현대 자동차 중국 연구소
CCA BUSBAR 테스트 결과

INTERMAX

○	의사결정
●	정보전달
○	지시사항

[Yantai FISEND, Luoyang COPPER ONE]

Copper Clad Aluminum (CCA) Bus Bar Test Report

beyond THE CAR

지시 사항

2020.06.24

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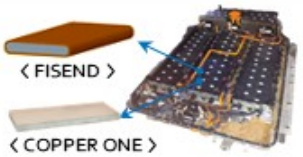
HYUNDAI MOTOR GROUP

Copper Clad Aluminum (CCA) Bus Bar Development

개요

➢ Developing copper clad aluminum (CCA) bus bar for EV battery packs cost-reduction
- Supplier: Yantai FISEND, Luoyang COPPER ONE
- Expected effects (comparing with Cu bus bar): Cost reduction (~30%), Weight reduction (~30%)



내용

구분		FISEND (fully-clad structure)		COPPER ONE (Sandwich structure)	
화학성분	Cu	C1100 규격 만족 (MS911-04)		C1100 규격 만족 (MS911-04)	
	Al	A1070 규격 만족 (GB/T 3190)		A1050 규격 만족 (MS911-04)	
기계적 성질	인장강도	130.8 MPa	규격 만족 (MS911-05, GB/T 30586)	133.4 MPa	규격 만족 (MS911-04)
	연신율	41.54%		37.01%	
단면분석	90° bending	No crack, no peel off of Cu layer		No crack, no peel off of Cu layer	
	180° bending	No crack, no peel off of Cu layer		No crack, no peel off of Cu layer	
	Z bending	No crack, no peel off of Cu layer		-	
	폭 bending	No crack, no peel off of Cu layer		-	
경도	HV0.5	이상없음 (no crack after bending)		이상없음 (no crack after bending)	
온도상승 시험	-	이상없음 (tested by FISEND)		-	

결론 및 계획

- Chemical composition, tensile property, bending property and temperature rise of CCA bus bar are OK
- Namyang's test results needed (conductivity, torque test, 경시균열시험 and other properties) for deciding the future plan

CCA Bus Bar Test Results

I. Chemical composition

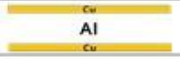
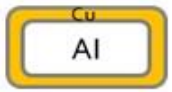
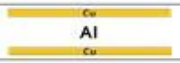
▶ Copper layer

	Cu	비고
C1100 (MS911-04)	≥99.9	Measured by spark-OES
FISEND	≥99.95	Meet MS C1100 requirement
COPPER ONE	≥99.95	Meet MS C1100 requirement

▶ Aluminum layer

	Cu	Si	Fe	Mg	Mn	Ti	Zn	Al	비고
A1050 (MS911-04)	≤0.05	≤0.25	≤0.40	≤0.05	≤0.05	≤0.03	≤0.05	≥99.5	Measured by spark-OES
A1070 (GB/T 3190)	≤0.04	≤0.20	≤0.25	≤0.03	≤0.03	≤0.03	≤0.04	≥99.70	
FISEND	0.0062	0.0470	0.0899	0.0007	0.0011	0.0007	0.0025	99.79	Meet GB A1070 requirement
COPPER ONE	0.0037	0.0432	0.2350	0.0003	0.0023	0.0001	0.0084	99.66	Meet MS A1050 requirement

II. Tensile properties

	Section type	Copper content (vol.%)	TS (MPa)	EL (%)	비고
MS911-04		Over than 30	≥120	≥25	Gauge length: 80mm Tensile speed: 50mm/min
MS911-05		20±0.7	≥98	≥30	
GB/T 30586		30 (Annealing state)	≥120	≥35	
FISEND		30 (Annealing state)	130.8	41.54	Meet MS & GB spec. requirement
COPPER ONE		30 (Annealing state)	133.4	37.01	Meet MS911-04 spec. requirement

