CHAPTER 1: INTRODUCTION

1.1   Introduction

Electrodeposition is one of the most commonly used methods for metal and metallic alloy film preparation in many technological processes. Alloy metal coatings present a wider range of properties than those obtained by a single metallic film and can be applied to improve the properties of a substrate/coating system. These coatings can be electrodeposited by the simultaneous reduction of two or more metallic cations present in an electrolyte solution. However, the simultaneous discharge of different ions on the cathode is not a simple process and it can be influenced by the substrate surface as well as by changes in the structure and activity of each metal cation in the double layer [Senna, 1991].

The electrodeposition of Cu-Pb alloys has received great attention in order to develop coating for particular purposes, notably wear and corrosion-resistant bearing coatings [Raub, 1976; Udupa et.al., 1975]. Binary systems of lead alloyed with copper, cadmium, cobalt, bismuth, tin, nickel, and zinc have been chosen by commercial manufacturers depending on factors such as mechanical, thermal, and electrical properties of the alloys and the environment in which they will be used are summarized in the book 'Modern Electroplating' by (Schlesinger and Paunovic, 2010).

According to Brenner (1963) noted that Cu-Pb alloy coatings have been deposited from both simple and complex ions typically in acid and alkaline baths respectively. The electrodeposition of copper-lead alloys has received little attention. Rahem El Abd et.al., (1997) electrodeposited Cu-Pb alloys from the bath containing mixtures of lead nitrate, copper nitrate and sodium gluconate. The deposits consist of a mixture of fine crystals of the two metals and the morphology of the deposits is mainly controlled by the composition of the deposit. Moreover, the plating system showed a regular consistent behaviour with copper being the preferentially depositable metal.

However, the lead (the less noble metal) content in the deposits increased with increase in current density. Another most important baths is a mixed bath containing lead as a tartrate complex and copper as the complex cyanide (Ferguson and Hovey, 1951). Although lead is the less noble metal under most conditions it deposits preferentially so that the alloy plating system belongs to the anomalous type. The copper content of the alloy decreases with increases in current density and cyanide content of the bath but increases with increases in tartrate content of the bath. Hespenheide et.al., (1956) reported that lead deposits preferentially from baths based on copper cyanide and lead gluconate complex yielding Cu-Pb alloy superior to those obtained from cyanide tartrate baths for bearing linear applications. On the other hand, Beerwald and Dohler (1947) electrodeposited Cu-Pb alloys from the bath containing copper citrate and lead tartrate and Bollenrath (1943) showed that in such baths lead is less noble than copper and deposits less readily as would normally be expected.

Certain metal salts such as those of Cu, Pb and Sn, are soluble in most acid electrolytes (e.g., H_2SO_4, HCl, HBF_4, CH_3SO_3H, etc.) and solubility considerations are not important in the selection of acid electrolytes for electroplating process involving such metals. MSA has largely replaced fluoroboric acid the previous industrial standard as the electrolyte of choice for electrochemical processes involving lead. In general the low toxicity of MSA especially when compared to HF complex acids like fluoroboric acid and fluorosilicic acid makes it a safe electrolyte to handle. The benign nature of MSA especially when compared to HF complex acids like fluoroboric acid and fluorosilicic acid makes it an environmentally advantageous electrolyte (Balaji and Pushpavanam, 2003; Hassan and Rohan, 2010).

MSA is an interesting supporting electrolyte with many desirable properties such as high salt solubility, high conductivity, low toxicity and low corrosivity which enables better waste management (Gernon, 1999). Being an acidic electrolyte has the

added benefit of being compatible with photoresist materials. It has been shown that plating parameter influencing the composition of deposit depends on current density and electrolyte composition.

