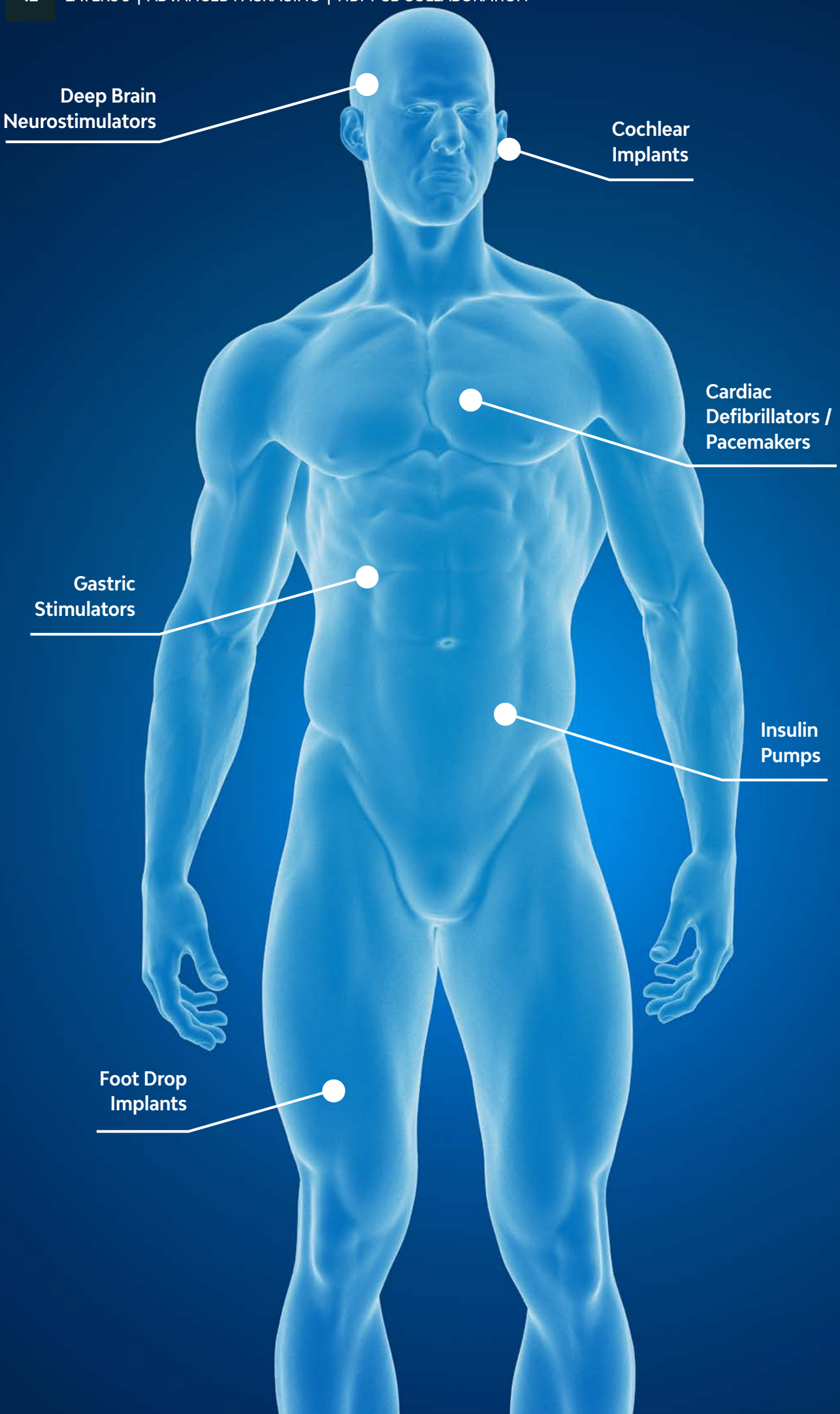

Deep Brain Neurostimulators
Cochlear Implants
Cardiac Defibrillators / Pacemakers
Gastric Stimulators
Insulin Pumps
Foot Drop Implants

