HDI alternatives

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Overview

Concept of a aluminium-copper flex

Bonding and interposer

Parameters

Plans at PSI

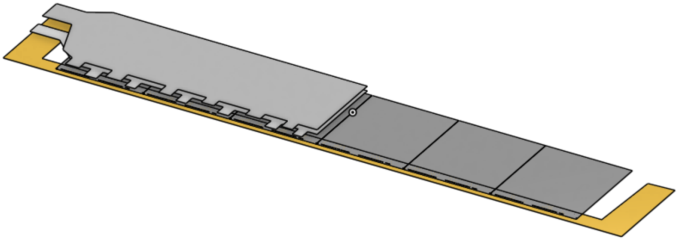
For comparison: a commercially available Cu flex (SwissPCB)

Conclusions

Concept of a aluminium-copper flex

- The current, sad situation with LTU calld for a mitigation plan
- Here I'm showing a concept I already had six years ago
- It is a hybrid copper-aluminium solution

Concept of a aluminium-copper flex



Barebone sketch.

A U-shaped HeiCoFlex copper flex for signals.

Two layers of aluminium for VDD and GND (shown for oine half ladder).

Concept of a aluminium-copper flex

HeiCoFlex is a ultra thin technology for flexes by HighTec MC AG in Lenzburg, Switzerland.
Used in CMS phase 0 and phase 1 pixels by PSI.

HeiCoFlex

Material	X0 (cm)	Thickness (µm)	x/X0	x/X0 (‰)	Sum (‰)
Cu	1.44	2	0.00013888	0.139	0.139
Polyimid	28.6	5	0.00001748	0.017	0.156
Cu	1.44	2	0.00013888	0.139	0.295
Polyimid	28.6	5	0.00001748	0.017	0.313

Note: We strive for a 1-layer design (see later), so count only half the total thickness.

Concept of a aluminium-copper flex

The aluminium power stack would look like this:

Alu power layers

Material	X0 (cm)	Thickness (µm)	x/X0	x/X0 (‰)	Sum (‰)
Al	8.89	12	0.00013498	0.135	0.135
Araldite	39.9	1	0.00000250	0.003	0.137
Polyimid	28.6	6	0.00002097	0.021	0.158
Araldite	39.9	1	0.00000250	0.003	0.161
Al	8.89	12	0.00013498	0.135	0.296

Each layer would max on the available surface to have the lowest possible R.

With the 6 µm polyimide, $C \approx 6\,\text{pF}$.
Maybe electrically helpful? We could go thinner using Mylar and increase C further.

Concept of a aluminium-copper flex

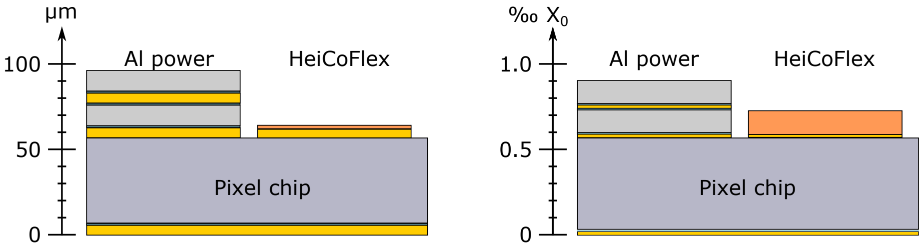
The sensors would be gloud to one layer of Polyimide:

Sensors

Material	X0 (cm)	Thickness (µm)	x/X0	x/X0 (‰)	Sum (‰)
Polyimid	28.6	6	0.00002097	0.021	0.021
Araldite	39.9	1	0.00000250	0.003	0.023
Si	9.34	50	0.00053533	0.535	0.559

Concept of a aluminium-copper flex

In total the stack would look like



Note 1: Drawn to illustrate total stack thickness. The HeiCoFlex would be on the bottom, of course.

Note 2: No need for impedance controlled Al layers allow to drop some polyimide. Hence thinner than LTU.

