
# Fluorescent lamp lifetime characterization

## Wet chemical analysis of barium consumption in the emitter

Lifetime performance and lifetime spread are key issues for various types of fluorescent lamp. Their lifetime is mainly determined by the electrode life. In turn, the electrode lifetime is basically determined by the amount and consumption of (free) barium in the emitter. Though some knowledge on fluorescent lamp electrode performance is readily available, there is a need for improved design rules to adequately influence and predict lifetime. Wet chemical analysis is very suitable to quantitatively chart the zero hour situation as well as the development of the emitter consumption during lifetime.

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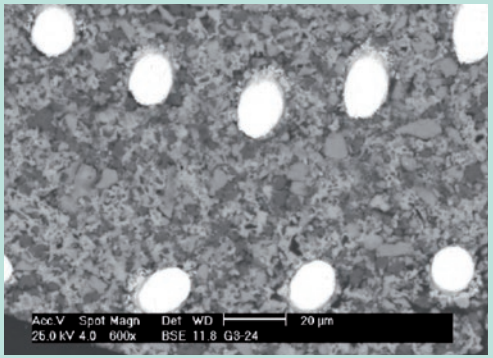


Fig. 1: SEM image of a cross-section of the emitter

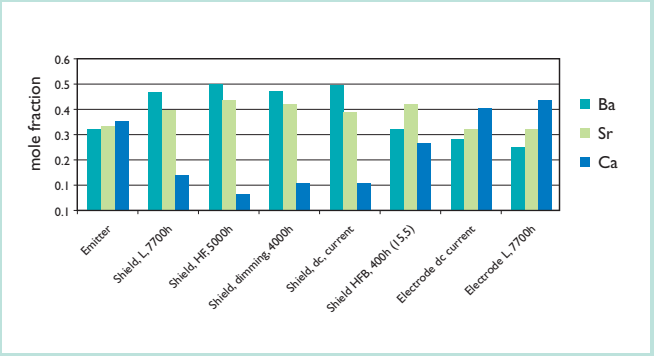


Fig. 2: Molar fraction of Ba, Sr and Ca in the original emitter mix, on the shield and on the electrode. Different modes of operation yield different distributions.

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## The emitter

The front page SEM image displays the electrode, consisting of a double-coiled W wire. In between the coils, emitter material is present. This emitter material improves the electron-emitting properties of the electrodes. The emitters used in fluorescent lamps consist of a mixture of calcium-, strontium- and barium-oxides. A cross-section of the emitter is shown in figure 1. The white, ellipsoidal regions are the tungsten wires. The three other grey scales represent grains of the different materials from which the emitter is made: BaO (light grey), CaO (dark grey) and SrO (grey). At the border of the white regions, small, lighter grey fountains are visible in the emitter material. Here, a reaction between W and emitter material took place by forming tungstates ($Ba_x(Ca,Sr)_yWO_6$).

## Emitter activation

Originally, the emitter material consists of $BaCO_3$, $CaCO_3$ and $SrCO_3$. These carbonates decompose during the lamp production process, (the so called "activation"), into their oxides. During activation the following reactions will take place:

$MCO_3 \rightarrow MO + CO_2$ (M = Ba, Ca, Sr)

$CO_2 + W \rightarrow WO_x$

$WO_x + MO \rightarrow Ba_2(Ca,Sr)WO_6$

$6\ BaO + W \rightarrow Ba_3WO_6 + 3\ Ba$

Note that after activation about 1/3 of the total barium is converted into $Ba_2(Ca, Sr)WO_6$ and is not available anymore for lamp burning.

## Ba consumption

The formation of tungstates implies a reduction of the amount of active BaO in the emitter. This is an ongoing process during lamp operation, because of the reaction

$$6\ BaO + W \xrightarrow{1100\ K} Ba_3WO_6 + 3\ Ba$$

Under normal operation conditions, just before end of life about 1/3 of the total amount of Ba can be found on the wall (the 'internal shield'). This is also called the Ba-reservoir of the electrode.

## Life time studies

The exact rate of Ba consumption is strongly dependent on operating conditions, such as switching cycle, discharge current and heating current. In lamp development, one is generally interested in the chemical composition of the electrode at zero-hour, i.e. the chemical condition of the electrode after activation. Furthermore, also of interest is the change in chemical composition during lamp life, i.e. as a result of the various burning and ignition conditions. Wet chemical analysis using Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES) provides the quantitative data for these studies.

## Wet chemical analysis

For the wet chemical method a (Compact) Fluorescent Lamp emitter is removed from the lamp and is treated with a mixture of chemicals. Subsequently, the total amounts of Ba, Ca, Sr and reacted W are determined quantitatively using ICP-AES. As the tungsten of the coil is not attacked in the wet chemical analysis, the amount of "reacted tungsten" (the total amount of tungsten fixated as oxide or tungstate) is determined. In figure 2 the results of these compositional studies are shown. Besides determining concentrations of the compounds on the emitter, the amount of material (Ba, Ca, Sr and W) that is sputtered and/or evaporated on the glass wall and/or electrode shield has also been analyzed. The various modes of operation clearly yield different distributions of the elements.