ULTRA–THIN FLEXIBLE HDI-PCBs

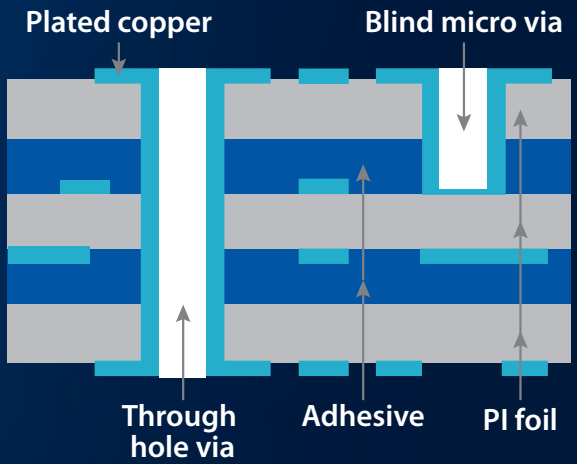
Overcoming challenges in fabrication using CLUSTERLINE® panel-sized etch and sputter solutions

Process and application teams from Evatec and GS Swiss PCB collaborated over the past two years. Evatec's Senior Scientist, **Mohamed Elghazzali** and **Dr. Rodica Ababei** from **GS Swiss** PCB explain how they developed a robust manufacturing solution for sputtered seed layers on ultra-thin substrates. The main focus was on maximizing the adhesion for the deposited titanium/copper seed layer in combination with the subsequent electroplating processes, all under the very demanding process reliability requirements from GS Swiss PCB and their customers.

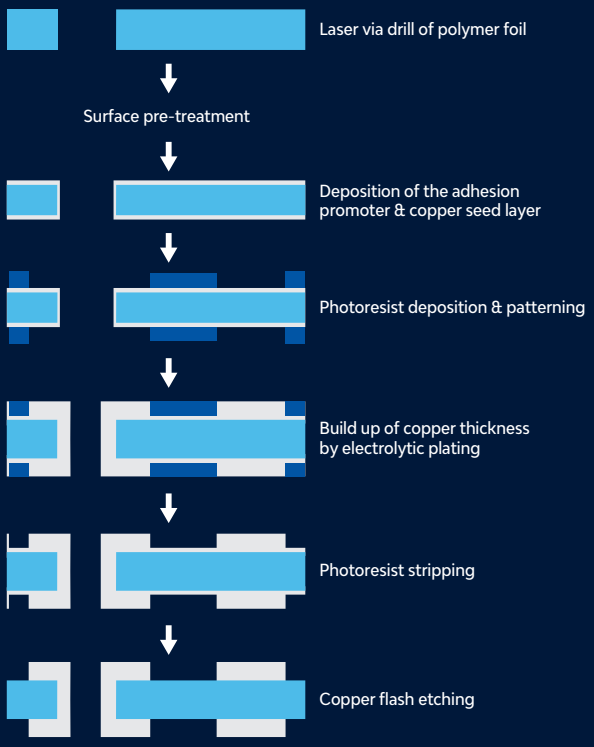
The compact nature and high performance of HDI-PCBs open up exciting new applications in areas including health care, aerospeace and consumer devices. Evolution in manufacturing processes will be required to make this possible. Reducing feature sizes below 5µm Line/Space and integrating new materials are the next challenges to be addressed for high end PCB manufacturers.

Successful handling and double-sided processing of thin substrates is also a pre-condition for successful process integration with the existing up-stream and down-stream process landscape.

The cross section of a typical flexible PCB structure is shown below.