Bonding and interposer

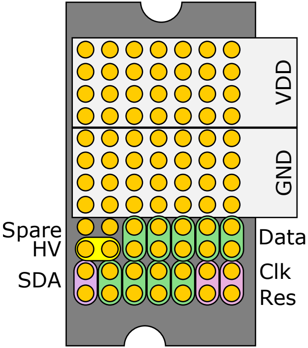
Connections to chip

- Signals: Al wirebonds (25 µm thick)
- Power: SpTAB

Connections to interposer

- Signals go directly to interposer pad-out
- SpTAB bonds on HeiCoFlex to connect the power layers
- Interposer area will need a stiffener as HeiCoFlex is too flexible

Bonding and interposer



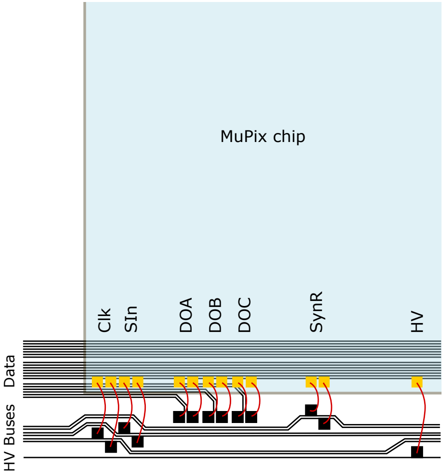
The pad arrangement on the interposer must follow an optimised pattern for this technology:

All signals occupy the bottom 4 rows.
On HeiCoFlex, routing between the pads is no problem (a few µm track width).

Power uses the 2×4 upper rows. Has to be grouped together for ultimately low R.

The interposer stretch of the signals is only maybe 0.1 mm, so this should not hamper the signal integrity.

Bonding and interposer



Sketch of a possible routing and bonding scheme.

HeiCoFlex can go down to 4 µm trace width, hence expect it to be denser. Z will govern the choice, of course.

Wire bonds seem feasible. No vias in this layout needed.

NB: Power would be SpTAB, excluded from this skech.

Parameters

For reference, these are the parameters used:

Material	Formula	σ	ρ	X_0	
		S/m	g/cm^3	g/cm^2	cm
Silicon	Si	5×10^{-4}	2.34	21.8	9.34
Copper	Cu	5.8×10^{7}	8.92	12.86	1.44
Aluminium	Al	3.7×10^{7}	2.70	24.0	8.89
Polyimide	$C_{22}H_{10}N_2O_5$	–	1.42	40.6	28.6
Araldite 2011	$C_{18}H_{20}O_3$	–	1.05	41.9	39.9
Mylar (PET)	$C_{10}H_8O_4$	–	1.38	40.0	28.5

Parameters

A few remarks on the HeiCoFlex design

- This is an expensive technology. Cost drivers are layers and vias.
- Hence we'd like to put all effort into a single layer design.

Plans at PSI

- Preparation of an HDI design using HeiCoFlex plus Al for a vertex detector ladder.
- Check with companies, come up with a cost estimate.
- Fabricate a prototype.

Team: Hans-Christian Kästli, Silvan Streuli, FMA

This proposal also scales to the outer layer ladders. After a vertex demonstrator this would be next.

Plans at PSI

Possible assembly sequence

1. Place HeiCoFlex and polyimide on chuck
2. Apply glue and place chips (sequentally). Let cure.
3. Apply glue and place preassembled power layers
4. Bonding: wirebonds and SpTAB (use two bonders or batch-wise)
5. Test ladder

The assembly of the power layers would be manual using jigs. This is ok for the vertex ladders.

For comparison: a commercially available Cu flex (SwissPCB)

A stack derived from what we use for the endpiece flex. Just two layers:

SwissPCB stack (not optimised)

Material	X0 (cm)	Thickness (µm)	x/X0	x/X0 (‰)	Sum (‰)
Photoresist	30	12	0.00004	0.040	0.040
Cu	1.44	12	0.00083333	0.833	0.873
Polyimide	28.6	12	0.00004195	0.042	0.915
Cu	1.44	12	0.00083333	0.833	1.749
Photoresist	30	12	0.00004	0.040	1.789

Plus 0.535‰ for the silicon gives **2.32‰** $\boldsymbol{x/X_0}$ for one detector layer.

Note: To have the same sheet resistance than 12 µm Al, 7.7 µm of Cu would suffice (subject to availability)

Conclusions

- A proposal for a hybrid copper-aluminium HDI has been made.
- The concept looks feasible.
- A plan for a first demonstrator exists.
- Should be doable in the next months. Manpower secured.

A remark on LTU: I'd like to recommend finishing all designs for them. Miracles are a rare thing but „$\varepsilon > 0$“ holds true.

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