Electrodeposition of Iron Alloys

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ABSTRACT

A review has been made of the electrodeposition of iron alloys with special reference to types of alloys, plating baths and industrial applications.

INTRODUCTION

The electrodeposition of alloys has received considerable attention in recent years. Electroplated alloys find application in decorative and protective finishing of metals as well as in engineering on account of some special properties. In the bright plate the alloying metal is sometimes present in small amounts. In other cases a metal is codeposited with a cheaper metal like iron to obtain a deposit which has the essential properties of the former, or it is combined with a less common metal like tungsten or molybdenum resulting in an alloy having some desirable properties. Among the recent developments in this direction, the electroplating of iron alloys has gained considerable prominence in view of their use in the electrical industry, for building up of worn parts, etc This paper outlines the developments in the field of iron alloy deposition. The investigations carried out in this laboratory have been reported. A good deal of the work is covered by patents.

IRON-NICKEL ALLOYS

Iron has been codeposited with nickel from various types of solutions: sulphate[1-4], chloride[5,6], sulphamate[7,8], cyanide[9] and pyrophosphate[10,11]. Nickel-iron alloys have been mentioned as bright protective coatings, as undercoats for nickel and tin plates and enamel, for magnetic shielding and in memories of digital computers[12-14]. For magnetic properties, deposits containing 20-50 per cent iron are generally used. It has been reported that a 21 per cent iron alloy had a greater tendency for pitting during saltspray tests than a dull nickel deposit from the Watts bath[4]. The anti-corrosive properties of these coatings, containing not more than 30–40 per cent iron, are stated to be equal to those of nickel, with the advantage of better magnetic properties[15].

IRON-ZINC ALLOYS

The baths used for iron-zinc alloy plating are: sulphate[16-19], chloride[18,20], sulphamate[21,22] and pyrophosphate[23,24]. A composition containing 94 per cent iron is bright, while with 35-65 per cent it is hard and corrosion resistant. A deposit with 40 per cent iron has been suggested as a base for chromium plating[16]. An alloy containing 85–98 per cent iron provides a good levelling of the steel surface prior to nickel/chromium plating, and renders buffing of the nickel plate either unnecessary or less expensive[21]. It is stated to be equal to or better than zinc for corrosion protection, less reactive in contact with paint films, and easily soldered[25]. An alloy containing 1·5 per cent iron has been found to be most suitable for use as antifriction metal in bimetallic bearings[17]. The greatest adhesive strength was on grey iron and steel, and stresses were negligible. The electroplating of this alloy has been mentioned as a new method of repairing machine parts.

IRON-CHROMIUM ALLOYS

There are several reports on the production of bright and hard deposits of alloys of iron with chromium over a wide composition range, 6-79 per cent iron. An earlier patent[26] describes the electrodeposition from a sulphate bath of a coating having sufficient hardness to be useful where hard deposits which do not soften at high temperatures are desired. Another patent[27] covers a bath containing trivalent chromium together with small quantities of the alloying metal in order to obtain bright alloy plates. Yoshida[28] as well as

McGraw and coworkers[29] have also used a trivalent chromium bath for the deposition of these alloys. In view of the higher efficiency and rate of deposition from this bath, more significant developments can be expected in future. There are several recent reports on the electrodeposition of these alloys which mention many special properties: abrasion resistance and a crack system similar to conventional chromium plate, hardness and corrosion resistance at elevated temperatures[29-31]. Spencer[32] has reviewed the electrodeposition of iron-chromium alloys. It is anticipated that further research in this field will yield plating methods which are both practical and economical.

ALLOYS OF IRON WITH TUNGSTEN AND MOLYBDENUM

Alloys of iron with tungsten or molybdenum are of special importance in view of their brightness, hardness particularly at elevated temperatures, and resistance to tarnish and corrosion 133-35. They are also promising substitutes for electroplates of chromium and hard nickel. Although tungsten and molybdenum are expensive, the unusual properties of the alloy plates may perhaps justify their utility in specialized applications. These alloys have been deposited from various types of solutions, the most important being those containing hydroxy-organic acids and particularly the ammoniacal citrate type [33-37]. Recently the pyrophosphate bath has been used for the deposition of iron tungsten[38,39] and iron–molybdenum[40] alloys. In both cases it is quite difficult to obtain alloys with a low iron content; there is a good similarity in the deposition process as well as the composition and properties of the deposits [41].

