Developing the Recuperative Rinsing Concept

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Among the multitude of methods suggested for the alleviation of environmental pollution problems, recuperation stands out as a technique involving neither sophisticated chemical processes, nor costly additional equipment. It is also capable of producing considerable material savings at negligible cost.

It was shown in an earlier article[1] that three-stage countercurrent recuperative rinsing can be implemented for such conditions where plating tank evaporation losses are higher than the corresponding drag-out solution losses. This holds true for most of the commonly used industrial plating processes, but not those for high speed deposition. A recuperative rinsing technique, which would achieve high recuperation rates for low evaporation to drag-out ratio cases without resorting to forced plating solution evaporation could have wide ranging practical implications. This paper outlines one possible solution to the problem and puts into perspective a number of recuperative rinsing techniques.

The difficulty with the low evaporation to dragout ratio recuperative rinsing is the steep first ~~time~~ concentration rise above that of the plating solution itself.[1] Elsewhere[2] it was shown that with single-stage recuperation a double-dip approach (reclaim tank parts rinsing both before and after plating) is instrumental in keeping the reclaim tank concentration down and effectiveness up for exactly those conditions which hindered the previously investigated multistage approach. The finding of this improvement led to the present study, where the double-dip approach is incorporated into the multistage model investigated earlier.

$$G(i) = \sum_{K=0}^{i} E(k) \qquad (1)$$

$i = 0,1,2,3$

$$G(i) \times C(i+1) + D \times C(i-1) = [G(i-1) + D] \times C(i) \qquad (2)$$

where $i = 0,1,2$ for case a (single-dip)
$i = 1,2$ for case b (double-dip)

$$G(1) \times C(2) + D \times C(0) = [G(0) + 2D] \times C(1) \qquad (3)$$

for case b (double-dip)

Rinse temp

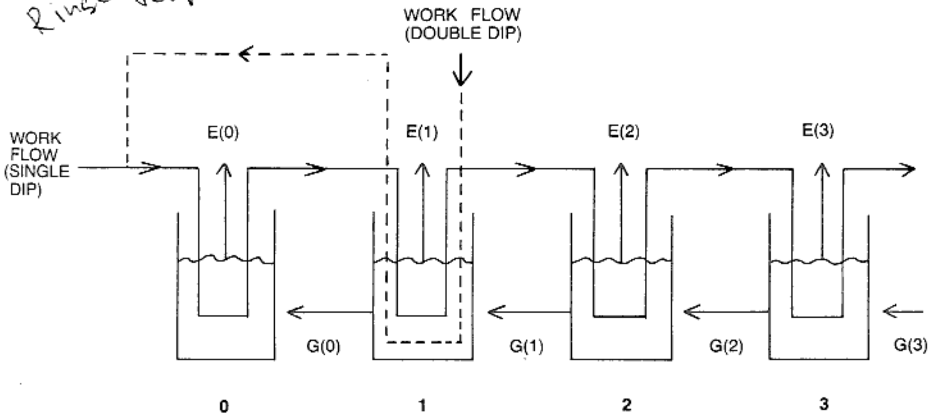

Fig. 1. Typical countercurrent recuperative rinsing setup and material balance equations.

MODEL DESCRIPTION

The investigated model includes (Fig. 1) a process tank 0 with solution concentration C(0) and a series of rinse tanks 1,2,3 with corresponding solution concentrations C(1), C(2) and C(3). Evaporation losses from every tank, denoted E(0) through E(3), are being made good by rinsewater, flowing as shown by the double lines, with flow rates denoted respectively G(0) through G(3). Work movement through the system is shown by solid and, where variants are considered, broken lines.

An approach, analogous to that used previously[1] with respect to stationary conditions, was used in this study. Under such conditions all the concentrations and material flows of the system, as well as solution volumes in each tank remain constant. It is appropriate to mention here that since in such a system equilibrium conditions establish themselves very slowly, practical concentrations C(2) and C(3) might never reach their calculated equilibrium (or stationary) levels. In fact, after every night-time and weekend shutdown period (when evaporation continues, though at a slower rate, and the flow of work stops), the tanks are refilled with fresh water, setting the rinse tank concentrations back considerably. This explains why the calculated equilibrium conditions actually represent the worst possible case. In addition, the evaluations obtained for concentrations and recuperation rates in this study must be taken as pessimistic, i.e. worst possible under the chosen process parameters.

If drag-out D, evaporation losses rates E(i) and rinsewater flow rates G(i) are expressed in consistent units, e.g. L/m^2 of processed work surface (see reference (1) for details),* then the system could be described by a set of algebraic material balance equations, given in the box.

