Development of an extraction method for rare earth elements from fluorescent lamps phosphor

Marcelo F.M.F. Azevedo[1](PG), Pedro H.M. Weingärtner[1](IC), Gabriel A. Freitas[1](IC), Rafael C.C. Rocha[1](PG), Jiang Kai[1](PQ), Tatiana D. Saint'Pierre*[1](PQ)

tatispierre@puc-rio.br

[1]*Departamento de Química, PUC-Rio, Rio de Janeiro, Brazil).*

Key Word: *Fluorescent lamps, rare earth elements, inductively coupled plasma mass spectrometry*

Introduction

Fluorescent lamps (FL) are still extensively used worldwide. However, the high concentration of toxic metals, especially mercury, have made these lamps a serious environmental issue when discarded. Moreover, FL are being substituted by LED lamps, which are greener and more efficient. Furthermore, the Brazilian law 5131 states that FL must be recycled, reinforcing that recycling methods are required.[1] The rare earth elements (REE), composed by Sc, Y and the lanthanides, are toxic metals that have been largely studied due to their luminescent properties.[2] This project aims the development of an extraction method of the REE from the phosphor of the FL to obtain an inorganic compound for future application in material sciences. The phosphor extraction is done by breaking the FL and submitting its shards to an ultrasonic bath. After obtaining the phosphor, three decomposition procedures were made using three different acid media (HNO_3; HCl; 3:1 HCl:HNO_3) followed by a sequential precipitation using NaOH and H_2SO_4. After all these procedures, the REE were obtained. All the steps of the process were optimized by quantifying the REE by inductively coupled plasma mass spectrometry.

Results and Discussions

The phosphor extracted from the lamp was submitted to leaching with 2 mol L^{-1} HCl or HNO_3 solutions (Table 1). The remaining powder was leached once more for a better extraction of REE.

Table 1– Concentration of major elements (mg kg^{-1}) in FL phosphor, after acid leaching with HCl or HNO_3 2 mol L^{-1}.

	Ca	Fe	Y	Ba	Eu
HCl	141	9.43	0.840	4.34	0.105
HNO_3	389	10.5	9.64	7.32	0.496

The best treatment was the HNO_3 solution, the HNO_3 solution was mixed with a NaOH solution, in order to precipitate the most barium and calcium. The concentrations remaining in solution are shown in Table 1 (Extract B1). Then, the solid was treated with a H_2SO_4 solution, for dissolving the REE, since they form soluble sulphate complexes. The concentrations in the final solution are also presented in Table 2 (Extract B2).

Table 2 – Concentrations in solution (mg L^{-1}), after treating with NaOH (B1) and then with H_2SO_4 (B2).

	Ca	Fe	Y	Ba	Eu
B1	<LD	<LD	66.4	3.6	63.9
B2	542	129	308.6	123	1464

It was noticed that sulfuric acid redissolve the REE, but also the interfering elements, then, a pH adjustment was carried out to optimize the separation. Preliminar studies were done, varying the pH from 0.5 to 3.5. The results indicates that Eu can be extracted to the solution with sulfuric acid at pH up to 3.0, but for Y, pH higher than 3.5 would promote higher extraction, table 3.

Table 3 – Concentrations in solution after pH adjustment (mg L^{-1}).

	Ca	Fe	Y	Ba	Eu
pH=0.5	2.07	0.150	101.1	0.012	1.384
pH=3	1.219	<LD	83.30	0.006	1.377
pH=3.3	<LD	<LD	6.0	0.006	0.050
pH=3.5	<LD	<LD	4.544	0.003	0.042

Conclusions

This work proposes a method for extraction and separation of REE from fluorescent lamps for recycling these elements. Preliminary studies have shown that sulfuric acid is the alternative for extracting soluble sulphate complexes, after the precipitation with alkaline solution.

Acknowledgements

We want to thank to CAPES, FAPERJ and CNPq for the financial support, which was fundamental for the execution of this project. Also thanks to PUC-Rio, for the support and infrastructure granted.

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