OTHER BINARY ALLOYS

Iron-Cobalt

Although iron-cobalt alloys have properties similar to iron-nickel alloys, there appears to be little developmental work. They have been deposited from sulphate [42,44], sulphate in oxalate [45], chloride [43-46], sulphamate [47] and pyrophosphate [48,49] solutions. An alloy containing about 50 per cent iron has been stated to be suitable for bonding aluminium to steel [50].

Iron-Manganese

Iron has been codeposited with manganese from sulphate and chloride baths [51-54]. Colloidal addition agents are found to improve the quality of the plates. They are adherent and bright, but brittle when the iron content is less than 5 percent. Even with a manganese content as low as 2 per cent or less, they were quite hard. The deposits have been reported to be more resistant than mild steel to corrosion by tap water.

Miscellaneous Alloys

Iron has been codeposited with several other metals, but detailed information is lacking. The alloying metal and the baths are given below in each case: (a) cadmium[55] - sulphamate, (b) zirconium[56] - carbonate - citrate, (c) titanium[57] - alkaline bath containing titanium hydroxide and organic acids, (d) gold [58] - cyanide, (e) copper [59], (f) vanadium [60] - chloride and (g) rhenium [61] - ammoniacal citrate. The corrosion resistance of the titanium alloy has been found to be very good in acid medium, but practically equal to that of titanium in sea water.

TERNARY ALLOYS

Electrodeposition of several ternary alloys containing iron has been reported, though not in such detail as for binary alloys. Ternary alloy deposition, if commercially feasible, will have many advantages since the properties can be altered by changing the composition of the constituent metals. The following alloys have been mentioned in literature: (a) iron and nickel with cobalt [62] or zinc [63] or copper [64-67], (b) iron and molybdenum with nickel [68] or copper [69], or manganese [69], (c) iron and tungsten with nickel [70-73] or cobalt [74] or tin [75] and (d) iron-chromium-nickel [76,77]. Plating solutions belong to the sulphate, sulphate-urea, citrate, cyanide and pyrophosphate types. Detailed information is available only for iron-nickel-tungsten and iron-chromium-nickel (18/8 steel) alloys. The deposition of ternary alloys merits detailed investigation. There is a report on quaternary alloys containing iron-nickel-molybdenum with manganese or copper [78].

GENERAL CHARACTERISTICS

Plating solutions containing iron in the ferrous state are to be preferred in view of the higher cathode efficiency and rate of deposition. The relationship between the ratio of iron to alloying metal in the solution to that in the deposit will depend upon the alloying metal as well as the type of bath. In general, addition agents appear to have little effect on either the nature of the deposit or the bath performance. There is a tendency for constancy of composition at higher current densities in most systems. The cathode

efficiency is rather low during the deposition of alloys containing chromium, manganese, tungsten and molybdenum. In the case of iron-zinc, sudden changes in deposit composition as well as cathode potential have been observed corresponding to changes in the phase of the deposited alloy.

CONCLUSION

A large number of iron alloys, including those with uncommon metals, can be electrodeposited from different types of baths. Some of these deposits have some special properties which are of great significance in metal finishing. Apart from the practical aspects there are many points of theoretical interest in the deposition of alloys. This is particularly so with alloying metals like tungsten or molybdenum, which have so far not been deposited in the pure state from aqueous solutions. In such systems the experimental data can throw considerable light on the mechanism of deposition of tungsten or molybdenum. Detail information of an academic character is lacking in published literature for a large number of cases. The electrodeposition of iron alloys, binary or ternary, and if possible quaternary, appears to be a field which warrants further research work. It is, of course, necessary to carry out pilot plant experiments in order to comment on the industrial aspects of the problem. Alloys containing chromium and manganese are of particular interest in India, keeping in view the abundant resources of these metals and the shortage of the common non-ferrous metals used in plating.

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