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Steel sheet is a very versatile product. It comes in many sizes and types, and is applied to many end uses including steel buildings, automotive panels, signs, and appliances. The low cost, strength and formability of steel sheet are some reasons for its widespread use. Unfortunately, as are most steel products, it is prone to rusting, a phenomenon that causes the surface to become unsightly and, over time, may contribute to product failure. For this reason, steel is protected by a variety of methods ranging from internal alloying (stainless steel, for example), to coating with paints or metallic coatings.

Corrosion is an electrochemical process that, in the case of steel sheet, oxidizes the iron in the steel and causes it to become thinner over time. Oxidation, or rusting, occurs as a result of the chemical reaction between steel and oxygen. Oxygen is always present in the air, or can be dissolved in moisture on the surface of the steel sheet. During the rusting process, steel is actually consumed during the corrosion reaction, converting iron to corrosion products. In the case of most low-carbon steel sheet products, iron oxide (rust) develops on the surface and is not protective because it does not form as a continuous, adherent film. Instead, it spalls, exposing fresh iron to the atmosphere which, in turn, allows more corrosion to occur. This aspect of steel sheet behaviour is very undesirable, both aesthetically and from the aspect of service life. Eventually, often sooner than desired, the steel sheet is corroded sufficiently to cause degradation in the service life, i.e., loss of structural strength, perforation and intrusion of water, etc.

Fortunately there are many coatings that can be applied to steel in a very cost-effective manner to confer sufficient corrosion protection to steel so that it can be used for a multitude of demanding applications.

Although cadmium electroplating offers many advantageous coating properties, it is strictly regulated due to its toxicity. For example, the use of cadmium is limited by stringent worker exposure limitations promulgated by the Occupational Safety and Health
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Administration. Waste water discharges from cadmium electroplating baths must meet effluent limitations dictated by regulations promulgated under the Clean Water Act. In addition, sludges from wastewater treatment must be managed as hazardous waste under the Resource Conservation and Recovery Act. Due to health, safety, and environmental issues, as well as regulations that necessitate high abatement costs, acceptable alternatives for cadmium must be identified and implemented.

The main mechanism by which galvanized coatings protect steel is by providing an impervious barrier that does not allow moisture to contact the steel, since without moisture (electrolyte) there is no corrosion. The nature of the galvanizing process ensures that the metallic zinc coating has excellent adhesion, abrasion, and corrosion resistance.

Galvanized coatings will not degrade (crack, blister, and peel) as with other barrier coatings such as paint. However, zinc is a reactive material and will corrode and erode slowly. For this reason, the protection offered by a galvanized coating is proportional to its thickness and to the corrosion rate. It is therefore important to understand zinc's corrosion mechanism and what factors affect the rate.

On the other hand, alloy electrodeposition is more complex than single metal deposition and involves control of several chemical and operational parameters. In practice, these parameters are often chosen empirically. Therefore, it is important to develop a more scientific approach leading to a better fundamental understanding of the codeposition phenomenon. This will lead to improved process performance and reliability, as well as establishment of new alloy systems.

In order to provide good corrosion resistance to steel with low cost and lower coating thickness, electroplated zinc alloys have been always used. These are mostly alloys of zinc with small percentage of Ni or Fe or Co or Mn. Zinc alloys (Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn) remain anodic to steel and are less active than zinc. They will corrode in preference to steel in corrosive environment, but at a much lower rate than that of zinc and without producing voluminous corrosion products compared to pure zinc coatings. Many factors involved in the selection of a particular alloy for a specific application include bath composition, ease of operation, cost and actual performance in corrosive atmospheres zinc alloy coatings have been considered feasible alternatives to both zinc and cadmium coatings.
Electroplating of zinc alloys have many advantages over galvanizing because of the stability of phase. Among the zinc coatings, Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn alloys also have received more attention because of their high degree of corrosion resistance and good mechanical properties. These alloys coatings have been considered for several other applications such as water electrolysis and coating for steel cord reinforcement of tires, etc. Zinc alloys have generated the great interest in defence and military aircraft industries because they meet the most of the requirements previous sought from cadmium. These alloys show very good corrosion resistance to heating and in saline condition.

Electroplating of Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn alloys is of anomalous codeposition type. Since the anomalous codeposition is rather rare, this phenomenon deserves a detailed study. The application of these alloys depend on the alloy composition, variation of alloy composition across thickness, uniformity of the surface and internal stress which are related to the plating conditions such as current density, temperature, bath pH, agitation of the bath solution and bath composition.

Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn alloys coatings can be obtained using plating baths of various composition and operating conditions. Most of the studies regarding codeposition of Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn alloys have been made with acid bath containing simple salts of the metals. The cyanide baths are not preferred because they have less nickel or iron content in the deposit than the required range and cause environmental hazard. Further, the effluent of cyanide baths has to be treated as per the pollution control board regulations.

