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Electroplating of Gold using a Sulfite-based Electrolyte

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Abstract- *Electroplating of gold is often used in optoelectronic and microelectronic devices for air-bridges, heat-sinks or gold-bumps for flip-chip techniques. The gold-cyanide electrolytes, which are commonly used in gold-electroplating, are toxic and attack resist patterns causing cracks during the plating process. In this paper we report our experimental results of gold-electroplating using a sulfite-based electrolyte $(NH_4)_3\{Au(SO_3)_2\}$. This product is environment- and userfriendly and moreover the electroplating rate is good (10-50 $\mu\text{m}/\text{hour}$). Results varying current density and stirring rate will be reported.*

Introduction

Over the past two years we have successfully integrated airbridge-fabrication in the realisation of microwave circuits on GaAs. Since then, investigations have been directed towards the development of high power GaN/AlGaIn transistors. The proper behaviour of these devices will rely heavily upon good heatsinking. In this respect we have to proceed in either flip-chip technology or fabrication of GaN/AlGaIn transistors on SiC-substrates. At present we have chosen for flip-chip technology, with its need for plated Au-bumps. Calculations have shown that we need Au-bumps of at least 15 μm height. These bumps function as current paths and will be bonded onto another substrate where some of the passive circuits (elements) are located. Bonding Au on Au demands smooth surfaces, and it was recognized at an early stage that using a $K\{Au(CN)_2\}$ -plating bath did not meet our requirements:

- The photoresist (PR), after plating $> 2 \mu\text{m}$, showed cracks, caused through the lateral expanding strain induced by growth of the deposits, resulting in undergrowth. This is shown in Fig-1.
- PR was attacked at current densities $> 0.15 \text{ A}/\text{dm}^2$ probably because of free CN^- -production [1] during reduction of the gold cyanide complex.
- Profiles of the plated Au-structures showed a dependence on flow direction caused by the rotational, magnetic, stirring [2].

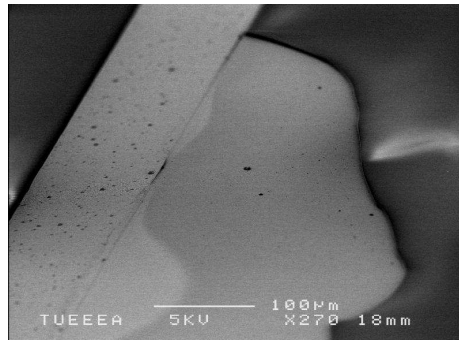


Figure 1- Gold undergrowth causing a partial PR lift-off.

Electroplating of Gold using a Sulfite-based Electrolyte

- Using a $K\{Au(CN)_2\}$ -platingbath is neither environment- nor operatorfriendly.

In order to fulfill, at least, part of the requirements we decided to investigate a new plating solution: Microfab Au-300 [3], because it was based upon the more “friendly” $\{Au(SO_3)_2\}^{3-}$ complex and because of its excellent bump characteristics.

Experimental

A Titanium/Gold layer (50 nm/ 200 nm) was e-beam evaporated on a (100) 3”-Silicon wafer. This wafer was sawn into 10 x 11 mm² pieces. These pieces were patterned using 3 μm thick AZ-4533 photo-resist . Two patterns were used: either 2-20 μm circles or square openings of 100 x 100 μm²). The samples were attached to a circular holder and placed face down in the plating solution. The sample holder was covered with a gold coating and it had a large diameter compared to the samples. In this way, small changes on the sample will only have a minor effect on the current density, and hence on the amount of metal to be plated. The solution was magnetically stirred

Prior to plating the PR was hardbaked for 30 minutes at 120 °C for the circular openings and 30 minutes at 105 °C for the square openings. The steps for obtaining a deposit are shown in Fig-2. In table I, the composition of the Au-sulfite platingbath and the operating conditions are shown.

Table I. Bath composition and operating conditions.

$(NH_4)_3\{Au(SO_3)_2\}$	$[Au^+]=10\text{ g/l}$
pH	9.5
Temperature	40 °C
Current density	0.15-0.5 A/dm ²
Agitation	Magnetic stirring

The actual plating cell is shown in Fig-3.

