Effect of Sugar Cane and Cassava Juices as Addition Agents in the Electrodeposition of Zinc from Acid Based Solution

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An experimental investigation has been made into the effectiveness of some tropical agricultural resources, sugar cane and cassava juices, as addition agents in the electrodeposition of zinc from an acid chloride bath. The electrodeposition of zinc on steel was performed by the partial immersion of the steel specimen and the zinc electrodes in the plating solution using a DC supplier. While a fairly good zinc electrodeposition on mild steel substrate could be obtained in the acid zinc chloride solution, using either cassava juice or sugar cane juice alone, the synergistic effect of the two juices combined gives a far better result.
KEY WORDS: Addition agents, electrodeposition, synergistic effect, plating.

Une étude expérimentale à été conduite sur la détermination de l'efficacité des quelques ressources agricoles tropicales, notamment les jus de canne à sucre et de manioc comme additifs du processus de dépôt par électrolyte du zinc dans une solution d'acide chloride. L'electro-deposition du zinc sur l'acier a été effectuée par une immersion partielle des échantillons d'acier et les électrodes à zinc dans une solution de placage en utilisant le secteur DC. Bien que l'utilisation du jus de canne à sucre ou de manioc séparement pouvait permettre d'obtenir un dépôt relativement acceptable du zinc sur l'acier doux, l'effet synergique d'une combinaison de ces deux jus à donne des meilleurs résultats.
MOTS CLES: Produits agricoles, jus de canne à sucre, jus de manioc, electrodeposition, zinc, acier doux, bain acide.

Introduction

The need to prevent corrosion and toxicity, and to enhance the aesthetic value of steel components in the automotive, construction, electronics, electrical appliances, recreational and materials handling industries and in our daily lives, has led to an enlarged interest in the field of electrodeposition of zinc on steel substrates.

Similarly, the stringent regulation against toxic waste and water pollution and hence costly effluent disposal of cyanide-based baths has led to the increased interest and accelerated growth of acid zinc based baths in the past few years.

Electrodeposition of zinc from acid solutions, both chloride and sulphate baths, now constitutes about 45-50% of all zinc baths, particularly in the developed nations. Zinc is very electro-negative and provides sacrificial protection for steel substrates. It is very economical to deposit and there is a good supply worldwide (D'Angelo,1986). Other depositing solutions in use, apart from acid solutions, are those based on cyanide baths, and to a lesser extent, fluoborate, alkaline zincate and pyrophosphate (Von Fraunhofer, 1978).

Cyanide zinc baths are the most widely used and have high throwing power, which is one of the important factors in zinc plating. However, due to their toxicity and the stringent regulations guarding against water pollution, along with costly effluent disposal, non-cyanide and low-cyanide baths have been investigated and used for commercial plating (Hanchanki, 1983; Morisaki, Mori and Tajima, 1981). There has been a steady trend to replace cyanide with non-cyanide baths for the past fifteen years, accelerating greatly in the last six years. Improvements in alkaline zincate, acid sulphate and acid chloride baths have been reported in recent years (Geduld, 1974; Berkin, 1975; Walker and Holt, 1980; Saubestre,Hajdu and Zehner, 1969; Pushpavanam and Shnoi, 1977).

Non-cyanide zinc plating solutions can be divided into two types – mildly acid solutions using chloride or sulphate anions, and alkaline-zincate solutions (Darken, 1979). The mild baths generally consist of zinc chloride dissolved in a solution of excess ammonium chloride. More recently, potassium chloride processes, which are far less corrosive, have been marketed and ammonia-free formulation is now the most popular in production (D'Angelo, 1986). Zincate baths consist solely of a small concentration of zinc metal dissolved in approximately 100g/l of sodium hydroxide solution (Darken, 1979). Chloride zinc solution does not only eliminate cyanide in plating, it also gives improved bath efficiency and exceptional brightness. Acid zinc baths are used where it is desirable to have a high plating rate and low cost. Chloride zinc plating offers considerable advantages over cyanide based systems, although it is

not without its share of routine operating problems (Schneider, 1987). Use of the acid zinc sulphate process is increasing due to its relatively low cost, safety features and pollution control characteristics, but poor throwing power and insufficient brightness from an acid sulphate bath are disadvantages (Morisaki *et al.*, 1981). In this work, the use of local agricultural resources, sugar cane and cassava juices, as addition agents in zinc electrodeposition from acid based solutions, makes this study unique. Further characterisation of the surface feature will be performed in subsequent works.

Materials and Methods

A flat mild steel, SIS 141147, 0.1cm thick, with a nominal composition of 0.038% C, 0.19% Mn and the remainder Fe, was cut into several test specimens of 10.0cm long and 1.0cm wide. A portion of 1.0 cm in length was marked off at one end for the electrodeposition of zinc.

