Zinc coatings are used for corrosion protection and decorative finishes of iron and steel for engineering materials and consumer goods. Zinc is anodic to iron and steel and hence it sacrificially corrodes in preference to iron and steel and thereby protects the base metal. No other commonly electrodeposited metal offers so much corrosion protection so economically compared to zinc and hence it has become a popular industrial finish.

Today zinc is plated in small, medium and large-scale industries by the conventional cyanide bath, which suffers from a serious drawback of toxicity and effluent treatment problems. Hence, it necessitates the stringent pollution control of cyanide up to 0.2 ppm (tolerance limit as per IS 2490-74 for surface draining). In large-scale industries some efforts are being made in this direction. The effluent treatment of the cyanide is not cost effective for the small and medium scale industries. Therefore, it was felt that there is necessity for a total change in the bath to cater to the plating industry as a whole.
Synopsis

For the last few years, non-cyanide baths (chloride, sulphate, fluoborate and sulfamate) are in vogue. Sulphate bath is in the forefront due to several favourable bath characteristics like less aggressive, ease of maintenance and effluent treatment. Like sulphate bath, the chloride bath is also used in large-scale industries because of its high throwing power and very similar quality deposits as that of cyanide baths. Non-cyanide alkaline bath poses no effluent treatment but its use is limited for the reason that it has restricted working parameters.

The work described in this thesis is directed towards the development of acid and non-cyanide alkaline zinc plating baths for industrial plating. Attention has been mainly focussed to prepare and use non-toxic, simple brighteners. Amines, aldehydes, amino acids and their condensation products are mainly selected for the study. Sodium lauryl sulphate and CTAB are used as surface-active compounds for acid sulphate-chloride and alkaline baths. Gelatin and EDTA are used as primary addition agents for acid chloride and alkaline baths, respectively. Three brighteners systems, i) Yeast extract with Hexamine, ii) condensation product of Glutaraldehyde with DL-Alanine and iii) condensation product of Glutaraldehyde with L-Lysine) are developed for acid sulphate bath. The combination of 3,4,5-Trimethoxy benzaldehyde with Gelatin has been found to be act as brightener for acid chloride bath. For acid sulphate-chloride bath two systems, i) N-Acetyl glycine in combination with Sodium lauryl sulphate and ii) condensation product of Glutaraldehyde with Semicarbazide are developed. The two systems, i) CTAB, EDTA, Salicylaldehyde and ii) CTAB, EDTA, condensation product of DL-Alanine with Glutaraldehyde, produce bright deposit in non-cyanide alkaline bath.

For each brightener system, using Hull cell experiments, plating conditions and plating variables are optimized. Throwing power and current efficiency for each system are
measured. Zinc coatings are subjected to corrosion resistance test, adhesion test, porosity test, hardness test, internal strength and thickness measurement. Basic studies like plating under Tafel region, polarographic and cyclic voltammetric analysis of plating bath solutions, corrosion behaviour of zinc deposits in presence of brighteners and IR studies for the scraped deposits obtained from respective baths are carried out to understand the actual behaviour of brighteners in plating bath solution. SEM technique was used to study the surface morphology of the deposit. Brightener requirement is calculated for each system.

Chapter 1 includes literature survey of electroplating of metal in general and industrial zinc plating in particular. Chapter 2 outlines the broad aim and scope of the work and highlights the absence of comprehensive approaches in understanding industrial acid and non-cyanide zinc plating. Chapter 3 contains the detailed experimental procedures adopted for:

a) Surface preparation prior to electroplating

b) Preparation and purification of plating bath prior to electroplating

c) Optimization of bath constituents and operating parameters through Hull cell studies

d) Measurement of current efficiency, throwing power, cathode potential and operating bath voltage

e) Porosity measurement, testing for the adhesion, thickness, hardness and internal strength of the deposit

f) Corrosion resistance measurement (Salt spray test)

g) Polarographic and Cyclic Voltammetric studies

h) Infra Red and Scanning Electron Microscopic studies
i) Measurement of thickness uniformity of the deposits.

j) Determination of brightener consumption and its stability.

Chapter 4 reports the results obtained pertaining to the plating of zinc from acid sulphate, chloride, and sulphate-chloride and non-cyanide alkaline baths containing various addition agents (primary and secondary). The results in the following sequence for each set of brighteners are included.

a) Selection of basic plating bath solution

b) Hull cell studies to optimize bath constituents and bath variables

c) Effects of bath constituents and bath variables on brightness range

d) Measurement of bath voltage and cathode potential

e) Influence of metal ion concentration, current density, $pH$, temperature and brightener concentration on current efficiency and throwing power

f) Metal ion distribution, polarisation studies and thickness measurement

g) Testing of hardness, porosity, adhesion and corrosion resistance of zinc deposits

h) SEM studies of the deposits

i) Determination of brightener consumption, and

j) Installation of 15 liter capacity bath for pilot plant studies.

Chapter 5 deals with the results of basic studies such as polarographic and cyclic voltammetric analysis of plating bath solution (with and without addition agents), corrosion of zinc deposit in the presence of addition agents, thickness uniformity of the deposit by acid
pickling, and IR studies of the scratched deposits obtained from the different baths.

Chapter 6 reports the summary of the main conclusions of the work.