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# Microwave integrated circuits fabrication on alumina substrate using pattern up direct electroless nickel and immersion Au plating and study of its properties

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ABSTRACT

Electroless NiP plating followed by immersion gold for depositing directly conductive layers on pattern alumina substrate can be used in the fabrication of microwave integrated circuits (MICs), as alternatives to the pattern up plating for which pattern in thick resist is mandatory.

A complete procedure for the fabrication of microwave integrated circuits has been described for patterning alumina substrates and further some properties of the conductive patterns obtained in this manner have been investigated, like: the adhesion between the metallic pattern and substrate, solderability, bondability, geometrical & dimensional accuracies and microwave losses in microstrip configuration for a broadband power divider.

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## 1. Introduction

Sputtering and evaporation, the two conventional processes used for the metallization, have some limitations [1]. The capital cost of the equipment required for conventional methods (i.e., evaporation and sputtering) is high, before the deposition of metal vacuum is required which takes time, numerous maintenance problems, waste of the materials as sputtered or evaporated not only deposit on the substrate but also throughout the dome of the system and fixtures inside it and both sides of the substrate cannot be coated at the same time. Electroless plating especially appropriate for plating nonconductive materials, overcomes the above limitations, as in this case procedure is simple, only a few chemicals are required, less machine maintenance is needed, both sides of the substrate can be coated in one operation without any metal waste and total time required to coat a substrate is considerably less than that in the conventional techniques.

In microelectronics, optical lithography is the dominant pattern delineation process. It is used widely in semiconducting devices, and microwave integrated circuits [2]. Not only this but also it is used to fabricate chrome masks for itself and pattern for other technologies mask-delineated evaporation. In this process, thin film photoresist coating is used on the surface where a pattern is to be delineated. Resist development selectively removes the resist according to its exposure state after exposing to an optical pattern using ultraviolet light. Depending upon process, additive, subtractive or semi-additive, remaining pattern of photoresist on the surface is used to delineate etching, plating, sputtering, evaporation or other processes commonly used in microelectronics.

Electroless NiP/immersion gold (ENIG) is used for surface finish layer of printed circuit boards (PCBs) [3–14]. Electroless NiP plating process is popular maskless and selective deposition method because it exhibits excellent material properties such as wear and corrosion resistance [15] as well as metal surface with uniform thickness [16,17]. Immersion gold layer is used to prevent the oxidation of NiP layer which prone to environment. Therefore immersion gold on the top of NiP enhances wettability of solders [9].

Till now, no attention has been given to the fabrication of MICs using pattern up direct elctroless nickel NiP and immersion Au plating even if these can be selectively deposited. To reduce the limitation of additive, wet chemical etching of subtractive and semi-additive: pattern up plating process, selective deposition of electroless Ni followed by immersion Au is described in present work for MICs fabricatatin. Adhesion, solderability, bondability and its microwave loss have been evaluated for MICs obtained by this method.

## 2. Experimental method

This work is mainly aimed to fabricate the MICs by using electroless plating method. Cr–Cu metallized alumina substrate has been used in this work. Photolithography and wet chemical etching have been used to fabricate the MIC on Cr–Cu metallized

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alumina substrate. Then this patterned substrate will be firstly brushed to remove the oxide layer physically until it become shining. Tarnish can be also used to remove the oxide in place of brushing. Next, it is immersed in the acidic solution temperature of 50–60 °C to remove any surface of copper oxide. Then DI wash and again patterned substrate is immersed in 10% $H_2SO_4$ at room temperature to deoxide the surface. Then again DI wash then immersion in catalyst solution is used to activate the copper conducting layers. After the activation process, it is washed in running DI water and then electroless nickel layer is deposited onto the patterned copper substrate with high phosphorus content (8.5–10%). The plating time took about 10 min in order to get 2.0–2.5 µm of nickel thickness. Chemical composition and typical process parameters for catalyst solution and electroless nickel plating are shown in Table 1 and Table 2 respectively.

To protect electroless nickel-plated copper substrates, an immersion gold layer is finally deposited onto the electroless nickel-plated patterned Cr–Cu substrates of DI water wash and hence thus four layers patterned Cr–Cu–NiP-immersion Au on alumina substrate is obtained. The immersion gold plating is conducted immediately after electroless nickel with no pretreatment, except rinsing in DI. water. The plating time used is 15 min to produce 0.1 µm layer of gold. Chemical composition and typical process parameters for immersion gold plating is shown in Table 3.