Copper has many technological applications that rely on its high conductivity. Alloying may improve the performance of the Cu in several of these applications (Hu, et.al., 1995), but the amount of alloying metal must be small in order that the conductivity is not seriously degraded. The plating of alloys in which the more noble metal is the major component presents electrochemical difficulties that must be overcome. It is generally necessary to complex the cations of the more noble metal to bring the deposition potentials of the two metals close together. In the absence of complexants the more noble metal deposits preferentially where the less noble metal is not co-deposited until the limiting current of the major component is reached and poor quality deposits are obtained. Moreover, metal alloy coating electrodeposition is a complex process involving the control of several chemical and operational parameters. In practice these parameters are often chosen empirically and the alloy is then produced at these ''optimum conditions''. Therefore to improve deposition conditions and produce layers that better fulfill industrial needs, it is important to develop a more scientific approach leading to a clearer fundamental understanding of the co-deposition phenomenon. This will lead to improved process performance and reliability as well as to the establishment of new alloy systems.

1.2   Aim and Objective of Work

The aim of the present work is to reveals the process of electrodeposition of binary Cu–Pb alloy coatings onto steel substrates from MSA electrolyte at room temperature in order to get high quality coatings. The measurements was made in solutions of methane sulfonic acid (MSA) which acetate was introduced as the source for Cu(II) and Pb(II). An optimized bath containing a fixed ratio (1:3) of metal ions were used for this purpose. Using experimental design procedures, the deposition parameter mainly current densities were evaluated for their effects on the cathodic current efficiency, alloy coating composition and hydrogen evolution. X-ray diffraction (XRD) experiments were carried out to determine the phases of the deposits. The surface microstructure and alloy composition of deposited material was examined using a scanning electron microscope (SEM) and energy dispersive X-ray (EDX) spectroscopy, respectively. Furthermore, the CV technique was used to investigate the electrochemical behaviour of a Cu-Pb electroplating bath that contained MSA.

As a brief, this project research includes four chapters. The introduction explains the summary and aims of this work (Chapter1). The design and operation condition of electrodeposition are explained in chapter (2). With regards to the electrodeposition layer, mass electrodeposition and characterization was done by some physical and chemical analysis such as XRD, SEM, EDX and CV (Chapter 3). This project research is completed by conclusion in chapter (4).

This work was done at the Department of Chemistry, University of Malaya in Kuala Lumpur.

1.3   Electrodeposition

Metal finishing is the name given to a wide range of process carried out in order to modify the surface properties of a metal, e.g. by the deposition of a layer of another metal alloy, composite or by formation of an oxide film. The origins of the industry lay in the desire to enhance the value of metal articles by improving their appearance but in modern times the importance of metal finishing for purely decorative reason has decreased. The trend is now towards surface treatment which will impart corrosion resistance or particular physical or mechanical properties to the surface (e.g. electrical conductivity, heat or wear resistance, lubrication or solderability) and hence, to make possible the use of cheaper substrate metals or plastics covered to give them essential metallic surface properties. It should be emphasized that not all surface finishing is carried out using electrochemical methods, but electroplating is still represents a large portion of the metal finishing industry.

The objective of an electroplating process is to prepare a uniform deposit which adheres well to the substrates and which has the required mechanical, chemical and physical properties. Moreover, it is of overriding importance that the deposit properties meet their specification on all occasions, i.e. the process is both predictable and reproducible. On the other hand, many metals may (by modification of the bath and electroplating conditions) be deposited with different properties. It is for this reason that it is not possible to define a single set of conditions for electroplating of each metal; the bath, current density, temperature, etc., these will depend to some extent on the deposit properties required.

It is important that the plating bath is stable for a long period of time because of the importance of the reproducibility of the deposit. It is also necessary that the quality of deposit is maintained over a range of operating conditions since some variations in concentrations and current density are bound to occur particularly when different

objects are to be plated. Tolerance of the bath to carry over from previous process liquors or mishandling during operation on the factory floor is an additional advantage. The principle components of an electroplating process are shown schematically in Figure 1.1. The essential components include:

1. An electroplating bath containing a conducting salt and the metal to be plated in a soluble form, as well as perhaps a buffer and additives.