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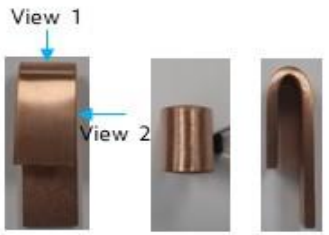
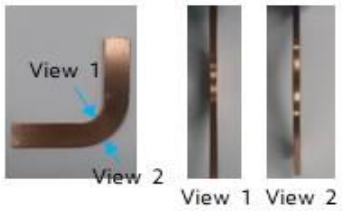
CCA Bus Bar Test Results

III. Bending tests: check the appearance and Cu/Al interface.

Summary

Bending type	90°	180° (bending radius 4mm)	Z bending	폭 bending
FISEND	No crack, no peel off	No crack, no peel off	No crack, no peel off	No crack, no peel off
COPPER ONE	No crack, no peel off	No crack, no peel off		

▶ Appearance: No crack.

Bending type	90°	180°	Z bending	폭 bending
FISEND				
COPPER ONE				

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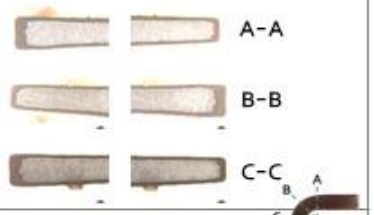
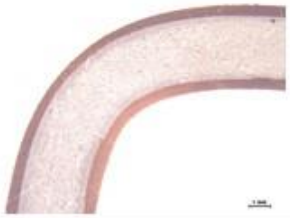
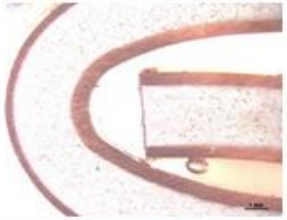
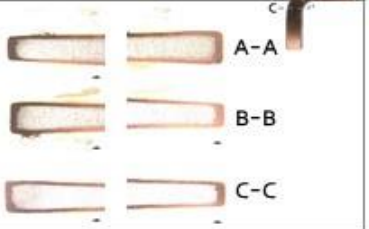
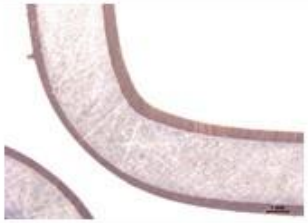
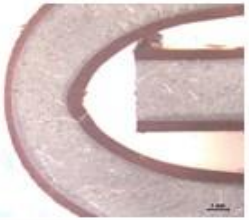
CCA Bus Bar Test Results

▶ Interface: No peel off after bending.

Bending type		90°	180°	Z bending	폭 bending
FISEND	#1				
	#2				
COPPER ONE	#1				
	#2				

