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Metallic atoms concentrations measurements in an industrial low voltage circuit breaker using broad band absorption spectroscopy

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In order to investigate the electrical arc in low voltage circuit breakers, metallic atoms concentrations measurements were performed using broad band absorption spectroscopy. From absorption spectrum in 510-523 nm range, copper atom concentration, electron temperature and silver atom concentrations were determined with LTE assumption. Absorption spectrum in spectral range around 430 nm enables to determine the iron atom density.

1. Introduction

In low voltage circuit breaker (LVCB) for high current, the arc established at contacts opening is usually moved by self-generated force towards the quenching area. For the development of such devices, it is necessary to have detailed knowledge about the behaviour of the moving arc. Because of the very complex processes involved, many experimental investigations and computer simulations of the arc in LVCB have been done by several teams [1]. In a previous paper [2], we have reported time resolved optical emission spectroscopy and imaging measurements in a LVCB adapted from an industrial device. These measurements revealed that metallic atoms (Copper, Silver and Iron) were presents in the air plasma arc. In order to determine the concentrations of these atoms, we have performed broad band absorption spectroscopy measurement using a bright radiation source developed in this purpose [3]. This investigation is useful for the modelling and the design of the LVCB. In this paper, we present some of measurement results. More results and information will be given during the conference.

2. Experimental set-up

The LVCB is shown in figure 1. An electrical arc is created during the discharge of a capacitor bank, when the separation of two contacts mounted on fixed and movable copper electrodes occurs. Then the arc expands and reaches the quenching area consisting of two symmetrical chambers. Materials of the contacts on copper fixed and movable electrodes are respectively silver-carbon and silver-carbon-tungsten. The quenching chambers consist of parallel arc splitter plates of different lengths. These steel plates are disposed on plastic holders. More details are given in reference [2].

The optical set-up is illustrated in figure 2. The radiation source light, driven by an optical fibre called F_Z, is polarised before going through the absorption medium (arc). The optical fibre F_{abs} collects polarised transmission light and one half of light emitted by the arc, while the fibre F_{emi} collects the other half of light. A spectrometer coupled with an intensified 2D CCD camera is used to convert simultaneously these two optical signals into two spectra. The subtraction of these two spectra gives the transmission spectrum of the absorption medium. More details concerning acquisition system are given in references [2,3].

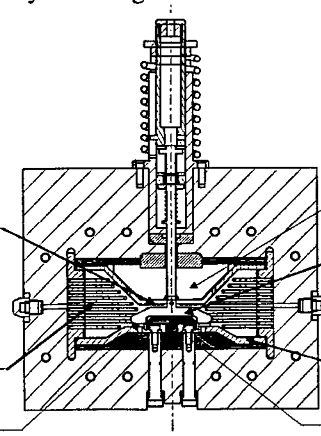

Fig. 1. Industrial low voltage circuit breaker.

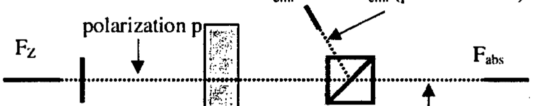

Fig. 2. Optical absorption measurement set-up.

3. Results and discussions

In figure 3, the spectrum (a) is the spectrum in range of 510-523 nm from the radiation source which emits as a black body of about *80 000 K* during more than 1 μs [3]. This spectrum is required without arc in LVCB. The optical opening time of ICCD camera is set to 1 μs during this experiment. The spectra (b) and (c) corresponding to light collected respectively by F_{abs} and F_{emi}, are required simultaneously when an arc is present in the LVCB. Measurement was done at 3 ms after the beginning of the current (i.e. 2 ms after the opening of the contacts) whose peak value was about 5 kA.

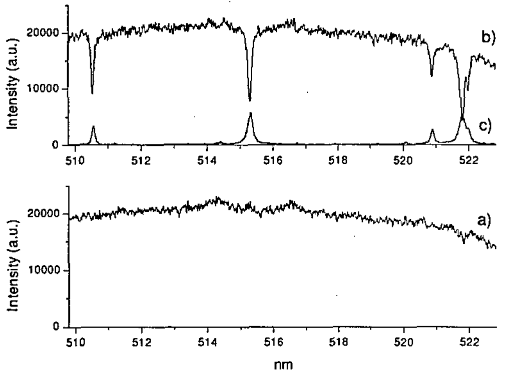

Fig. 3. a) spectrum I_a without absorption of arc, b) and c) spectra I_b and I_c from F_{abs} and F_{emi}.

From these three spectra, the transmission spectrum is derived with calculating of $(I_b-I_c)/I_a$ and is given in the figure 4. The five main absorption lines are respectively CuI 510.55, 515.32, 521.82, 522.01 nm and AgI 520.91 nm.