2. The electronically conducting cathode, i.e. the workpiece to be plated

3. The anode (also electronically conducting) which may be soluble or insoluble.

4. An inert vessel to contain (1)-(3), typical, e.g. polypropylene or polyvinylchloride

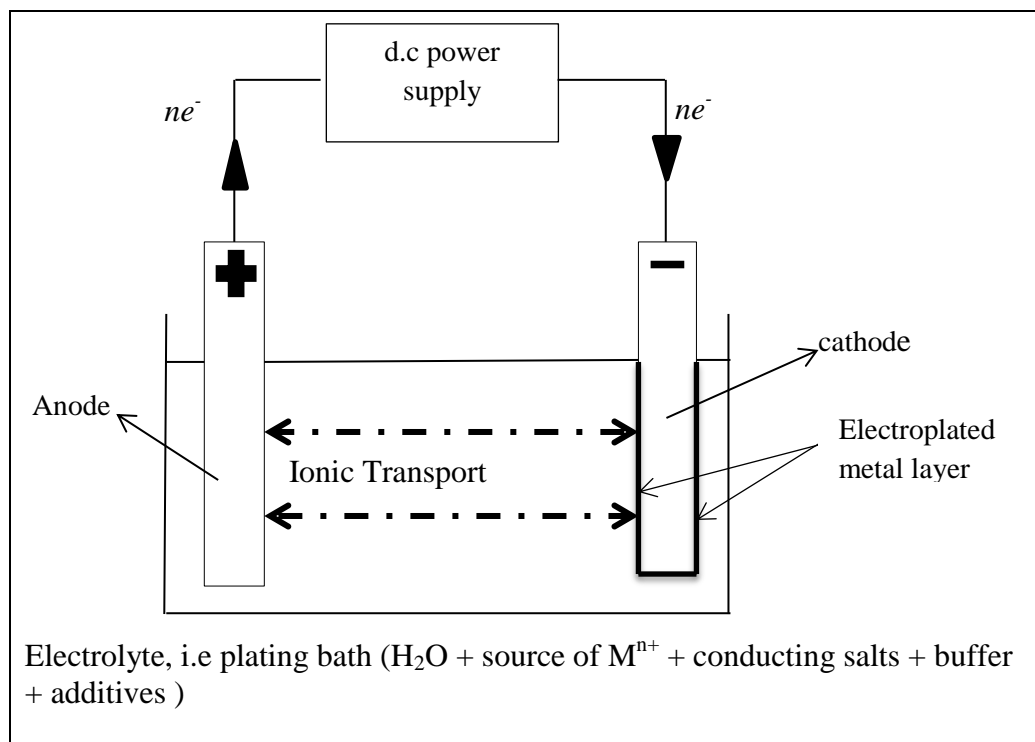5. A direct current source, usually a regulated transformer/rectifier

d.c power supply

ne^-

ne^-

cathode

Anode

Ionic Transport

Electroplated metal layer

Electrolyte, i.e plating bath (H_2O + source of M^{n+} + conducting salts + buffer + additives)
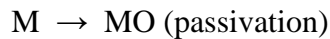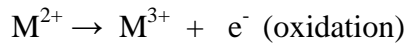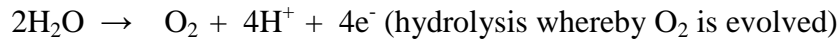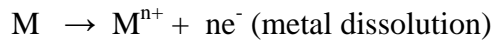
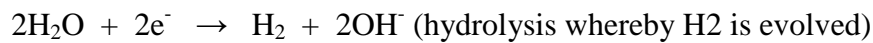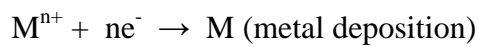Figure 1.1 Schematic diagram showing an principle of electroplating process

During electrolysis, all the ions in solution carry current and the current capacity depends on its concentration and mobility at the electrode. Eventually this leads to a build-up (i.e. an excess) of positive ions or cations at the cathode and those with the most positive discharge potential are first reduced. The anions with most negative

discharge potential are oxidized at the anode. At each electrode, there are more than one reaction occurring.