Two groups of cases have been considered: those without the double-dip approach where work flow into the process tank is given by the solid lines and those where the double-dip approach was integrated into the recuperation system where work flow into the plating tank is given by the broken lines. In every group two variants were considered: a two-stage and a three-stage countercurrent process. Recuperation rates as determined earlier[1] were accepted as the main system characteristic.

PROCESS ANALYSIS

For every considered case the effects of a number of important variables on the recuperation rate, R, had to be established and comprehensively represented. To this end, equations (2) and (3) were divided by D, and C(0) was set equal to unity. Appropriate sets of equations, describing particular cases, were chosen from equations (1), (2) and (3) and solved to find C(1), C(2) and C(3). Next, recuperation rate, R, was calculated as a function of two or three unified variables (parameters) E(0)/D, E(1)/D and E(2)/D (for the three-stage system).

These results can be clearly and easily represented as a series of curves, each corresponding to a different R value, in the space of two parameters, E(0)/D and E(1)/D, for the two- and three-stage systems, the latter requiring additional determination of E(2)/D. To further simplify the problem, only the first two parameters were considered for the three-stage cases and the remaining one was held equal to zero. Nonzero values of E(2)/D improve on R rates, obtained under this assumption.

RESULTS AND DISCUSSION

The resulting curves for equal values of R plotted against the most important parameters of the rinsing process are shown in Figs. 2 to 5. As could be expected, two-stage processes achieve lower recuperation rates than three-stage ones, but are superior to single-stage recuperation, investigated earlier.[2] It could be noticed that generally with the double-dip approach higher values of R are reached under equal conditions than without it, the difference becoming more pronounced for lower values of E(0)/D.

Actually, when E(0)/D = 0, there is no recuperation at all with the single-dip approach and the vertical (E(1)/D) axes in Figs. 2 and 4 correspond to zero R values. Moreover, due to low plating tank evaporation rates, the first rinse equilibrium concentration rises over unity (C(1)>1, C(0) = 1) could not possibly be used in practical single-dip recuperative rinsing. These zones, shaded in Figs. 2 and 4, demonstrate that no matter how high the first rinse evaporation rate is, under certain conditions when we are unable to raise the plating tank evaporation, single-dip recuperation simply does not work.

Just the opposite is the case with double-dip multistage recuperative rinsing. The lowest limiting value of R, reached at the origin (E(0)/D = 0, E(1)/D = 0), equals 0.5 and can be improved upon by elevating the evaporation rates from either the plating or the first rinse tank. No previously discussed limitations apply to the double-dip approach, since the first rinse concentration never rises above one half of that for the plating solution. This makes double-dip recuperative rinsing particularly suitable for high-speed plating processes. Here even small evaporation rates produce considerable material savings with no limitations whatsoever.

CONCLUSIONS

This investigation demonstrates that recuperative rinsing is a feasible option for the whole spectrum of plating processes. Depending on the process type, a particular recuperative system (single, or multistage, single- or double-dip, natural or forced evaporation) could be chosen, the choice being gov-

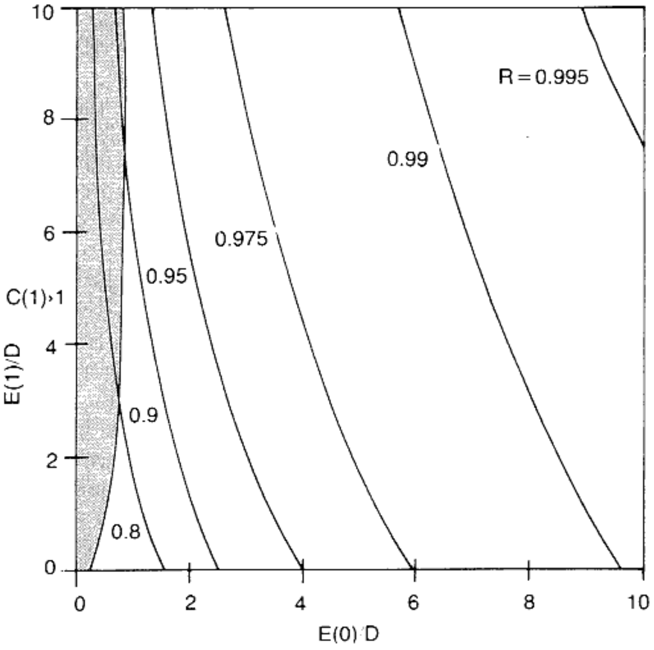

Fig. 2. Effect of rinsing parameters on the performance of two-stage countercurrent single-dip recuperative rinses.

