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Applied Films New Product Introduction

Sputter Metallizing of Polyimide Film for FCCL

Hans Maidhof, Reiner Kukla, Peter Sauer

1. Introduction

1.1 Requests for Flexible Copper Clad Laminates, FCCL for HDI

Flip-type Mobile Phone with 2 Mega-pixel camera and High Definition Flat Panel TV, with diagonal > 40” require flexible printed PC boards with thinner and smaller conductors. These are called flexible High Density Interconnects, HDI. For this application only adhesiveless flexible copper clad laminates can be used.

Definition of HDI:

- conductor thickness <10 µm
- conductor width < 20 µm
- substrate: PI film < 40 µm

1.2 Types of Flexible Laminates

Flexible printed circuits, FPC, are made of flexible copper clad laminates, FCCL. There are two types of FCL:

- Adhesive FCCL
- Adhesiveless FCCL

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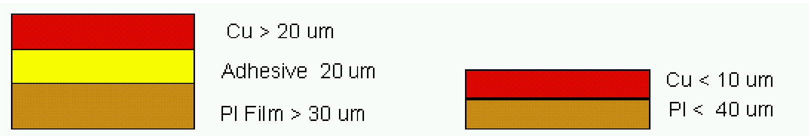

Fig 1: Adhesive Type Adhesiveless Type

Adhesive type FCCL consist of a Polyimide or PET film and a copper foil, which is attached to the film by an adhesive, acrylic based or other material. These laminates have PI films of more than 30 µm, adhesive of > 15µm and copper foil > 50 µm thickness. The total thickness and the temperature sensitivity of the adhesive does not permit to use this type for HDI application.
Adhesiveless FCCL have copper foil thickness of < 20 µm, no sensitive adhesive and PI thickness of less than 30 µm and can be used for HDI application. Actually cast technology is most common for the production of adhesiveless FCCL

1.3 Copper Foil Technology

In general, the standard flexible copper clad laminates are made of Polyimide which is clad with thin copper foil. The standard copper foil for FCCL is the roll-annealed, RA copper. This is produced with a minimal thickness ≥ 10 µm. For thinner copper foil other techniques than RA are employed.

a) Subtractive Technique

The thickness of the RA copper foil is reduced by chemical etching.

b) Electro-deposited Copper

-Copper is deposit onto a rotary drum in electro-deposition system and peeled-off or

- A thin copper layer is deposited on a sacrificial standard RA copper foil. After bonding the copper on the Polyimide film the RA copper foil is stripped off.

These techniques are complicated and not material efficient !

c) Additive Technique

A thin copper seed layer is deposited on a Polyimide film (electroless copper, vacuum coating process) This thin copper layer is strengthened to the desired thickness by an electroplating process.
This technique features the highest production efficiency!

One can see, that remarkable efforts are made to produce thin copper foil of less than 10 µm thickness.

This is the time when sputtering comes into play

2. Electroplating on a Sputtered Seed Layer

The most efficient method to make thin FCCL for HDI application is to make the electrodeposition of copper of the required thickness direct onto the PI film. For the electroplating process, the base material must be conductive. Polyimide is an insulating material. The initial conductive layer, the so called "Seed Layer" can be deposited by several processes:

- Electroless copper

This method requires several wet-chemical treatment steps. The chemicals are not harmless, the copper adhesion is not good.

-Vacuum coating processes

- Evaporation:

  simple process, poor adhesion

  Sputtering

  high performance coating process, good adhesion

Advantages of Sputtering

-The costly subtractive production step of thinning the copper foil is omitted.
- Only the desired copper thickness is deposited
- The thin copper seed layer can be structured prior to the electrodeposition, only the required conductors are strengthened by electroplating

The total sputtering –electrodeposition process comprises

- plasma pre-treatment of the Polyimide film for better copper adhesion
- sputter metallizing of the PI film
- - electrodeposition of the required copper conductor thickness

3. The Sputtering Process

3.1 Principle Sputtering

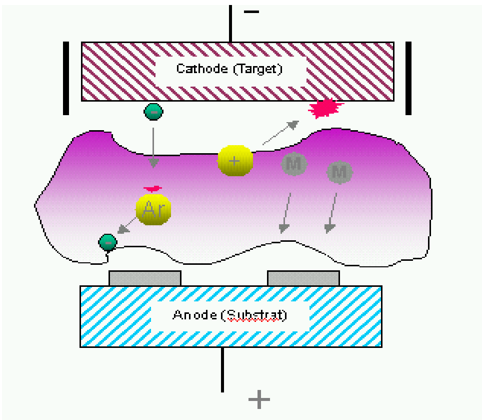

Fig. 2 Principle of sputtering

Sputtering is a vacuum-based physical deposition method. In a vacuum chamber at a pressure less than atmosphere a glow discharge is ignited (=plasma). In this plasma the cathode (target) is atomised and the particles are deposited onto the surrounding (Anode, substrate)

3.2 Features of sputtering

- clean deposition, no chemicals involved
- good adhesion due to high particle energy
- cost effective roll-to-roll (r2r) process

3.3. Substrate Pre-Treatment

An inverted sputtering process can be applied for a plasma pre-treatment of the Polyimide film. For this application the film is guided in narrow distance in front of a sputtering cathode, operated at low power. In this case there is no or only minor metallizing of the film, but the ions and the electrons of the plasma hit the film surface. This effect removes contaminations and surface modifications can be initiated.