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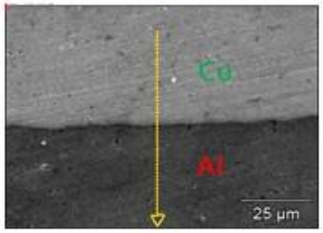
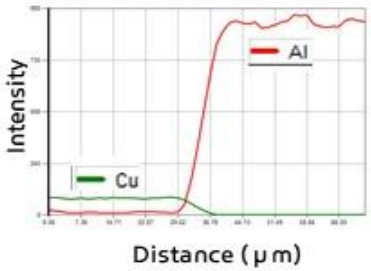
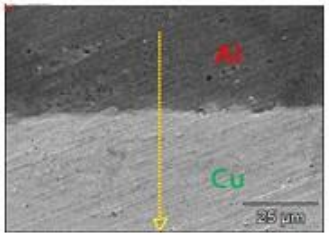
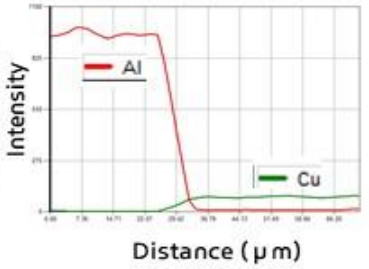
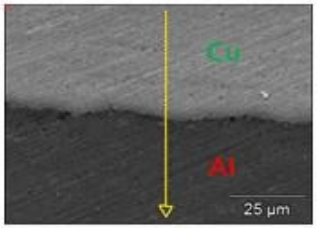
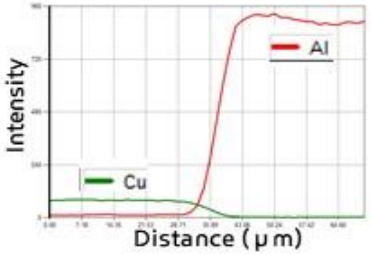
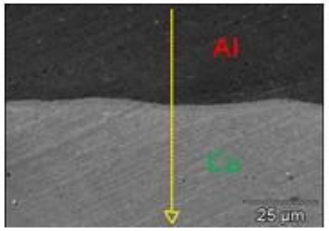
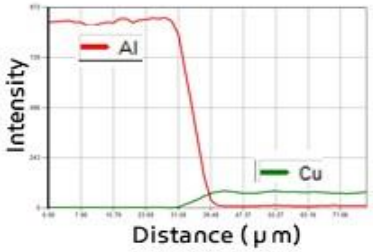
CCA Bus Bar Test Results

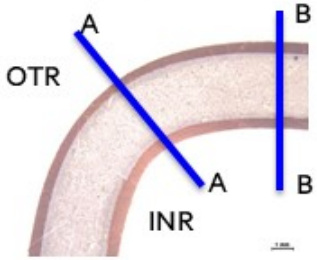
▶ Interface: Cu/Al distribution at interface (SEM-EDS).

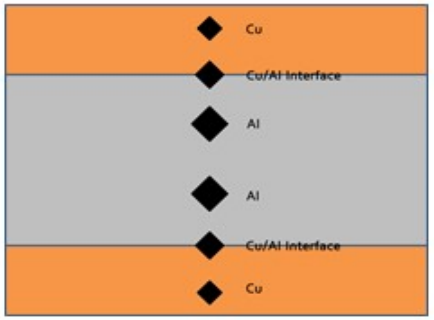
	ONE SIDE	THE OTHER SIDE
FISEND	  Alloy layer exists at the Cu/Al interface, alloy layer thickness about 8-12μm.	  Alloy layer exists at the Cu/Al interface, alloy layer thickness about 8-12μm.
COPPER ONE	  Alloy layer exists at the Cu/Al interface, alloy layer thickness about 8-15μm.	  Alloy layer exists at the Cu/Al interface, alloy layer thickness about 8-15μm.

CCA Bus Bar Test Results

IV. Hardness test (HV0.5)

Hardness on both two sides were checked, as shown in the right graph.





1. 90° bending

☞ Two positions were checked (A and B).

☞ Hardness in A area is higher due to work hardening.

☞ FISEND and COPPER ONE showed similar results.

Details shown in the following table.

90° bending (FISEND)		Cu (OTR)	Interface (OTR)	Al (OTR SIDE)	Al (INR SIDE)	Interface (INR)	Cu (INR)
A-A	Sample 1	105.90	43.76	42.49	39.28	59.89	104.30
	Sample 2	100.90	68.33	39.39	35.59	40.36	105.80
B-B	Sample 1	79.34	38.62	40.11	40.23	58.53	74.89
	Sample 2	80.75	47.93	37.80	40.23	39.23	83.44

90° bending (COPPER ONE)		Cu (OTR)	Interface (OTR)	Al (OTR SIDE)	Al (INR SIDE)	Interface (INR)	Cu (INR)
A-A	Sample 1	103.90	56.35	42.21	36.12	38.15	108.10
	Sample 2	106.80	43.14	40.27	32.08	37.00	113.10
B-B	Sample 1	84.89	44.20	36.45	40.62	35.27	86.86
	Sample 2	86.89	37.00	35.92	44.20	36.78	71.19

CCA Bus Bar Test Results

IV. Hardness test (HV0.5)

2. 180° bending

☞ FISEND and COPPER ONE showed similar results.

