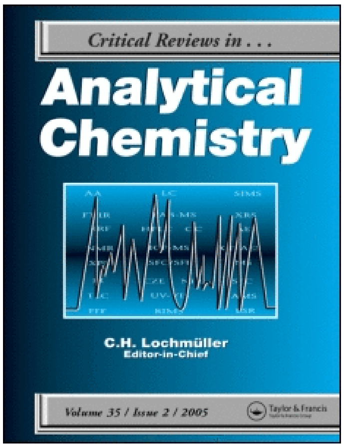


**Critical Reviews in Analytical Chemistry**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713400837

# ENVIRONMENTALLY FRIENDLY CHEMICAL TECHNOLOGIES

Algirdas Vaškelis; Mudis Šalkauskas

Online publication date: 03 June 2010

**To cite this Article** Vaškelis, Algirdas and Šalkauskas, Mudis(1998) 'ENVIRONMENTALLY FRIENDLY CHEMICAL TECHNOLOGIES', Critical Reviews in Analytical Chemistry, 28: 2, 159
**To link to this Article: DOI:** 10.1080/10408349891194595
**URL:** http://dx.doi.org/10.1080/10408349891194595

*Critical Reviews in Analytical Chemistry*, 28(2):[SI]157–[SI]159 (1998)

# ENVIRONMENTALLY FRIENDLY CHEMICAL TECHNOLOGIES

ALGIRDAS VAŠKELIS and MUDIS ŠALKAUSKAS
Institute of Chemistry, Vilnius

## 1. INTRODUCTION

Chemistry and chemical technology are the main transformers of materials and therefore are most responsible for the chemical conditions of environment. Our efforts to take from the Nature's treasury are quite well developed and perfect, but our skills to give back are undeveloped and limited in its means. Therefore our production activities must be prudent and careful. The main object of environmentally friendly chemical technologies is to avoid any waste at the very beginning. In this report we shall present our interpretation of this principle and our efforts to apply it to the electro- and electroless plating of metals.

## 2. ECONOMICALLY AND ECOLOGICALLY SUITABLE TECHNOLOGIES

Economical criteria reveal fitness of chemical technologies to fulfill societies needs and benefits and ecological criteria set a system of environmental protection requirements for chemical technologies. Sound environment is a basis for healthy society and therefore economical criteria must account for the quality of environment. On the one hand the environment may be considered as a raw material for living, but on the other hand the environment is a product of our efforts to protect and to improve it for better living. The life cycle analysis of chemical technologies and financial functional analysis may help to point out dangerous and risky elements in the whole system of production-consumption [1-3].

## 3. WASTELESS TECHNOLOGIES

Wastless or Clean technology concept has been developed in the course of recent decades and is especially widely used now [4]. These terms are partly self-understandable but their definitions are not very rigorous (as those of most environmental concepts). The definition of the Engineering and Physical Sciences Research Council [5]:

A Clean Technology is a means of providing a human benefit which, overall, uses less resources and causes less environmental damage than alternative means with which it is economically competitive, shows some relativity of "wastelessness" or "cleanliness". It is evident that the absolutely clean and wasteless technologies are impossible, and it is necessary to define the degree of wastes and "uncleanness" acceptable for society at the moment, and the aspects of technologies impact should be analyzed.

It follows from the definition given above that:

1) overall resources used and environmental damage should be analyzed using Life Cycle ("cradle-to-grave") method,

2) economic performance of technologies is an important part of the concept ( not only environmental effects).

Generally, the Wasteless (Clean) Technology thinking leads towards a service of "dematerialized" economy in which materials are systematically used and re-used to bring about the drastic increase in resource productivity needed to make human activity sustainable [6].

All products manufactured by society become wastes after all, since they are useless in the result of distribution and consumption. Only some short interval or separate phases in the life cycle of products are wasteless. The main goal of Environmentally friendly technologies is to mine, transform, produce, consume and dispose materials with a minimal environmental impact.

The main components of Wasteless (Clean) technology in our case of surface treatment technologies are the Waste Minimization and Pollution Prevention [7, 8].

## 4. SURFACE TREATMENT TECHNOLOGIES

Traditional surface treatment processes - electroplating, electroless plating, chemical treatment (etching, pickling, degreasing, activation, passivation, etc.) are performed in solutions and includes also numerous rinsing steps. These processes are technically efficient and rather a simple equipment is needed. Alternatively, they are big sources of environment pollution by heavy metals and other dangerous chemicals. The competing technologies of surface treatment in vacuum and gas phase (PVD, CVD, etc.) are cleaner and now widely used bur they are not always so versatile and simple.

The minimizing of wastes and of the damage to environment when improving the existing surface treatment processes and developing new ones is achieved by several ways:

1. Changing the chemical composition of solutions used by excluding highly toxic or otherwise dangerous chemicals. E.g., chromium (VI) compounds are replaced by Cr(III) in chromium electroplating baths (but traditional Cr(VI) baths technical performance remains higher than baths based on Cr(III), containing no Cr(VI) solutions of Zn and Cd passivation and plastics etching compositions are being developed; such metal ion ligands and buffering substances as EDTA, ammonia, phosphates are replaced by other compounds having lower impact on environmental or more easily destructible (EDTA drastically changes metal ion equilibrium in natural media due to a high stability of its complexes, nitrogen and phosphorus compounds act as fertilizers); toxic (cancerogeneous) formaldehyde is not desirable in electroless plating solutions but its replacement is difficult - an alternative is a replacement of electroless plating process; many efforts have been made to replace highly toxic cyanide in electroplating baths - but it does not present a great danger to environment due to a low chemical stability and easy decontamination, and the main danger is at operation site (some additional safety measures are needed).