At the anode:

$M \rightarrow M^{n+} + ne^-$ (metal dissolution)

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ (hydrolysis whereby O_2 is evolved)

$M^{2+} \rightarrow M^{3+} + e^-$ (oxidation)

$M \rightarrow MO$ (passivation)

At the cathode:

$M^{n+} + ne^- \rightarrow M$ (metal deposition)

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (hydrolysis whereby H2 is evolved)

$M^{3+} + e^- \rightarrow M^{2+}$ (reduction)

If the metal deposition process is the major process, it is said to have good current efficiency (Pletcher, 1990).

1.4 Electrodeposition of Alloy

A large proportion of cast or wrought metals are alloys rather than pure metals. This is because the properties of alloys vary over a wider range than those of pure metals and thus alloys can be designed to meet most of the mechanical or chemical requirements more satisfactorily than pure metals. On the other hand, electrodeposits are mostly unalloyed and are usually produced and used in a state of fairly high purity. In fact a lot of efforts are made to keep the plating baths free of metallic contamination. This is not because the electrodeposited alloys are not desirable but because (1) the closer control required for the alloy deposition complicates commercial electroplating processes, (2) the properties of the electrodeposited alloys are not adequately known. Another less important reason is that electrodeposited metals even at high purity can display broader properties according to the service requirement by controlling the plating process [Kanani, 2004]. The most important practical consideration involved in the co-

deposition of two metals is that their deposition potentials should be fairly close together. The importance of this consideration follows born the well-known fact that the more noble metal deposits preferentially frequently to the extent that the less noble metal cannot be deposited at all. Therefore, to simultaneously co-deposit the two metals conditions must be such that the deposition potential of the less noble metal can be attained without employing an excessive current density. Hence, it is necessary to have the potentials of the two metals close together [Gabe, 1978; Paunovic and Schlesinger 1998].

The table of standard electrode potentials serve as a rough guide for deciding if two metals may be co-deposition from a simple salt solution [Gabe, 1978]. The electrode potentials in Table 1.1 apply only to the equilibrium potentials of the metals in a solution of their simplest ions with unit concentrations. These potentials are just theoretically the most positive (most noble) potentials at which the metals can be deposited. In actual deposition because of polarization the deposition potentials are more negative than the equilibrium potentials.

Table 1.1: Standard reduction electrode potentials at 25 °C [Gabe, 1978]

Metal couple	E° (Volts)
Au^{3+}/Au	+ 1.50
Au^{+}/Au	+ 1.70
Ag^{+}/Ag	+ 0.799
$Cu+/Cu$	+ 0.52
Cu^{2+}/Cu	**+ 0.337**
Bi^{3+}/Bi	+ 0.317
Cu^{2+}/Cu	+ 0.153
Sn^{4+}/Sn^{2+}	+ 0.15
Al^{3+}/Al	+ 1.66
Zn^{2+}/Zn	- 0.763
Fe^{2+}/Fe	- 0.44
Co^{2+}/Co	- 0.277
Ni^{2+}/Ni	- 0.25
Sn^{2+}/Sn	- 0.136
Pb^{2+}/Pb	**- 0.126**

Approximately the potentials of Table 1.1 represent the potentials of metals in slightly acid solutions of the simple salts such as the chloride or sulfate. In solutions of metals complex ions their potentials are more negative (less noble) than in their uncomplexed states. Therefore this table can be utilized to derive some conclusions regarding alloy deposition from acid solutions of simple ions. Metals which are close together in Table 1.1 should generally be more readily co-deposited than metals which are widely separated. For example, lead and tin, nickel and tin, copper and bismuth, nickel and cobalt can be readily co-deposited to form alloys because their potentials are less than 0.1 V apart. On the other hand, silver and zinc do not co-deposited readily because of their potential difference of 1.5 V apart.