The test specimens were degreased ultrasonically for 5min with an alkaline degreasing chemical, code named Henkel VR 6362-1, and then removed from the solution, rinsed in distilled water, immersed in methanol, and air dried. The specimens were, in turns, etched for 50sec in 3M HCl, rinsed in distilled water, immersed in methanol, air dried and stored in a desiccator for further experimental process.

Before immersion in acid chloride solution, the surface film composition, and hence the steel's surface purity, was determined as an impurity that could affect the zinc's deposition and adhesion characteristics. An ESCA HP5958A instrumentation using the X-ray photoelectron spectroscopy (XPS) analysed the surface. The surface film was further sputtered by Ar^+ ion etching to a depth of 0.3nm for an indepth study of the steel's film composition. The ESCA (Electron Spectroscopy for Chemical Analysis) test was performed at the Department of Engineering Metals, Chalmers University of Technology, Gothenburg, Sweden and the degreased specimens were then brought to Nigeria for electrodeposition experiments.

The acid chloride solution for the electrodeposition consisted of ZnCl (71g/1), KCl (207g/1) and H_3BO_3 (35g/1). Extracted cassava and sugar cane juices, (each 25-30ml/l of acid chloride solution) were used as the addition agents.

Electrodeposition of zinc on steel was performed by partially immersing the steel specimen and the zinc electrodes in the plating solution (20mm deep) through the rectangular hole made on a prepared perspex cover for the 250ml beaker used as the plating bath. The steel specimen was connected to the negative side of a DC supplier while the zinc electrodes were also connected with a wire. The plating solutions were put in turns into the beaker and their respective pH was obtained by adjusting the original solution with potassium hydroxide. Four different plating baths were used:

(a) plating from the solution without the addition agents;
(b) plating from the solution with cane sugar juice only (25 ml/l) as an addition agent;
(c) plating from solution with cassava juice (30 ml/l) alone as the addition agent; and
(d) plating from solution with cassava and sugar juices (30 ml each) as the addition agent.

The operating conditions are:

pH of the solution	= 4.8 - 5.2
Temperature	= 28-30°C
Current	= 3.0mA/cm
Plating time	= 15min
Gentle stirring	

After each zinc electrodeposition, the plated specimen was taken out, rinsed in distilled water, immersed in methanol and quickly air dried before the surface photograph was taken. The unavailability of a scanning electron microscope prevented the plated specimen surface from being characterised. The adhesion of the zinc coating to the steel substrate was tested by using cellotape fastened to the surface and later pulled off and visually observed for any zinc stripping from the plated steel's surface. The plated surface was scratched with a scapel to test for the zinc adhesion. The specimens were too small for a bending test.

Results and Discussion

The ESCA spectra recorded from the steel's surface are presented in Fig. 1. No significant impurity was observed at the steel's surface; however, the surface film consisted of oxygen, iron, chloride and carbon elements. The deconvolution of the signals showed the two oxygen peaks consisted of oxide (O^{2-}) and hydroxide (OH), respectively. The two peaks from the Fe signal represent Fe^{3+} and Fe^{2+}. The chloride came mostly from the HCl used to etch the metal, while the carbon element is believed to have originated from the methanol used to rinse the specimen before air drying. The very acidic plating medium could easily destroy the unstable surface film of the metal specimen and thereby render the steel's surface a good electrodeposition substrate.

The photomacrograph of the as received unplated specimen is presented in Fig. 2(a). The plated specimen without any of the addition agents, cassava or sugar cane juices, Fig. 2(b), showed dull plating, but was as effective as expected. In Fig. 2(c), which shows the plated specimen with the cassava juice as addition agent, the plating was comparatively brighter than that shown in Fig. 2(b). This shows that cassava juice as an addition agent in the plating medium is effective to some extent. A similar result was obtained with the addition of sugar cane juice (Fig. 2d). The effectiveness of these two additives was actually due to their chemistry.