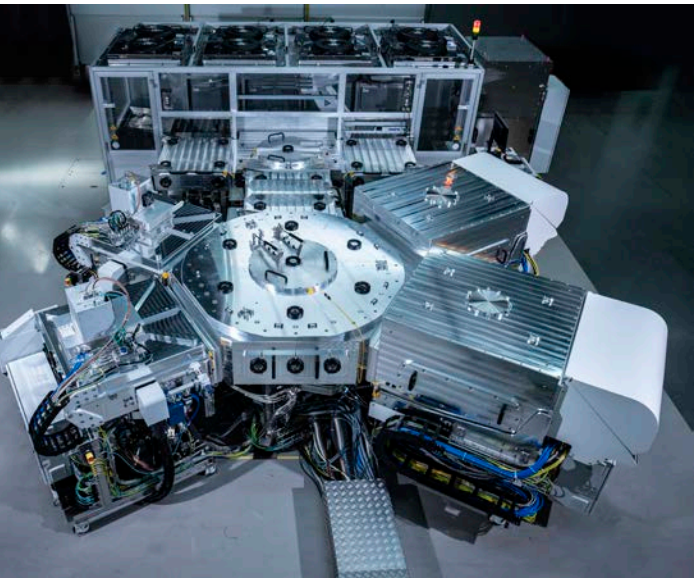
The typical steps of the manufacturing process flow for flexible PCBs known as the "Semi-Additive Process" (SAP) are illustrated below.



Leveraging know-how in sputtering at Evatec

Evatec's CLUSTERLINE® 600 (below) integrating degas, RIE (Reactive Ion Etching) or Ar-sputter etch and sputter deposition capability is already established for panel level Fan-out. Its also capable of carrying out the initial surface treatment plus deposition of the required titanium adhesion promoter and conductive seed layer for rigid PCB and IC Substrate manufacturing. For flexible PCBs however, handling and deposition processes on ultra-thin polymer foils down to thicknesses of only 12 microns posed new questions. The Evatec and GS Swiss PCB teams worked together to address the main challenges:

- What were the best polymer materials capable of fulfilling customer's performance specifications?
- How could these thin foils be handled safely for the complete process flow effectively without costly changes to existing fabrication systems?
- What polymer plasma surface treatment/cleaning was necessary to create the best interface to the subsequent adhesion layers?
- How could thermal management during the outgassing, plasma surface cleaning and deposition processes for the adhesion promoter and the conductive copper seed layers be optimized?
- And finally, would the integrated solution still result in the best adhesion strength for mass production?



Establishing a Design of Experiment (DoE)

The investigation included different designs of experiment (DoE) with various combinations of Polyimide (PI) materials, foil thicknesses, for example 12 or 25 microns, different surface treatments before metal film deposition using different reactive ion etched gases mixtures or argon sputter etch, process environments, adhesion promoters and film deposition conditions applied either on single or both sides.

Fabricating samples for adhesion strength testing required several process steps. The polymer foils were first outgassed, surface treated and deposited with the adhesion and seed layers at Evatec. The copper electroplating and patterning processes for the test strips needed for the adhesion peeling strength test were then completed at GS Swiss.

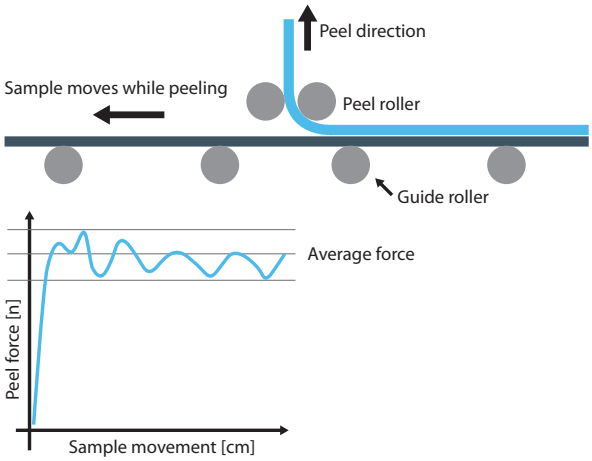
Peel strength test and metrology

Peel strength tests were used to evaluate the quality of both "as deposited" foils and foils passing through reflow and environmental testing according to the following conditions:

- A thermal stress test comprising 5x Reflow at 260°C
- HAST (Highly Accelerated Temperature and Humidity Stress test) comprising exposure for 96h at 130°C and 85% relative humidity.

Testing was made in accordance with IPC-TM-650 test methods and standards. Six (6) test strip measurements were made to evaluate the material adhesion for each set of process conditions. The average value and variance were compared in the analysis.