For metals with rather large differences potentials as listed in Table 1.1, their potential can be brought closer together by:-

1. Increasing the current density

2. Adjusting the concentration of species in solution, this can be achieved by introducing complexants

3. Using organic additives to preferentially inhibit the deposition of the more noble metal.

However these factors are effective only if the polarization of the more noble metal is increased to a larger extent than is that of the less noble metal [Zhang and Abys, 2000]. Brenner has listed five types of deposition system:

1. Regular solutions under diffusion control. Uncomplexed metal ions and two metals of widely differing nobility.

2. Irregular solution under cathode potential control. Static potential affected by complexing alone; e.g. cyanide bath for copper-zinc alloys.

3. Equilibrium solution where at low current densities the bath metal concentration give the deposit metal directly; e.g. lead-tin alloys from acid baths.

4. Anomalous solutions in which the less noble metal deposits preferentially; e.g. iron, cobalt or nickel.

5. Induced solutions in which a metal can be co-deposited as an alloy although it will not deposit singly; e.g. molybdenum or tungsten with iron group metals.

1.5   Structure of Electrodeposited Metal / Alloys

In the majority of electrodeposited materials, the atoms are arranged in a uniform, three-dimensional array. The volume over which this arrangement extends uniformly is called, when many crystals form a solid material, they are called grains. If the array of atoms is random, the material is amorphous. However, in materials considered to be amorphous, there are generally still very small groups of atoms that possess the same arrangement as crystals.

Most electrodeposits exist in one of three crystal habits (Figure 1.2). The most common one is face-centered cubic (FCC) in which atoms or atom groups are located at the corners of a cube and in the center of its faces. Another common crystal structure is body-centered cubic (BCC) in which atoms or atom groups are located at the corners of a cube and in its center. Materials less often have the hexagonal structure. The atomic arrangement of the basal plane of the cube diagonal of the face-centered-cubic one. The habits only differ in the third atom layer.
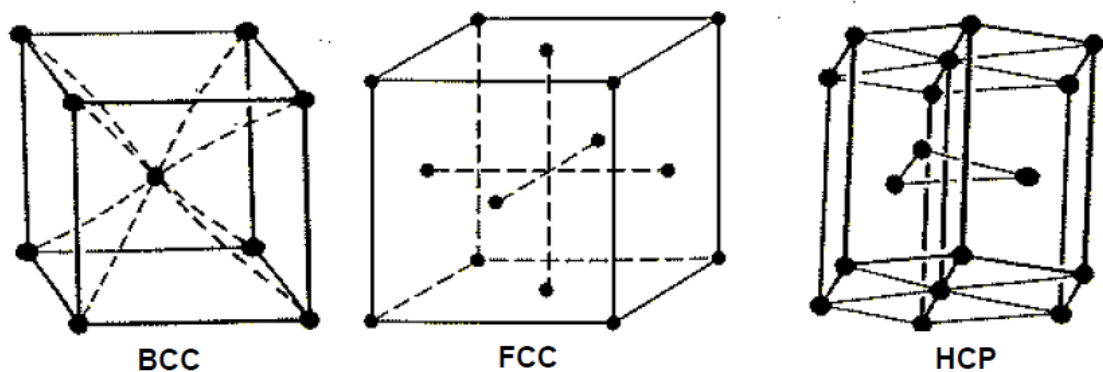

Figure 1.2 Units cells of the three most importance lattices

In many electrodeposits there is a crystal direction that grows faster toward the anode than the other ones. Grains possessing this direction can also grow sideways and cover the less favourably oriented ones. They can grow sideways until they encounter grains of the grains possessing the favourable growth direction. If the grains are not randomly oriented, the condition is called a texture. In the case of electrodeposits the texture is a fiber axis because just as in a wire drawn through a die, the directions perpendicular to preferred orientation are randomly oriented. When electrodeposits are annealed they generally recrystallize, the texture often changes.