4. Steps of a Sputter Coating Process

The entire sputter-metallizing process for the copper seed layer comprises:
- loading of the film reel
- high vacuum pumping
- plasma pre-treatment of the PI film for cleaning and surface activation for better adhesion of the deposited material
- Ni/Cr "tie coat", 10 nm, intermediate layer to improve the adhesion of the subsequent copper
- sputtering the Copper seed layer, thickness 200 nm
- vending the chamber to atmospheric pressure
- unloading of the coated film and loading of the fresh film.

5. Requirements to a FCCL – Sputter Metallizer

In order to achieve high quality seed layers the following is required:
-"clean" high vacuum, oil free
- plasma film pre-treatment
- sputtering of an adhesion -improving layer, the tie-coat made of Nickel/Chromium alloy
- high efficient copper sputtering
- excellent adhesion of the sputtered copper
- no scratches on the film during winding
- virtually no pinholes in the coated copper,

this means:
- a clean room compatible machine design

6. Drawbacks of standard roll coater design for FCCL metallizing

Standard roll coaters, as built for other applications than FCCL often show the following characteristics:

One common chamber, unwind, coating and rewind in the same chamber.
Oil diffusion pumps for high vacuum
The winding system commonly consists of more or less vertically arranged rollers, most are above the coating drum
The winding system is mounted to the chamber sidewall (base-plate)
For loading and unloading the vacuum chamber is completely opened

Issues:

Lots of particles generated by slitting of the film stick to the outer area of the film reel. With vertical rollers in a common chamber, the particles fall down on the rollers and are transferred through the system, sticking to the film, thus creating pinholes respectively surface defects.

Oil back streaming from diffusion pumps contaminates the film, reducing copper adhesion

For loading and unloading the chamber is opened, lots of particles from the chamber go in the working room, no clean-room environment possible.

Insufficient tension control by can cause a slip of the rollers and scratches on the film

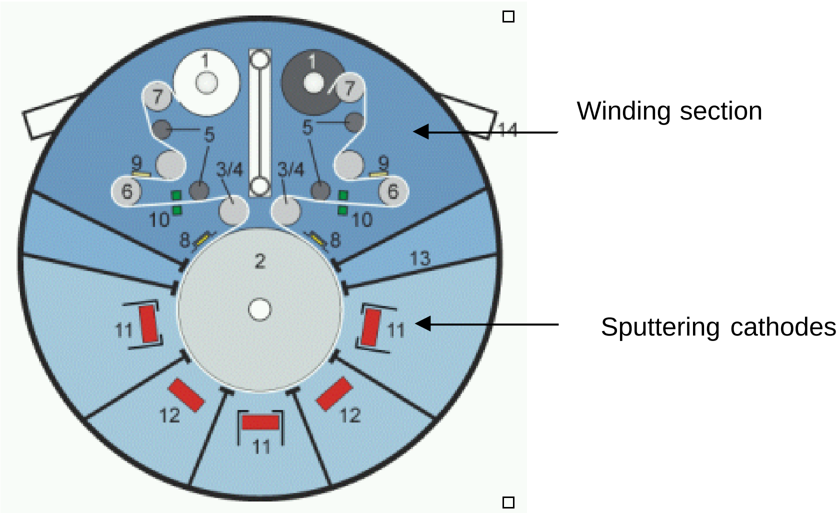

Fig 3 Cross Section of a standard sputter web coater, one chamber for winding and coating

7. Characteristics of a modern Sputter coater for FCCL Metallizing

7.1 Hardware

To generate defect free seed layers with excellent adhesion the vacuum metallizers must show the following features:

- Separated winding and coating sections
- Oil free vacuum
- Horizontal winding, means no particle transfer through the winding system
- Double ended machine, means separate loading and unloading of the web reel and
- Coating chamber kept closed for loading and unloading of the film reel that means it is a fully clean room compatible machine design.
- For service and target change the chamber is opened in a grey room, no contamination of the coating area.
- non-slip winding system to prevent scratching of the film surface

7.2 Productivity:

Sputter coating of the 200 nm seed layer at speed of 4 m/min should be possible.