Flow charts of MICs fabrication using the proposed method in this work, pattern up plating and subtractive method are shown in Figs. 1a–c respectively for the comparison.

Several techniques and characterization tools have been employed for analysis and measurement such as XRF for thickness, dc four-probe method for sheet resistance, optical microscope for microstructure and sharpness of the edge, bond pull test for bond strength, adhesion test for adhesion, wetting balance analysis for solderability and die-shear test for solder joint strength. An Agilent PNA-X network analyzer (N5242A) was used to collect full, two-port S-parameters and account for the contribution of the test apparatus.

## 3. Results and discussion

Each fabricated sample was visually inspected under a microscope to ensure there was no damage. In addition, physical measurements (line widths) were carried out to ensure the microstrip lines were within an acceptable tolerance. Some anomalies found at this stage appeared to be dependent on imaging quality. MIC shown in the Fig. 2a is used for the bondability and solderabilty test while MIC shown in the Fig. 2b is known as adhesion pattern because it used in adhesion test. To check the process limitation for the typical MICs fabrication, several typical MICs having different shape have been fabricated by this method as shown in Fig. 3 and it is found this method has no limitation for the typical MICs of different shapes. There are no physical damages and line dimensions are well within an acceptable tolerance.

Edge finishing of the MICs fabricated by the proposed method in this work and subtractive method has been compared. And it is shown in Figs. 4a and b respectively. From Figs. 4a and b, it is obvious that edge finishing of MICs obtained by the proposed method is better that the subtractive method. It is also obvious that all the three sides of copper are well covered by electroless nickel and all the three sides of electroless nickel covered copper are well covered by immersion gold therefore neither copper nor NiP is prone

**Table 1**
Chemical composition of catalyst solution, $PdCl_2$.

| Chemicals | Compositions |
|---|---|
| $PdCl_2$ | 0.3 g/L |
| HCl | 20 ml/L |
| $H_2O$ | Balance to 1L |
| *Operating conditions* | |
| Temperature (°C) | 25–27 |
| Immersion time (min) | 3–4 |

**Table 2**
Chemical composition of electroless nickel plating bath and its operation condition.

| Chemicals | Composition (g/L) |
|---|---|
| Nickel chloride | 7.5 |
| Sodium hypophosphite | 7.5 |
| Ammonium chloride | 8.8 |
| Sodium citrate | 6.3 |
| *Operating conditions* | |
| pH | 4.8–5.1 |
| Temperature (°C) | 85–91 |
| Magnetic stirring (rpm) | 400 ± 25 |

**Table 3**
Chemical composition of immersion gold plating bath and its operating condition.

| Chemicals | Compositions (g/L) |
|---|---|
| Potassium dicyanoaurate ($KAu(CN)_2$) | 2.0 |
| Ammonium chloride | 75 |
| Sodium citrate, dihydrate | 50 |
| Sodium hypophosphite | 10 |
| *Operating conditions* | |
| pH | 5.5–6.3 |
| Temperature (°C) | 75–90 |

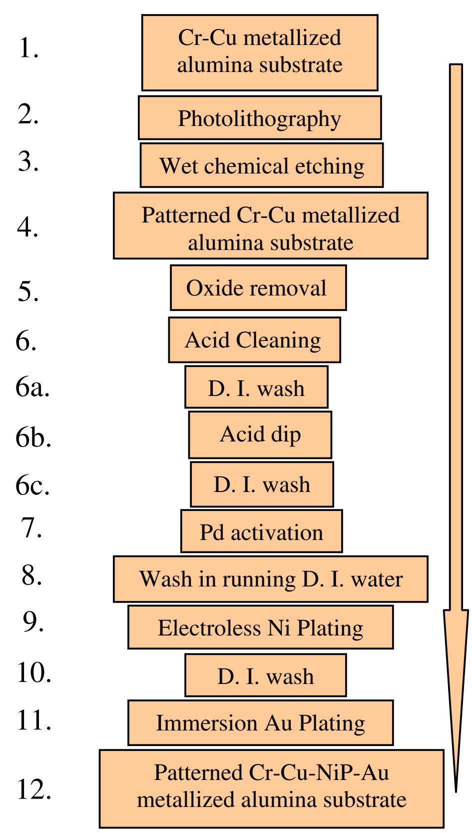


**Fig. 1a.** Flow chart of the proposed method for MICs fabrication.

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