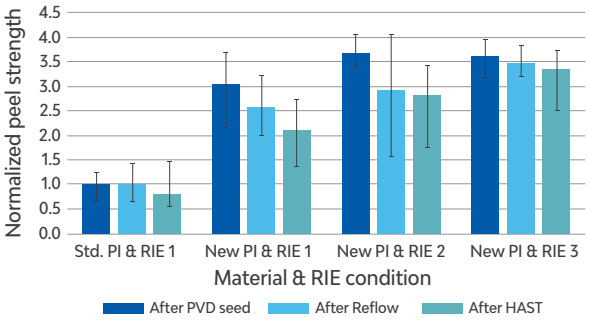
The illustration below shows the principle of the technique. Separation takes place along perpendicular axes. The peel force required is plotted as a function of sample movement.



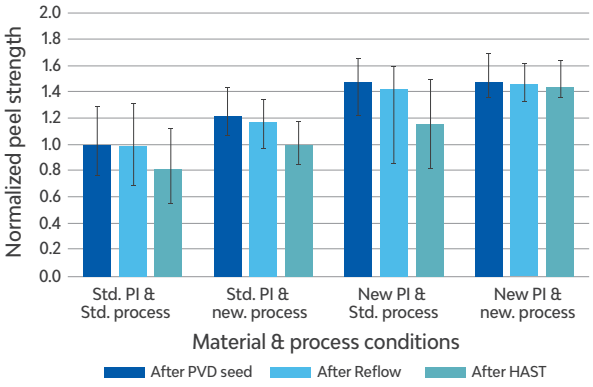
Results and discussion

The graphic below plots the average peel strengths recorded for different PI's and processing conditions. Varying Reactive Ion Etching (RIE) gas mixtures and ratios showed different results. Process conditions "RIE 3" resulted in excellent adhesion values after all reliability tests were performed. Equally important however, we observe two additional phenomena for this set up:

1. Less degradation during Reflow and HAST tests
2. Less statistical fluctuation of the measured values around the average value



The graphic below shows the importance of choice of PI material in combination with the selection of material for adhesion promotion (including outgassing, surface treatment and adhesion layer deposition, e.g. Ti) prior to copper seed layer deposition, all at controlled temperatures of lower than 120°C. All these factors have a large impact on the adhesion of the film after deposition and post treatment during reflow and HAST. Once again, the adhesion performance with good peel strength values achieved for the optimum set show only minor change and degradation.



Flexible substrate handling

Cooperation with GS Swiss PCB led to the development of a simple handling system solution for thin foils down to 12 µm thick. The new handling system adds two essential advantages:

1. Enhanced material robustness and stability to handle and process the sensitive PI foil through the whole PCB-fabrication process
2. Simplifcation and cost-reduction

Conclusion

Optimizing conditions for pre-treatment, metal film deposition and handling for flexible foils using CLUSTERLINE® 600 in cooperation with GS Swiss PCB has achieved important milestones:

- The qualified process is compatible with the existing manufacture flow for foil processing without major changes to CLUSTERLINE® hardware and at low cost of ownership
- The polymer foil could be processed on both sides with excellent adhesion promotion and copper seed layers showing improved adhesion exceeding expectations and withstanding the reflow and HAST environments
- Cost effective fabrication of HDI-PCBs is a reality

About GS Swiss PCB

GS SWISS pcb technologies

GS Swiss PCB AG is a Swiss manufacturer of flex, rigid-flex and HDI-substrates employing over 170 people. The company specializes in miniaturization and the production of IC-substrates and printed circuit boards for chip on board (COB), chip on flex (COF), flip-chip and multi-chip modules (MCM). A second focus is the fabrication of rigid-flex circuits for the medical and aerospace markets. Company capabilities range from laser and mechanically drilled micro vias, contours and depth milling with narrow tolerances to ultra fine line structures and copper filled vias in combination with sequential build up (PVA-Technology). The company has invested more than 10 million Swiss Francs for implementing Semi Additive Process capability (equipment, cleanrooms etc.).

Their PCBs can be found worldwide in the medical field, aerospace applications and challenging industrial products thanks to excellent quality and high reliability.

The GS Swiss PCB team

www.swisspcb.ch/en/

All images and figures courtesy of GS Swiss PCB