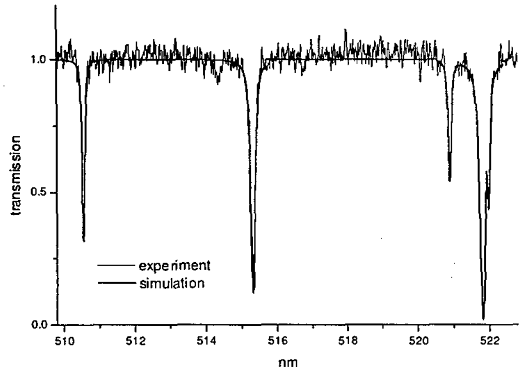

Fig. 4. Transmission spectrum and its best fit.

This transmission spectrum is fitted by a synthesised spectrum given by the relation :

$$t = e^{-\alpha_T(\lambda)\,L} * F_a$$

where L is the length of the absorbing medium which is supposed homogeneous, F_a is the apparatus function of detection system and * is convolution operator. The theoretical value of the absorption coefficient α_T is given by the following relation :

$$\alpha_T(\lambda) = \frac{\lambda^4 A_{ul}}{8\pi c} \frac{g_u}{g_l} N_l S(\lambda)$$

Here λ is the wavelength, A_{ul} is the transition probability between the upper level u and the lower level l, g_l and g_u are respectively the statistical weights of these two levels, c is the speed of light in vacuum and finally, N_l is the population of the atom in lower level. (Here the stimulated emission term is neglected). $S(\lambda)$ represents the normalised true line profile which has a nearly Lorentzian shape in our case. $S(\lambda) = \frac{1}{\pi} \frac{w}{(\lambda-\lambda_0)^2 + w^2}$ where λ_0 is the wavelength at line centre and w is the HWHM of the true line profile. So, the best fit of line transmission spectrum enables to determine the population of atoms in the lower energy level of the corresponding transition.

The best fit shown in figure 4 yields copper atom density in the four lower levels listed in the table 1. In this experiment, the uncertainty is estimated to be *30%*.

Table 1 Spectroscopy data and population in lower level

CuI line (nm)	E_l (eV)	g_l	A_{ul} (s^{-1})	N_l (m^{-3})
510.55	1.39	6	1.949×10^{6}	3.9×10^{20}
515.32	3.79	2	1.034×10^{8}	5.4×10^{18}
521.82	3.82	4	1.221×10^{8}	1.1×10^{19}
522.01	3.82	4	2.180×10^{7}	1.2×10^{19}

With LTE assumption, the population of an excited level is linked to the one of fundamental level by the Boltzmann law. In this case, if one plots $\ln(N_l/g_l)$ as a function of E_l, the slop should be $-1/T_e$ with T_e in eV when E_l is in eV. The Boltzmann's diagram yields an electron temperature of 0.77 eV. Since the energy gap between the two lower levels of the two CuI lines (510.55 and 515.32 nm) is as large as 2.4 eV, the uncertainty is quite good, and is estimated to be *20%*. The total concentration of copper atom is 1.4×10^{21} m^{-3}.

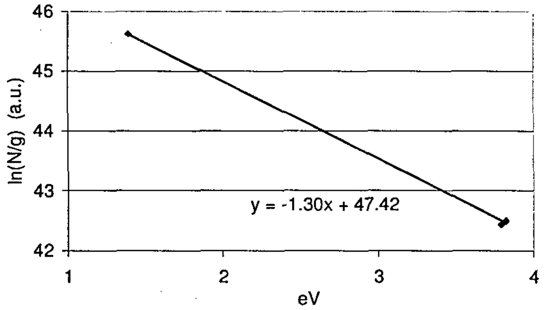

Fig.5 Bolztmann diagram from four CuI lines

The best fit of transmission spectrum yields a concentration of 2.0 $\times 10^{18}$ m^{-3} for the lower level of AgI 520.91 nm. A total silver atoms concentration can be yielded with LTE assumption, it is 2.5×10^{20} m^{-3}.

Measurements were also performed for the iron lines in spectral range around 430 nm. Results will be presented during the conference.

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4. References

[1] M. Lindmayer, proceedings of the XIV Int. Conf. on Gas Discharges and their Applications, **2** (2002) 318-324.

[2] S. Guillot, J. M. Bauchire, E. Le Menn, C. Fleurier, C. Fiévet and F. Gentils, proceedings of 15^{th} ISPC, **III** (2001) 1097-1100.

[3] D. Hong, G. Sandolache, K. Lan, J. M. Bauchire, E. Le Menn and C. Fleurier, Plasma Sources Sci. Technol. **12** (2003) 1-7.