)and($X_1 + X_2$)through deleting S_1 and S_2.

$$\left.\begin{aligned} P_1X_1X_2+P_2[-(X_1+X_2)]=P_3 \\ P_2X_1X_2+P_3[-(X_1+X_2)]=P_4 \end{aligned}\right\} \quad (5)$$

from (5).

And $\Delta=\begin{vmatrix} P_1 & P_2 \\ P_2 & P_3 \end{vmatrix}$,

$\Delta_1=\begin{vmatrix} P_3 & P_2 \\ P_4 & P_3 \end{vmatrix}$,

$\Delta_2=\begin{vmatrix} P_1 & P_3 \\ P_2 & P_4 \end{vmatrix}$

△ , △ 1 and △ 2 is corresponding matrix determinant of (5) equation including coefficient P1 – P2. From above equations, we can get (6), X1andX2 are roots of (6),

$$X^2+\frac{\Delta_2}{\Delta}X+\frac{\Delta_1}{\Delta}=0 \quad (6)$$

When △ =0, it means that only a element radiation in the decay of luminescence.

When △ ≠ 0, S1 or S2 is a possible negative value, but the values of P1,P2,P3,P4 must more than zero.

So the attenuation value is not the sum but is a difference between two power exponents.

We had the conclusion applied in the case that the current be described with m power exponents, Then we can define 2m unknown numbers { $\tau_1,\tau_2\cdots\tau_m$ } and { $I_{01},I_{02}\cdots I_{0m}$ } ,

so n=2m (2m areas), the area is shown $P_1,P_2\cdots P_{2m}$ separately.

The last interval time is [t_{2m-1},∞], then we can determine unknown number of the equation $X_1,X_2,\cdots X_m$. We get (7).

$$X^m+\frac{\Delta_m}{\Delta}X^{m-1}+\frac{\Delta_{m-1}}{\Delta}X^{m-2}+\cdots+\frac{\Delta_2}{\Delta}+\frac{\Delta_1}{\Delta}=0 \quad (7)$$

We can calculate the $\Delta,\Delta_1,\Delta_2,\cdots\Delta_m$ value from the measured value $P_1,P_2\cdots P_{2m}$, 2m values of P(area) to confirm the m decay elements .

The determinant Δ value is confirmed by (8), then the replacing $X_1,X_2\cdots X_m$ with independent term $P_{m+1},P_{m+2},\cdots P_{2m}$ array of corresponding determinant

linear (5).

$$\begin{Vmatrix} P_1P_2P_3\cdots P_m \\ P_2P_3P_4\cdots P_{m+1} \\ \cdots\cdots \\ P_mP_{m+1}P_{m+2}\cdots P_{2m-1} \end{Vmatrix} \quad \begin{Vmatrix} P_{2m+1} \\ P_{2m+2} \\ \cdots\cdots \\ P_{2m} \end{Vmatrix} \quad (8)$$

We can get the corresponding value of $S_1,S_2\cdots S_m$ from equation (7), and $S_m=\tau_m I_{0m}$, spit of the value is positive or negative in (9)

$$\left.\begin{aligned} & S_1+S_2+\cdots+S_n=P_1\rangle 0 \\ & S_1X_1+S_2X_2+\cdots+S_nX_n=P_2\rangle 0 \\ & \cdots\cdots \\ & S_1X_1^{2m-1}+S_2X_2^{2m-1}+\cdots+S_nX_n^{2m-1}=P_{2m}\rangle 0 \end{aligned}\right\} \quad (9)$$

If $\Delta=0$, then only a element radiation included in the decay of current . The current impulse decrement curve parameter is { $\tau_1,\tau_2,\cdots\tau_{m,}I_{01},I_{02},\cdots I_{0m}$ },

P_{2m} is the areas under the time interval [t_{2m-1}, ∞]. The area measuring error decides the systematic error of the algorithm. There is systematic error because of finite lasting measurement time, it's value [$0, T_0$] but not [$0, \infty$], so the shadow area (slant lines shows) can be ignored and the finally measurement time is T_0.

$$\Delta P = \sum_{1}^{m} \tau_m I_{0m} \exp(-\frac{T_0}{\tau_m}) \tag{10}$$

S get to largest relative error when we measure the last time interval [t_{2m-1}, T_0] in the fig 1. A series of decay time is $\{\tau_1, \tau_2, \cdots \tau_m\}$, $\tau = \tau_{\max}$ (maximum).

So we can write the followed equations

$$P_{2m} \approx S(\tau_{\max}) = \tau_{\max} I_{0\max} \exp[-\frac{(2m-1)\Delta t}{\tau_{\max}}]$$

and $\Delta P \approx \tau_{\max} I_{0\max} \exp(-\frac{T_0}{\tau_{\max}})$

Thus the maximum relative error δ is shown (11).

$$\delta = \frac{\Delta P}{P_{2m}} \approx \exp(-\frac{T_0}{\tau_{\max}}) \cdot \exp[\frac{(2m-1)\Delta t}{\tau_{\max}}] \tag{11}$$

The value m, Δt, T_0 are independent parameters. The area values of $P_1, P_2, \cdots P_{2m}$ are 10^{+2}, and the relative error value δ is 10^{-2}.

3. Setting Blocking Diagram And Operating Principle

The optical impulse comes from measured objects is inputted No. 1 ray-radiation receiver and is converted current impulse. The current is amplified in preamplifier. The time-response and frequency of ray-radiation characteristic can get synchronization in the preamplifier. The external stimulating light impulse is inputted to the No.2 ray-radiation receiver, current impulse output from it can be converted stroboscope gating switch synchronization impulse in synchronization impulse compulsator [4].

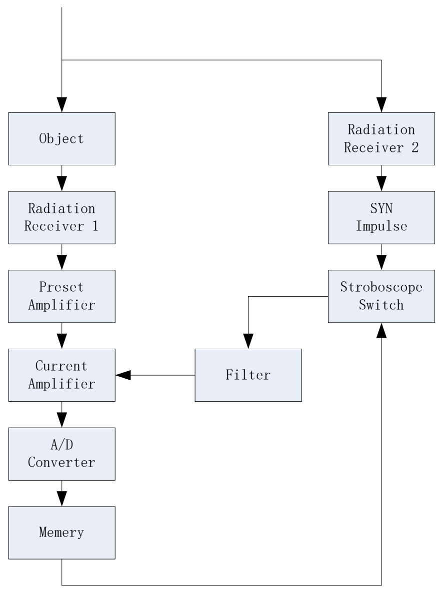

Fig. 2 System Setting Diagram

Electric charge (current) amplifier is used for signal amplification and converting the current impulse into area(P) measurement. The stroboscope gating switch can determine time interval [t_{n-1}, T_0]. The measured signal is converted digital in the Analog/Digital converter, then the digital signal is sent to computer memory for enlarging the Signal /Noise ratio. There is a pre-installed over-cut unit for cutting the dark-current and clutter (noise).

So the clutter comes from current AMP IN only can be determined signal/noise ratio by root means quare [4].

4. Conclusion

We can only use computer key-board to control measuring according to above algorithm, it is very simple . In addition, the measurement is more sensitive than other typical measurement applying with gating-switch.

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