Cassava juice is known (Coursey, 1983; Conn, 1983; Nastey, 1983) to contain mainly the cyanogenic glycoside linamarin-2 (B-d-glucopyranosyloxy)

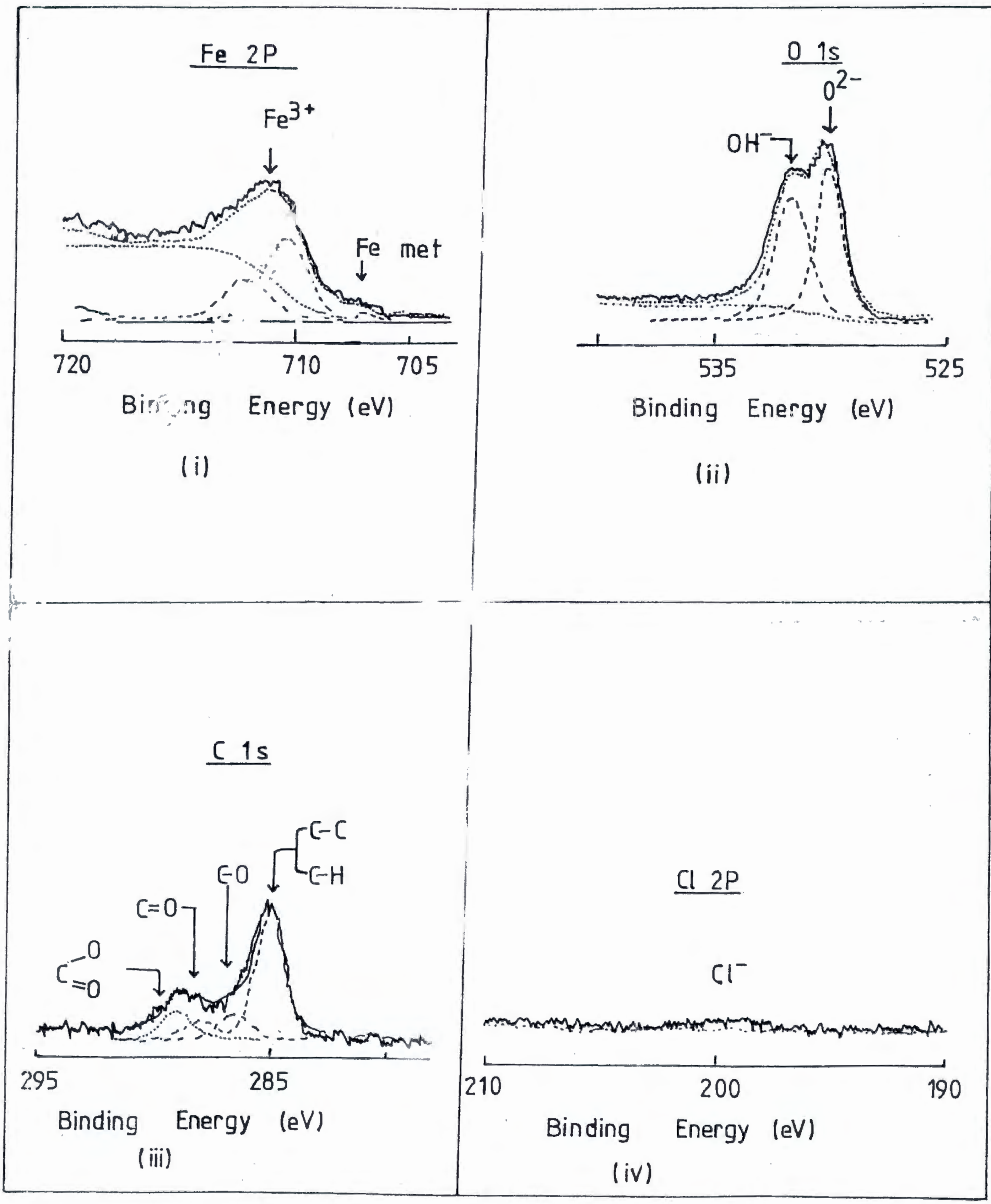
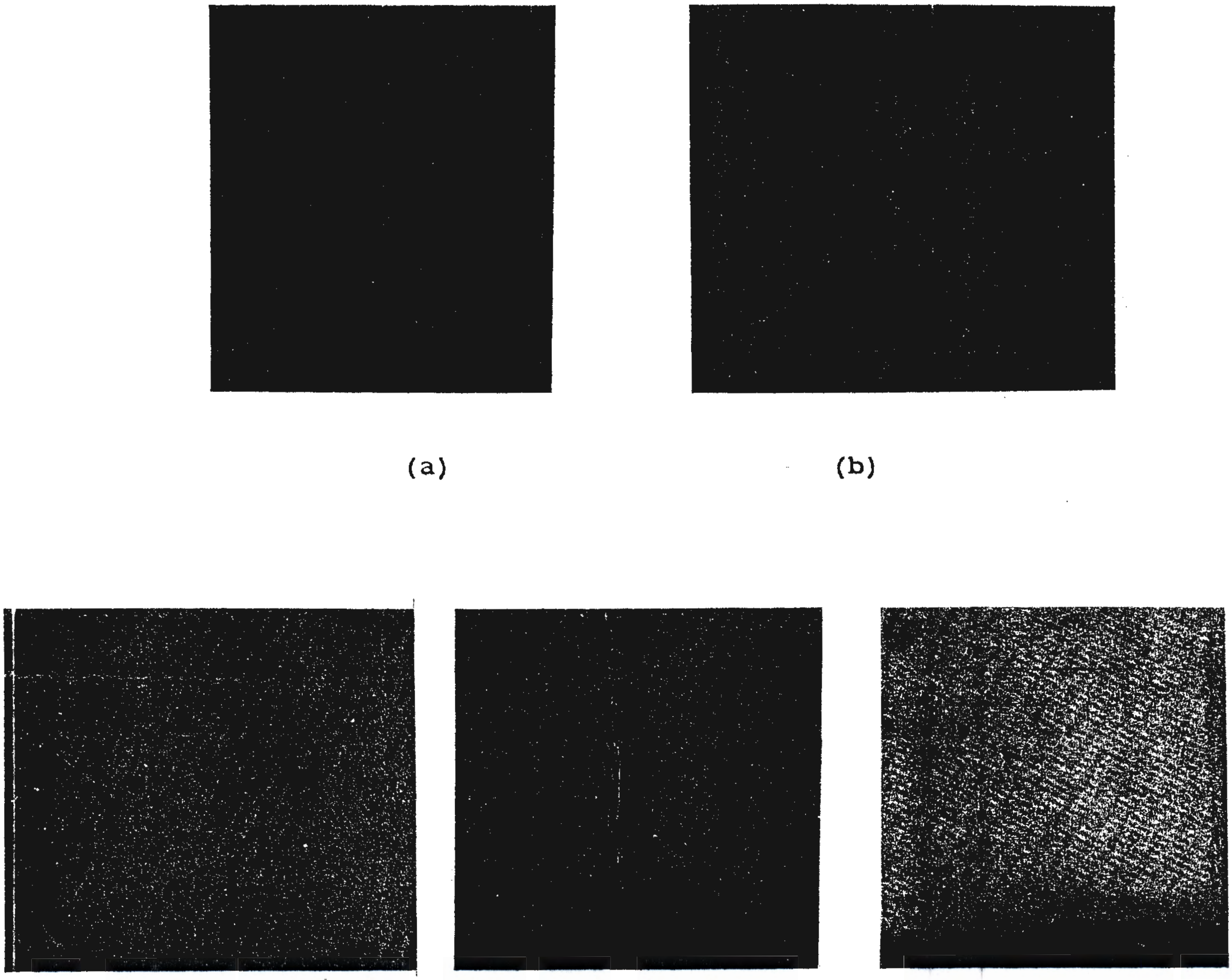