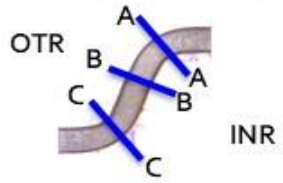
Details shown in the following table.

180° bending		Cu (OTR)	Interface (OTR)	Al (OTR SIDE)	Al (INR SIDE)	Interface (INR)	Cu (INR)
FISEND	Sample 1	110.70	44.64	42.48	41.67	80.79	112.50
	Sample 2	115.80	46.16	46.68	35.06	84.93	112.00
COPPER ONE	Sample 1	111.90	48.77	42.35	37.92	65.33	117.50
	Sample 2	111.30	46.32	41.40	36.23	69.15	115.30

3. Z bending

Three positions were checked (A, B and C as shown in the right graph)

A and C hardness results are similar, higher than B area. (B area deformation is less than A and C)



FISEND Z bending		Cu (OTR)	Interface (OTR)	Al (OTR SIDE)	Al (INR SIDE)	Interface (INR)	Cu (INR)
A-A	Sample 1	102.50	46.48	45.70	37.69	38.97	109.00
	Sample 2	107.90	45.70	43.89	37.69	76.61	111.50
B-B	Sample 1	73.69	42.08	37.23	45.09	43.61	70.93
	Sample 2	78.09	36.78	39.48	35.81	40.10	75.36
C-C	Sample 1	105.60	63.52	40.23	40.23	42.63	105.10
	Sample 2	108.80	43.76	38.51	44.64	41.27	105.10

CCA Bus Bar Test Results

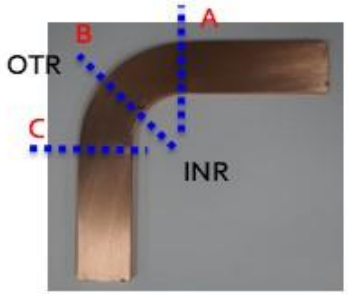
IV. Hardness test (HV0.5)

4. 폭 bending

For FISEND 폭 bending samples, three sections' hardness were checked.

The hardness results of the three sections are similar.

No peel off or cracks were found at the Cu/Al interface.



〈 Section graph 〉

FISEND 폭 bending		Cu (OTR)	Interface (OTR)	Al (OTR SIDE)	Al (INR SIDE)	Interface (INR)	Cu (INR)
A-A	Sample 1	98.12	49.16	33.95	32.15	37.70	102.4
	Sample 2	104.6	52.17	31.61	34.25	49.46	99.45
B-B	Sample 1	103	44.05	39.94	34.35	41.67	100.5
	Sample 2	95.55	46.57	33.86	35.95	55.79	98.85
C-C	Sample 1	103	39.86	33.81	35.91	39.11	102.6
	Sample 2	105.1	58.98	30.24	33.46	55.93	104.3

CCA Bus Bar Test Results

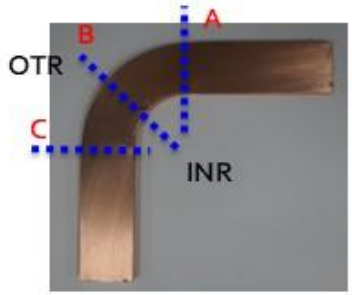
IV. Hardness test (HV0.5)

4. 폭 bending

For FISEND 폭 bending samples, three sections' hardness were checked.

The hardness results of the three sections are similar.

No peel off or cracks were found at the Cu/Al interface.