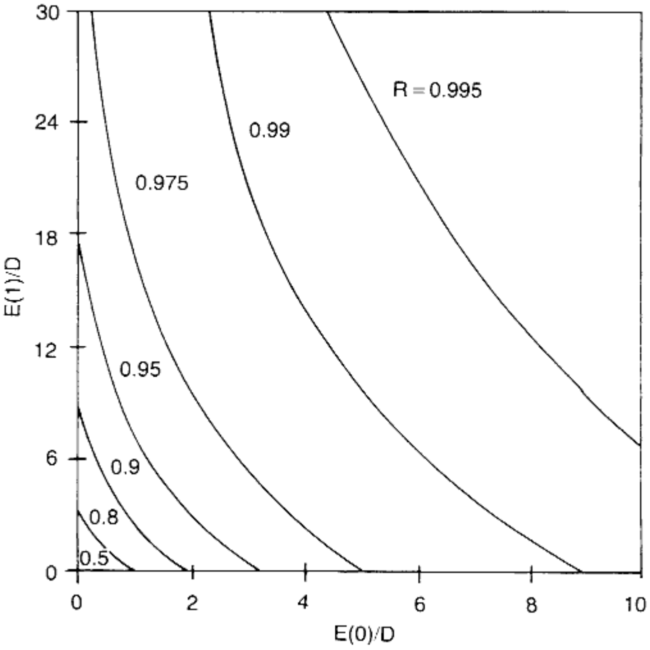

Fig. 3. Effect of rinsing parameters on the performance of three-stage countercurrent single-dip recuperative rinses.

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*Note: formula (4) of reference(1) contained a printer's error and should be read as follows: $E = E_s(T) \cdot \tau / F_s$

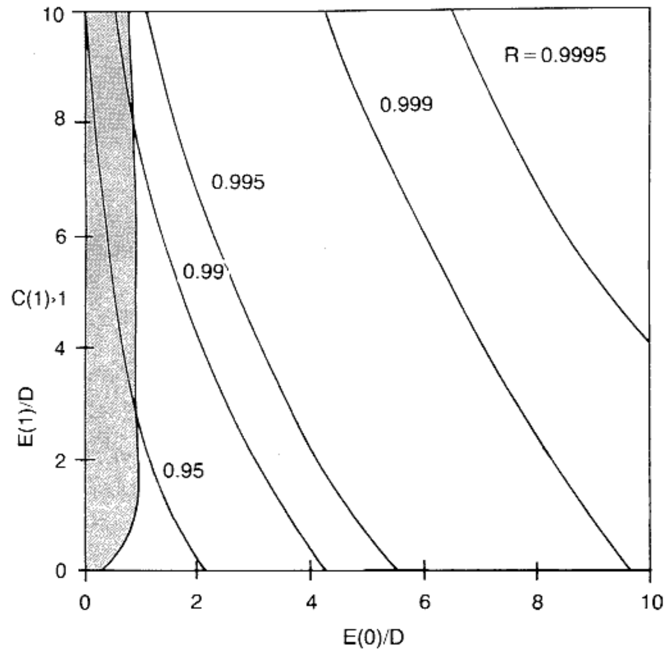

Fig. 4. Effect of rinsing parameters on the performance of two-stage countercurrent double-dip recuperative rinses.

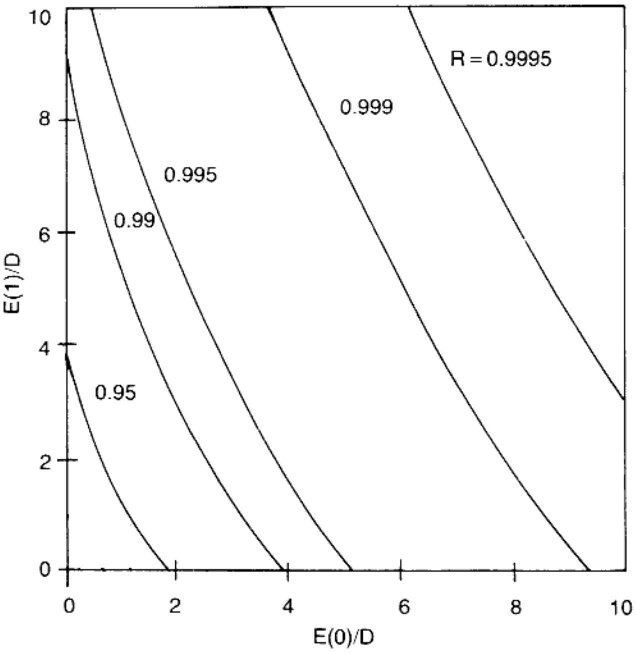

Fig. 5. Effect of rinsing parameters on the performance of three-stage countercurrent double-dip recuperative rinses.

to fig. 3

erned by economic as well as environmental considerations. Graphs of the type given in this paper and an earlier one[2] could greatly facilitate the choice and design of an optimum rinsing system. **MF**

References

1. B. Stein, Metal Finishing, 86, 27 (Jan. 1988).
2. B. Stein, Metal Finishing, 86, 50 (Oct. 1988).