1.6   Selection of Substrate

There are at least two reasons why steel is used as a substrate in this alloy plating experiment;

1. One of the aims of the electroplating experiment is to prepare alloy plating for automotive application which most substrate is steel.

2. Alloy plating is more difficult to be implemented on steel rather than on copper because the equilibrium potential of steel is significantly lower than that of copper. Therefore if alloy plating can be successfully done on mild steel it will be successfully conducted on copper e.g. for plating electric connector.

1.7   Methanesulfonic Acid Electrolyte

In the past two decades, increasing environmental regulations have led to the development of environmentally benign electrolytes where copper and lead can be dissolved in reasonable quantities such as MSA (Gernon et.al., 1999). MSA is also an emerging electrolyte choice for the electroplating of pure tin on sheet steel. The wide acceptance of methanesulfonic acid (MSA) as an acid electrolyte for electrochemical processes especially those involving lead and copper has resulted from a combination of diverse physical and chemical properties. These properties include high saturation metal salt solubility, high conductivity, ease of effluent treatment and low relative toxicity.

The high aqueous solubility of metal salts of MSA makes it an ideal electroplating electrolyte (Table 2.0). From Table 1.2 clearly shows the high solubility of the Ca^{2+}, Ba^{2+}, Ag^+, Sn^{2+}, Pb^{2+} and Hg^{2+} salts of MSA relative to the corresponding salts of sulfuric acid. Also the high solubility of the Ag^+, Pb^{2+} and Hg^{2+} salts of MSA relative to the corresponding salts of hydrochloric acid is clearly seen. The universal aqueous solubility of metal salts of MSA is similar to the universal aqueous solubility of metal salts of nitric acid and perchloric acid. Therefore MSA offers a significant number of other advantages in addition to this universal aqueous metal salt solubility.

Table 1.2 The aqueous saturation solubility of some metal methanesulfonates, chlorides and sulfates at room temperature (22°C)

Metal Cation	Aqueous saturation solubility (mol dm^{-3} as metal)		
	Methanesulfonate	Sulfate	Chloride
Mg^{2+}	1.40	2.63	5.02
Ca^{2+}	2.92	0.0249	5.51
Ba^{2+}	1.59	0	1.71
Co^{2+}	2.53	2.16	3.87
Ni^{2+}	2.13	2.44	4.38
Cu^{2+}	**2.00**	**1.35**	**4.87**
Ag^+	3.72	0.0556	0
Sn^{2+}	3.73	1.42	4.91
Hg^{2+}	1.81	0	0.239
Pb^{2+}	**2.60**	**0**	**0.0338**

1.7.1 Some pertinent properties of MSA

The utility of MSA in numerous application areas (esterification catalysts, alkylation catalysts, polymer solvents, electroplating, electrochemistry, etc.) derives from a number of physical and chemical properties which in combination are unique. For instance, MSA allows for excellent solubilisation of metal salts and surface active agents. MSA has a low tendency to oxidize organic compounds. MSA is a strong acid (pK_a = -1.9) which is almost completely ionized at 0.1 M in aqueous solution (Patai and Rappoport, 1991). MSA solutions exposed to open atmospheric conditions display a

unique stabilization of metal ions in their lower valence states or stated differently MSA solutions allow for a unique resistance to the oxidation of metal ions to their higher valent states.

