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Analysis of hybrid reverse osmosis cascades for ultrapurification of chemicals

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Electronic chemicals (chemicals and materials used to manufacture and package semiconductors and printed circuit boards) require extreme low content of metallic impurities to minimize reliability problems in microdevices. In order to avoid contamination because of the chemicals themselves, ultrapurification processes become necessary to achieve these exigent limits. Hydrogen peroxide (H_2O_2) is one of the most employed liquid phase electronic chemicals because of its use for cleaning silicon wafer surfaces of foreign contaminants, removing photoresists or etching copper on printed circuit boards.

Reverse osmosis membrane processes demonstrated their potentiality for hydrogen peroxide ultrapurification from technical chemical to semiconductor requirements [1] and optimization according to economic criteria of design and operation variables of integrated multistage cascades were carried out [2]. Both polyamide (PA) and cellulose acetate (CA) reverse osmosis membranes were tested. Polyamide membranes appeared as more productive in terms of permeate flux but the effective lifetime of cellulose acetate membranes was assessed to be three times longer.

Anyway, both types of membranes can be competitive and the dominance of each of them depends on the unitary membrane prices. Further investigation has been carried out to analyze the performance of hybrid cascades combining PA and CA membranes and compare the results with the installations employing only one type of membranes.

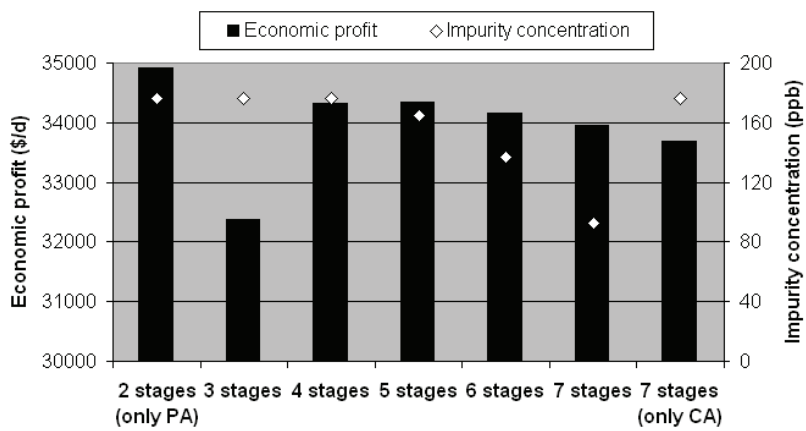

Figure 1: Economic profit and product quality as concentration of the main impurity for the hybrid cascades incorporating the PA stage as the first one.

For this case of study, given an annual consumption of 9000 tons of technical grade hydrogen peroxide, hybrid cascades have been limited to no more than 7 stages and they could only include 1 stage of PA membranes to produce SEMI Grade 1 hydrogen peroxide. The Fig. 1 shows the results obtained from cascades incorporating the PA stage as the first one and the comparison to the PA cascade (using only PA membranes, that requires 2 stages for H_2O_2 SEMI Grade 1), and the CA cascade (7 stages are required when using only CA membranes).

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As it can be seen, the most profitable configuration for hybrid cascade is that integrating 5 stages but it has to be taken into consideration that the product of the obtained product is not comparable for all the cases: the concentration of the main impurity for the cascades with 5 or more stages is lower than the target one (176 ppb), so higher product quality is being obtained and the definition of bypass streams should be considered.

The optimum cascade working only with PA membranes (2 stages) results more profitable than the optimum five-stage hybrid cascade when both unitary prices are equal to 50 $/m^2, but taking into account that the effective lifetime of the PA membranes can be critical, the hybrid configuration (PA first stage + CA rest of stages) offers an alternative to the use of only CA membranes that require higher number of stages and lower economic profit for the same level of product quality.

The influence of the position of the unique PA stage integrated in the cascade has been also studied, but the outcome suggests slight significance of this design variable, Fig. 2.

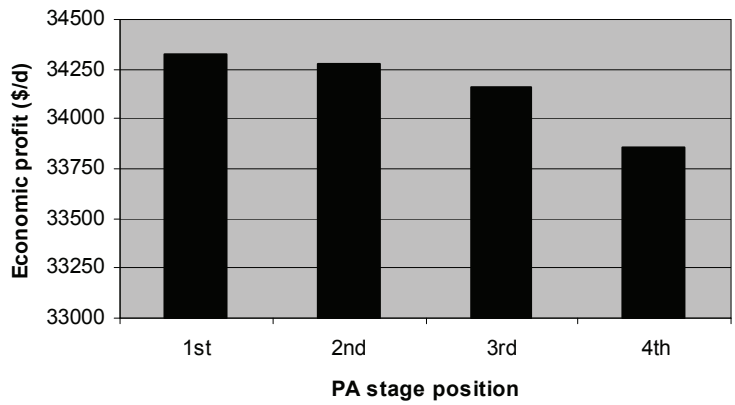

Figure 2: Influence of the position of the only PA stage in a hybrid cascade over the economic profit of the process

The option of bypass streams to improve the economic profit of the cascades with higher quality product than the target has been investigated. The possibility of bypassing until 90% of the feed stream of each stage to mix it with the corresponding permeate stream of the same stage has been considered. For the particular case of a five-stage cascade, the economic profit is increased 0.7% by the use of bypass streams for the last two stages (55% and 90% respectively) and modifying the recovery rates of these stages from 0.9 (without bypass) to 0.3.

References

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