After plating a 2 μm thick gold layer, the PR was removed with acetone and, if necessary, an O₂-plasma was used to remove any residual resist. Height measurements, using a Tencor Alpha-step 200, on 5 different locations on the sample were done: 1) plating rate at the center of the structure 2) average deviation in plating height within a structure. The rms value for the plating rate for the 5 locations tells something about the difference in plating height across the sample; the rms value for the average deviation is related to the difference in plating height within a structure (a square bump in this case).

Scanning Electron Microscopy (SEM) observations was used to evaluate the smoothness of the Au-deposits.



Figure 2- A schematic overview of the processing steps of electroplating.

Results and discussion

Fig-4 shows a SEM photograph of plated gold at 800 rpm with a current of 40 mA (corresponding to a current density of 0.2 A/dm²). The surface is very smooth and it has no 'rabbit ears'.

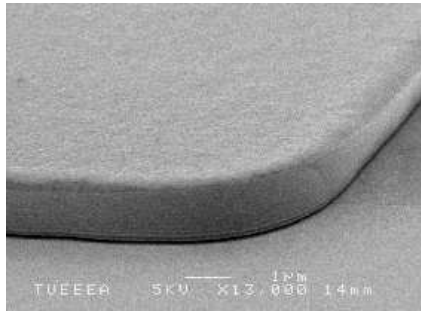


Figure 4: SEM picture of plated gold.

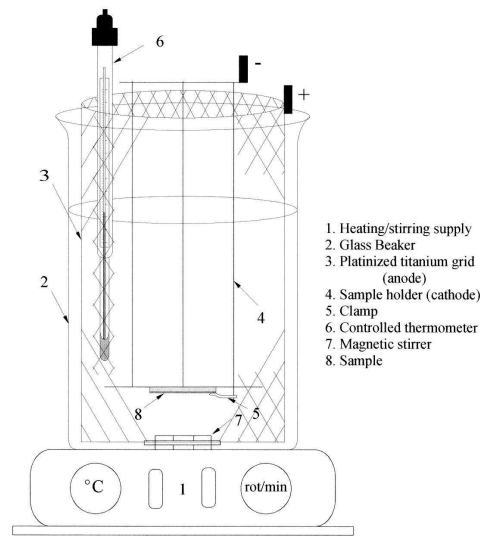


Figure 3- A schematic of the electroplating cell.

Fig-5 shows that the best results are obtained at low currents (40-80 mA or 0.2-0.4 A/dm²) and at a stirring rate around 400 rpm. After plating at high currents and low stirring rates the sample holder has a brownish colour and the samples have extremely high 'rabbit ears'. Assuming that the gold complex can reach the sample by forced convection, which increases with the stirring rate, and diffusion, which largely depends on the current density, we can state that the optimal setting can be found in the region where the diffusion mechanism dominates. The brownish colour can then be attributed to the diffusion-limited process (Fig-5-right at 400-800 rpm and at currents of 40-80 mA).

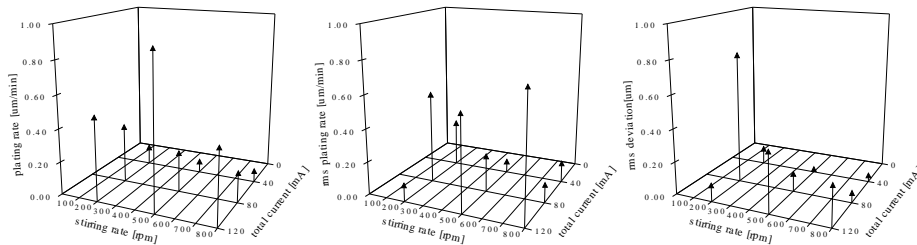


Figure 5- Distribution of Plating rate [um/min] (left), rms value for the plating rate across the sample (centre) and deviation of rms value within a structure (right).

Conclusions

We have optimised the electroplating conditions using a gold-sulfite electrolyte instead of the commonly used gold-cyanide which is by far less environment- and operator-friendly. Smooth and flat gold mesa-like shapes are reproducibly obtained when using low current density (0.2-0.4 A/dm²) and medium stirring rate (400 rpm) resulting in a plating rate of about 8 μm/hour.

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