1.7.2   MSA in Electrochemical Processes Involving Lead

The design of acid electrolytes for the electroplating of Pb and Pb alloys is dominated by solubility, performance and environmental considerations. Two important modern technologies depend integrally on the aqueous electrochemistry of lead; these are the electrodeposition of Sn-Pb solder in the electronics industry and the production of Pb acid batteries for the automotive industry. In addition, the refining of crude Pb obtained from mining and or recycling operations is sometimes carried out electrolytically. As of today only fluoroboric acid, fluorosilicic acid and methanesulfonic acid based electrolytes have been used with commercial success (Rosenstein, 1990: Gonzalez, 1993). MSA is functionally and environmentally superior to fluoroboric acid (HBF_4), fluorosilicic acid (H_2SiF_6) and other HF complex acids (e.g., HPF_6, $HSbF_6$) as an electrolyte for electrochemical processing. The advantages of MSA are evidenced by the recent (starting in about 1980 and continuing to today) substitution of MSA for HBF_4 in the commercially important electroplating of Sn-Pb solder. In this process, acidic aqueous solutions of Pb^{2+}, Sn^{2+} free acid and surface active additives are employed. In the electro refining of lead, for instance, crude lead bullion anodes contained in an undivided electrochemical cell are electrolytically dissolved into and simultaneously cathodically redeposited, in purer form, from fluorosilicic acid based electrolytes. The substitution of MSA for fluorosilicic acid in the electro refining of lead offers a number of functional and environmental advantages. In lead electro refining, acidic aqueous solutions with a high concentration of Pb^{2+} ions are required.

Only certain acid electrolytes will allow for a high aqueous solubility of Pb^{2+} ions. These electrolytes include methanesulfonic acid (MSA, CH_3SO_3H), fluoroboric acid (HBF_4), fluorosilicic acid (H_2SiF_6), nitric acid (HNO_3), perchloric acid ($HClO_4$), chloric acid ($HClO_3$), acetic acid (CH_3COOH) and dithionic acid ($H_2S_2O_6$). The aqueous saturation solubilities of the relevant lead salts are shown in Table 1.3.

Table 1.3 Saturation solubility of some lead salts: temperature and solubility units in parentless

Lead Salt	Aqueous saturation solublelity
Methanesulfonate, $Pb(O_3SMe)_2$	143 g per 100 g H_2O (25 °C)
Fluoroborate, $Pb(BF_4)_2$	50 wt.% (20 °C)
Fluorosilicate, $PbSiF_6.4H_2O$	69 wt.% (20 °C)
Nitrate, $Pb(NO_3)_2$	37 wt.% (20 °C)
Perchlorate, $Pb(ClO_4)_2$	226 g per 100 g H_2O (25 °C)
Chlorate, $Pb(ClO_3)_2$	255 g per 100 g H_2O (25 °C)
Acetate, $Pb(O_2CMe_3)2$	55 g per 100 g H_2O (25 °C)
Dithionate, $PbS_2O_6 \cdot 4H_2O$	115 g per 100 g H_2O (20 °C)

Various factors make the use of many of these 'solubility permissible' lead electrolytes untenable. For instance, the dithionate anion in lead dithionate is unstable at low pH decomposing into sulfate and sulfite. Aqueous solutions of lead acetate in combination with acetic acid have insufficient conductivity to allow for high-speed electroplating operations. Lead chlorate, lead perchlorate and lead nitrate all tend to decompose cathodically and the corresponding acids are very corrosive. Some of the problems with alternative Cu-Pb plating electrolytes are summarized below

1. H_2SO_4, HCl $\longrightarrow$ Precipitation of $PbSO_4$, $PbCl_2$

2. HNO_3 $\longrightarrow$ Cathodic decomposition of nitrate

3. $MeCO_2H$ $\longrightarrow$ Low conductivity

4. HBF_4, H_2SiF_6 $\longrightarrow$ Environmental problems H_2NSO_3H,

5. $H_2S_2O_6$ $\longrightarrow$ Hydrolysis problems, low conductivity

With respect to electrochemical processes involving lead, MSA based process electrolytes are particularly advantageous in that they are less toxic and easier to waste treat than the existing alternatives. Into the foreseeable future industrial electrochemical processes especially those involving tin and lead will likely continue to be converted to safe, functional, efficient and environmentally friendly MSA.