Figure 1. ESCA spectra recorded from the surface of the degreased and etched mild steel test specimen.



(a) (b)

(c) (d) (e)

Figure 2. Photomacrograph of the unplated and plated surfaces of the mild steel specimen: (a) unplated mild steel specimen; (b) plated mild steel without addition agent; (c) plated mild steel with cassava juice as addition agent; (d) plated mild steel with sugar cane juice as addition agent; and (e) plated mild steel with cassava and sugar cane juices as addition agent.

isobutyronitrile with a little of the closely related lotaustralin-2 (B-d-glucopyranosyloxy) 2-methylbuty-ronitrile. During fermentation, these substances hydrolyse under the influence of the endogeneous enzyme linamarase to liberate hydrogen cyanide (Coursey, 1983). Cyanide ions from the cyanide bath have been known to give the brightest zinc plating. Though making an effective contribution, the very low percentage of CN in cassava juice did not give the very bright plating characteristics associated with the cyanide bath. Sugar cane juice consists of sucrose, a nonreducing sugar which has been known to be a d-glucopyranosyl-B-d fructose (Finar,1969). Sucrose can be hydrolysed by dilute acids such as those in the acid zinc bath, or by the enzyme invertase to an equimolecular mixture of D (+) glucose and D (–) fructose. The two monosaccharide molecules are linked through their reducing groups.

Glucose is commonly used as an addition agent in zinc electroplating.

The synergistic effect of the combined use of cassava and sugar cane juices is apparent as presented in Fig. 2(e). The chemistry of both juices gives a chemical complex that becomes very effective in giving a good zinc electrodeposition on steel. The cellotape test confirmed the strong adhesion of the zinc to the steel surface.

Conclusion

A good zinc electrodeposition on a mlid steel surface could be obtained in the acid zinc chloride solution using either the cassava juice or the sugar cane juice alone. However, the combination of the two juices gives a better synergistic result. The adhesion test in combination with the ESCA analysis confirms the cleanliness and suitability of the steel specimen surface for electrodeposition.

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