2. Using lower concentrations of metal ions in working solutions. The lowest level of metal concentration is limited by technical process parameters, but sufficiently effective nickel and chromium electroplating processes were developed with ca. fivefold lower metal concentration in the plating bath solution.

3. Improvement of electroplating process balance; it minimizes replenishment and recovery procedures of the solutions and wastes. E. g. balancing the cathodic and anodic reactions efficiency it is possible almost to avoid replenishment by a metal salt and the ideal closed cycle of metal transfer from the anode to the cathode is approached.

4. Minimization of water and heavy metal consumption and, as a result, minimization of waste production is achieved by improving rinse systems using reverse flows to process bath, reusing water several times before disposal.

5. Combination and unification of process steps reduces rinsing operations. E. g. combined etching and activation procedures in plastic metallization may be carried out in one solution.

6. Closed cycle implementation in electroless plating processes. Conventional electroless plating solutions life is limited by accumulation of reducing agent oxidation products (formate, phosphite) which are not reducible to the former state. Recently developed electroless process for copper and silver deposition using Co(II) complexes as reducing agents are suitable for almost closed-cycle type usage. The reaction product Co(III) complexes are reducible to Co(II) . Electrochemical regeneration of reducing agent (cathodic process) may be carried out together with metal (Cu, Ag) dissolution (anodic process) acting as metal ion replenishment instead of a conventional one by adding metal salt; an electrochemical

replenishing is more "clean" - no additional anions are added to solution and the salt wastes of conventional process are excluded [9, 10].

At the Institute of Chemistry (Vilnius) some efforts were made towards cleaner technological processes for surface treatment [7, 8, 11]. The electrolytes for nickel or chromium electroplating with substantially lower concentration of metal ions, solution for zinc and cadmium passivation containing no chromium compounds, non-cyanide bath for copper alloys electroplating, were developed. Technologies for plastic metallizing were improved (united technological operations, electroless plating replacement by electroconductive layers from copper sulfides, etc.). A new type of electroless plating solutions containing reconvertable reducing agent - Co(II) complexes was developed.

In cooperation and with financial support of the Institute for Product Development (Denmark). The project for clean electroplating technology implementation is being carried out for several years in five factories of Lithuania. The project includes changes in some technological steps (without changing the main bath solution composition) leading to minimum water consumption. The save rinse systems with reverse flow to process baths and evaporators to force the necessary water flow are used. Water is used several times before disposal. These and other innovations result in tenfold or more decrease of water consumption and lower metal (nickel, zinc, chromium) wastes in 3 Lithuanian plating shops.

## 5. SUMMARY

- Environmentally friendly chemical technologies have minimal separate operations and use minimal quantities of auxiliary materials, which are spoiled and thrown away as wastes.
- Metal electroless and electroplating technologies may be environmentally friendly when the principal metal transfer and transmutation process is not disturbed by contaminants or inaccurate actions.
- Life cycle analysis and proper material flow account helps to manage environmentally friendly technology with a minimal environmental impact.
- A proper combination and unification of different chemical operations in the same process help to solve the waste elimination problems.

## REFERENCES


1. E. Davidavičius, M.Šalkauskas, R. Daubaras, E. Ramoškienė, A. Grinkevičius, G. Fomin, and S. Rastrigin,. *Copper recuperation and Regeneration of Copper Etching, Electroless and Electroplating Solutions*. Moscow, Izd. Stand., 1991. (in Russian).
2. I.N. Dorokhov. and V.V. Kafarov. *System analysis of Processes of Chemical Technology. Expert Systems for Improvement of Industrial processes of Heterogeneous Catalysis*. Moscow, Nauka. 1989. (in Russian).
3. V.A. Gorelik and A.F. Kononenko. *Theoretical Game Models for Decision Making in Ecological-Economical Systems*. Moscow, Radio i sviaz, 1982. (in Russian).
4. I. Franc and D. Brownstone, . *The Green Encyclopedia*.- New York, Prentice Hall, 1992
5. R. Clift, *J. Chem Techn. Biotech.* 1995, Vol. 62, pp. 321.
6. R. Clift, J. *Chem Techn. Biotech.* 1997, Vol. 68, pp. 347.
7. M. Šalkauskas and D. Kimtienė, *Galvanotechnikos atliekų perdirbimo galimybės* (Electroplating Waste Reprocessing Possibilities). Vilnius, LII, 1990. (in Lithuanian)
8. M. Šalkauskas, M. G. Klimantavičiutė, J. Budilovskis. and A. Mickis, *Galvanotechnikos kenksmingumas ir jo mažinimo būdai Respublikoje* (Electroplating Hazards and Ways to Diminish them in Lithuania). Vilnius, LII, 1990. (in Lithuanian)
9. A. Vaškelis, J. Jačiauskienė and E. Norkus, *Chemija* (Vilnius), 1995, Nr. 3, p.16.
10. A. Vaškelis, E.Norkus and G. Rozovskis, Trans. Inst. Metal. Fin., 1997, Vol. 75, p. 1.
11. M. Šalkauskas and O.Gylienė, Metal Recovery from Spent Electroless Plating Solutions by Oxalate Precipitation, *Plating and Surf. Finish.*, 1995, No 10, p. 61.