1.8   Common Uses

Lead is frequently added to copper alloys to increase their machinability. The role of lead in copper alloys is twofold it acts as a lubricant and in the free machining grades the lead assists in chip break up. Lead is added to many copper alloys making all types of free machining alloys. Lead does not affect the structure and properties of copper because it is practically insoluble in solid copper. The pure copper solidifies first leaving the lead to solidify last as almost pure lead globules at the grain boundaries or in the inter dendritic regions. The size and concentration of lead particles depends upon the concentration of lead in the alloy. Leaded coppers are categorized as low lead alloys, or free machining alloys and high lead alloys. In the free machining alloys, the lead acts as chip breaker and lubricant making these alloys easier to machine than their non-leaded counter parts. The high leaded copper alloys are used in bearing applications. In the bearing materials, the lead acts as a solid lubricant and the copper is the load bearing support. Lead is added to many of the copper alloys producing free machining brasses, bronzes and other copper alloys. The free machining brasses and other alloys are presented in the sections with the specific alloy types.

Copper-lead alloys are used extensively in automotive, aircraft and general engineering application. These alloys are cast or sintered to a steel backing strip from which part are blanked and formed into full-round or half round shapes depending on final application. Cooper-lead alloys continuously cast on steel strip perpendicular and securely anchored to the steel back with an interdendritic lead phase. In contrast,

sintered copper-lead alloys of similar composition are composed of more equiaxed copper grains with an intergranular lead phase.

High lead alloy SAE 48 can be used bare on steel or cast iron journals. Tin content in this alloy is restricted to a minimum value to maintain a soft copper matrix which together with the high lead content improves the antifriction/antiseizures properties of the alloy. Bare bimetal copper-lead bearing are used infrequently today because the lead phase present nearly pure lead is susceptible to attack by corrosive products that can form in the crankcase lubricant during extended oil change periods. Therefore, must copper-base alloys with lead content >20% including both SAE alloy 48 and alloys 49 are now used with plated overlays in trimetal bearing for automotive and diesel engines. SAE 485 is a special sintered and infiltrated composite material produced by P/M methods. By these methods it is possible to combine a very strong continuous copper alloy matrix structure with a very high lead content and to alloy the lead-rich constituent with sufficient tin to make it resistant to corrosion. SAE 485 is used principally for bushing and bearing applications that involve alignment, shaft surface finish or unusual dirt contamination problem. Table 1.4 lists of characteristic and application for copper-lead sliding bearing. Table 1.5 give specification numbers and nominal compositions of copper-lead bearing alloys, as well as the forms in which the alloys are used.

Table 1.4 Characteristic and application of copper –lead bearing alloys

Alloy	Characteristic	Application
Leaded copper (C98200-C98840)	High conductivity, low to moderate strength, depending on composition but somewhat better fatigue resistance than Babbitts(tin or lead base bearing alloys). Usually cast onto and supported by steel backing rings; may require electroplated Pb-Sn overlay for corrosion resistance	Automotive main and connecting-rod bearings

Table 1.5 Designation and nominal composition of copper-lead bearing alloys

	Designation		Composition, %				
No	SAE	ISO	Cu	Pb	Sn	Product Form	Application
1	Alloy 49	CuPb24Sn(G)	75	24	1	Cast on steel back	Trimetal intermediate layer
2	Alloy 49	CuPb24Sn(P)	75	24	1	Sintered on steel back	Trimetal intermediate layer
3	Alloy 48	CuPb30(P)	70	30		Sintered on steel back	Bimetal surface layer, Trimetal intermediate layer
4	Alloy 485	-	48	51	1	Sintered on steel back, infiltrated with lead	Bimetal surface layer

Cast copper-lead alloys possess binary microstructure where consisting of lead particles distributed throughout the copper matrix serves as a solid lubricant in sliding friction applications and are used for manufacturing sliding bearings, bushings and other sliding friction components.