Composite plating is a method of co-depositing fine particles of metallic, non-metallic compounds or polymers in the plated layer to improve material properties such as lubrication, wear resistance and corrosion resistance. The demand for metal matrix composites is reaching new heights for aerospace and defense applications in order to cope with the severe environments and stresses encountered during operation. Electrodeposited composite coatings find applications as wear and corrosion resistant coatings, self lubricating films and thermal barrier coatings have been widely developed for various engineering applications due to the interesting possibilities it offers.
Composite coatings based on zinc are finding increased interest in surface technology and corrosion protection. Potential fields of application are improved corrosion and wear resistance of zinc-composite layers with extended life time.

Electroplating of zinc, zinc alloys and zinc-composites from the bath solution containing complexing agents are still in their developing stage. Some of organic compounds form complexes in aqueous solution with zinc, nickel, cobalt and manganese. The stability of each complex depends on pH of the bath solution, temperature and ratio of concentration of metal ion to complexing agent in the bath. In the literature very little work has been reported on the electroplating Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn alloys and zinc-composites from acid baths containing complexing agents.

Also it is evident from the available literature that single addition agent generally does not produce good deposit over a wide current density range. To overcome this, combination of two or more addition agents are used. These addition agents are usually of organic nature and their solubility in aqueous zinc plating solution is limited. Also, presence of many addition agents in the bath creates problems in determining the brightener requirement. Some addition agents also cause pollution and health hazard.

A new class of zinc and its alloy electroplating baths allows one to obtain remarkable performances in the technique, owing to new additives of strong complexing nature. Bright electrodeposits can be obtained by the addition of brighteners into the plating bath. Bright deposits improve the appearance of the article and offer better corrosion resistance. Good quality bright deposit is always obtained from plating baths containing addition agents. A brightener generally possesses the following characteristics:

i) shifts the cathodic potential in more negative direction,

ii) forms complex with zinc, nickel, cobalt and manganese ions,

iii) brings down the surface tension at the interface of electrode surface and solution,

iv) increases the viscosity of bath solution,
controls the rate of growth of fresh nuclei and hence rate of deposition,

increases the throwing power of the bath solution.

Many researches have focused on the co-deposition of nanoparticles such as metallic powder, silicon carbides, oxides, polymer and diamond etc to further enhance the corrosion inhibition. By combining the properties of various kinds of particles, many new functional materials were created with more comprehensive applications.

Incorporation of diamond nano particles (DNPS) into the deposits is important especially for Zn-base coatings which are expected to replace the Cr-containing coatings.

Among the various nanoparticles graphite nanoparticles (Gnps) have attracted especially close attention. Gnps, with sp² hybridization, has got good electrical conductivity and low coefficient of friction, high wear resistance and superior lubricating property.

In the present work attempts have been made to develop baths with suitable composition and operating conditions for bright and corrosion resistant. Zn, Zn-Ni, Zn-Fe, Zn-Co, Zn-Mn alloys and Zn-composites on steel substrate from respective electrolytes. Also it is aimed to develop bath solutions containing minimum number of addition agents and to obtain bright defect-free deposit over wide current density range. Efforts have been given to optimize the bath with improved current efficiency and throwing power. The study is focused on to get the deposit with improved brightness, corrosion resistance, wear resistance, adherence, ductility etc. Emphasis has also been given to develop industrial baths possessing minimum or no effluent treatment.

The present thesis comprises the results obtained during detailed investigations on the development of optimum plating baths for zinc deposit from acid sulphate, acid chloride and alkaline baths. Zinc alloys such as Zn-Ni from acid sulphate and acid chloride baths, Zn-Fe from acid sulphate bath, Zn-Co from acid sulphate bath and Zn-Mn from acid chloride and sulphate baths have been deposited. The Hull cell experimental technique is used to optimize bath composition and operating parameters. In each case, bright current density range is evaluated. The dependence of bright current density range on the bath variables (pH, bath composition, concentration of conducting salts and
brightener) and operating variables (current density, temperature and agitation) are presented. Throwing power and current density of plating baths were determined. The zinc, Zn-Ni, Zn-Fe, Zn-Co and Zn-Mn alloys deposits obtained under optimum plating conditions are tested for industrial applications (porosity, adhesion, brightness, ductility, corrosion tests etc.). Explanation for the dependence of alloy composition on the bath composition, $pH$, current density, concentration of complexing agent and agitation of plating bath solution are given. The effect of addition agent on the surface morphology was investigated by polarization, SEM, XRD and TEM studies.

Further certain nanosized materials like graphitic carbon and diamond nanoparticles have been codeposited into the zinc matrix from acid sulphate bath. Salt spray test and electrochemical measurements were made in order to assess the corrosion behavior of the composite coating in 3.5 wt% NaCl solution. The surface morphology and coating thickness are measured by SEM studies and particles size by XRD and TEM studies.