Typical PI film width: 600 mm

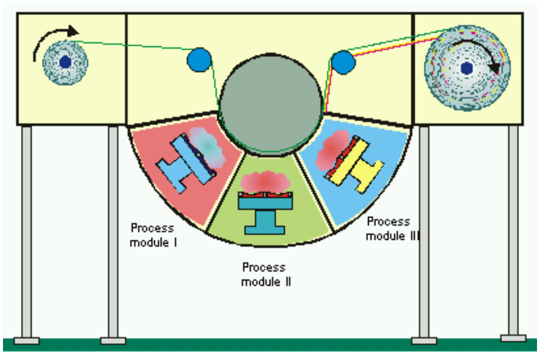

Fig 4. Modern Concept of a Sputter Web Coater, separated winding and coating Section

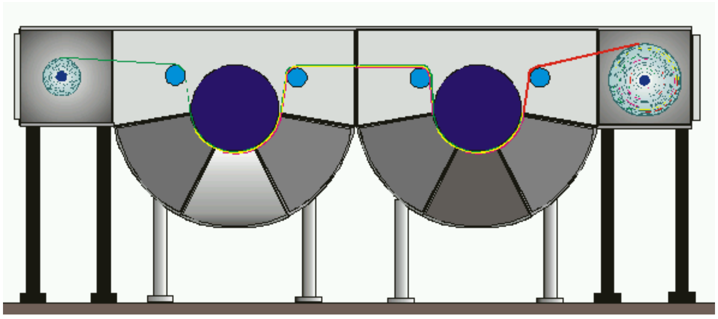

Fig 5 Double chamber module for double productivity

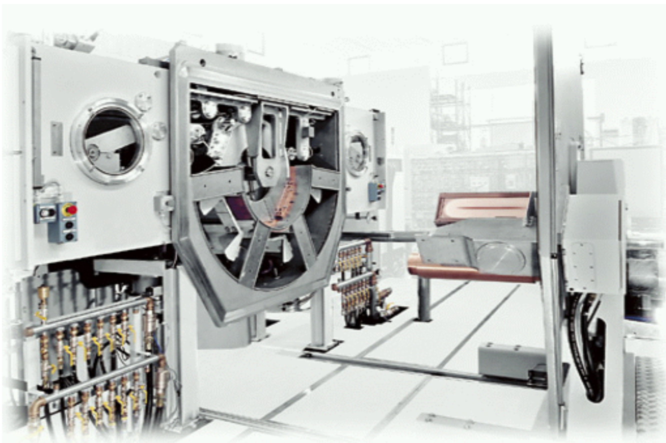

Fig 6 SMARTWEB Sputter Metallizer for PI film

8. Copper Adhesion to the Polyimide Film

One important parameter for the quality of the FCCL, among others, is the adhesion of the copper to the Polyimide film. In terms of FCCL it is called the "Peeling Strength". Accepted values for the production of flexible printed circuits, FPC are higher than 0.5 N/mm of 5 N/cm. The future requests are in the range of 1 N/mm. The physical limits of the

Peeling Strength seems to be 1.4 N/mm. First tests have shown, that Kapton E is destroyed during peeling test in the range of 1.4 N/mm.
This reported data are gained from the same Kapton E film reel. The electroplating process and the tests were performed by two independent companies in Korea and Germany.
Comparable results have been obtained several times.

Results Sample 1

Electroplating process 1

Peel strength:	initial:	0.8 N/mm
	7 days @ 150°C:	0.5 N/mm
electro-plated copper		8 µm
Test standard		IPC- TM- 650

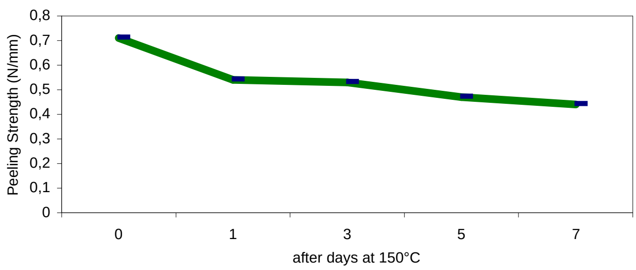

Fig. 5 Peeling Strength during a temperature test of 7 days. This is a “passed” sample

Results Sample 2

Electroplating process 2

Peel strength	initial:	1.0 --0.8 N/mm
	after 7 days @ 150°C:	1.0 -- 0.8 N/mm
electroplated copper		20 µm
Test standard		ASTM B 533-85

The different graphs mean different film pre- treatment parameters

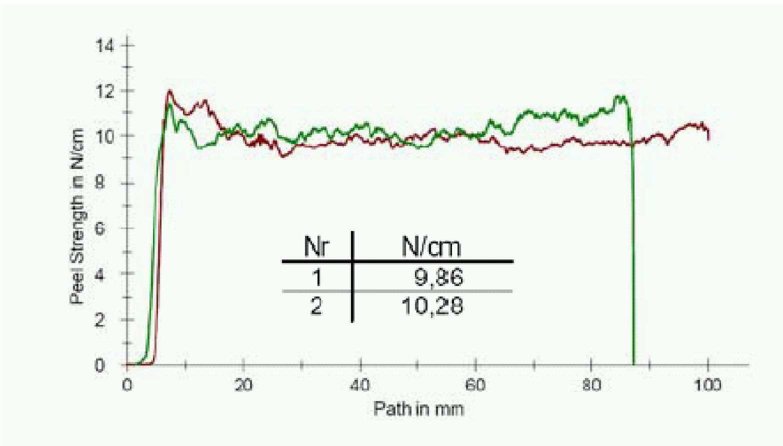

Fig. 5 Peeling Strength after 7 days @ 150°C. This is a “passed” sample