〈 Section graph 〉

FISEND 폭 bending		Cu (OTR)	Interface (OTR)	Al (OTR SIDE)	Al (INR SIDE)	Interface (INR)	Cu (INR)
A-A	Sample 1	98.12	49.16	33.95	32.15	37.70	102.4
	Sample 2	104.6	52.17	31.61	34.25	49.46	99.45
B-B	Sample 1	103	44.05	39.94	34.35	41.67	100.5
	Sample 2	95.55	46.57	33.86	35.95	55.79	98.85
C-C	Sample 1	103	39.86	33.81	35.91	39.11	102.6
	Sample 2	105.1	58.98	30.24	33.46	55.93	104.3

CCA Bus Bar Test Results

V. Temperature rise (FISEND)

Compared the temperature rise between ① Cu bus bar and ② CCA bus bar (① Cu bus bar: 20×3×150mm; ② CCA bus bar: 20×4×150mm) at the electric current condition of 100A, 200A, 300A and 3 coating types (bare, Sn, Ni), respectively.

According to the results, temperature rise of Cu bus bar and CCA bus bar are in the same level (CCA bus bar is slightly higher)

Details are shown in the table below.

No.	Current	Comparison Samples	Connecting bus bar size	Surface treatment	Temperature rise / K		
					Cu	CCA	Connecting bus-bar
1	100A	20×3×150mm Cu vs. 20×4×150mm CCA	20×4×1000mm CCA, 3 ea. (straight×2 + U shape×1)	No coating	9.08	9.76	9.08
2				Sn coating	9.99	10.41	10.49
3				Ni coating	10.08	9.57	8.75
4	200A	20×3×150mm Cu vs. 20×4×150mm CCA	20×4×1000mm CCA, 3 ea. (straight×2 + U shape×1)	No coating	26.57	26.73	26.67
5				Sn coating	29.14	30.16	31.25
6				Ni coating	27.92	28.39	27.65
7	300A	20×3×150mm Cu vs. 20×4×150mm CCA	20×4×1000mm CCA, 3 ea. (straight×2 + U shape×1)	No coating	52.52	53.49	53.45
8				Sn coating	56.36	57.32	58.59
9				Ni coating	54.48	55.50	55.17

Connected CCA bus bar test method

〈 Before connecting 〉

U connecting CCA bus bar

Target CCA bus bar
(for testing)

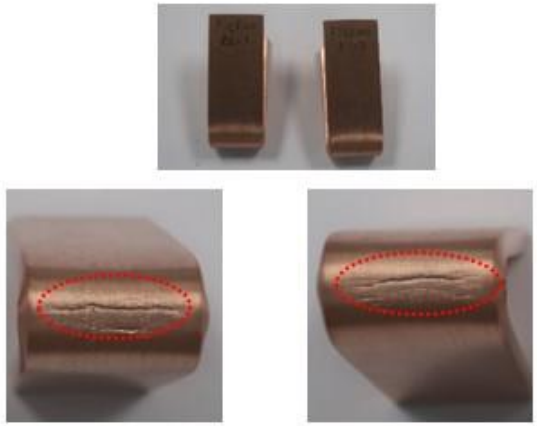
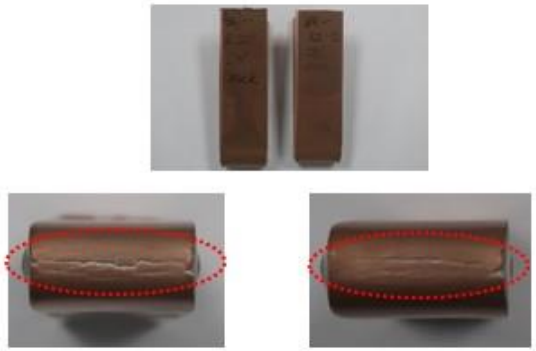
Connecting CCA bus bar

〈 Connected state 〉

Thermocouple

CCA Bus Bar Test Results (180° bending)

For reference, when perform 180° bending with inner radius 2mm, both FISEND's sample and COPPER ONE's sample cracked.
(sample raw thickness: 4mm)

	180° bending (radius 2mm, crack)
FISEND	
COPPER ONE	

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