

The Influence of Intermetallic Compounds, (IMC), on High Speed Shear Testing with a Specific Interest in Electroless Palladium / Autocatalytic Gold

IMC Evaluation

BTT-SF | Berlin | 2017-03-09



Technology for tomorrow's solutions

Background

Evaluation Considerations

Foreword

- Full paper available
- Purpose is to evaluate that solder joint reliability (SJR)
- Abbreviations:
 - Immersion tin (i-Sn)
 - Organic Surface Protection (OSP)
 - Electroless Nickel/ Immersion Gold (ENIG)
 - Electroless Nickel /Electroless Palladium and Immersion Gold (ENEPIG)
 - Electroless Palladium / Semi Autocatalytic Gold (EPAG)
- HSS testing is a numerical method to simulate dropping a device
 - Aligned to mobile devices



IMC evaluation

Test Plan

Leg	Surface Finishing	Ni [μm]	Pd [μm]	Au [μm]	Remark
1	OSP	-	-	-	Pb free
2	I-Sn	-	-	-	Target 1 μm
22	ENIG (HP)	5 (3-5)	-	0.03 – 0.05	HP
3	ENEPIG	1	100	100	Thin Ni
6	EPAG (-)	-	0.05	0.05	
11	EPAG	-	0.1	0.1	

>1000 rows of data

IMC evaluation

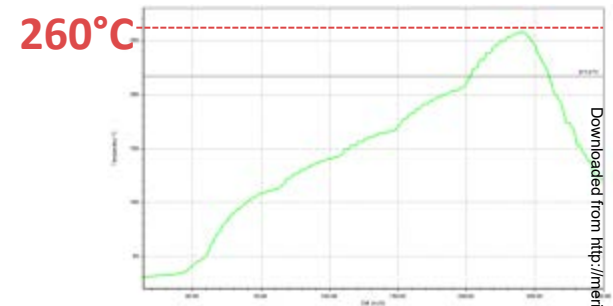
Test data

Sample	Test	DateSave	Shear Strength (g)	Total Energy (mJ)	PrePeakEnergy (mJ)	PostPeakEnergy (mJ)	Speed (m/s)	TestTime (ms)	Project / T-Number	Customer	Surface Finish	Fr
4317	6845	14	1484216933	355	0.4	0.1434606761	0.235777989	1.1910675049	0.2100000129	10079989	SF	ENIG (HP)
4318	6845	15	1484216933	368	0.4	0.1678150594	0.2670309544	1.1942910156	0.2200000163	10079989	SF	ENIG (HP)
4319	6845	16	1484216933	403	0.3	0.1267864257	0.1916255802	1.1909360352	0.194000022	10079989	SF	ENIG (HP)
4320	6882	1	1484228789	1534	2.6	0.9454149008	1.6726204157	2.0108024902	0.2170000225	PS170112	SF	EPAG
4321	6882	2	1484228789	1423	2.5	0.7917931676	1.744402647	2.010784668	0.2140000142	PS170112	SF	EPAG
4322	6882	3	1484228789	1449	2.1	0.8172786236	1.2631857395	2.0176031494	0.2100000129	PS170112	SF	EPAG
4323	6882	4	1484228789	1435	2.7	0.924471736	1.7907530069	2.0175317383	0.2090000198	PS170112	SF	EPAG
4324	6882	5	1484228789	1420	2.8	0.9530066252	1.870216012	2.0200424805	0.194000022	PS170112	SF	EPAG
4325	6882	6	1484228789	1261	2.2	0.719409287	1.5280776024	2.0116569824	0.2070000191	PS170112	SF	EPAG
4326	6882	7	1484228789	1543	2.6	0.9839174747	1.5992226601	2.0175310059	0.2230000246	PS170112	SF	EPAG
4327	6882	8	1484228789	1460	2.7	0.8530420065	1.8232454062	2.0141672363	0.2220000169	PS170112	SF	EPAG
4328	6882	9	1484228789	1514	2.4	0.8677790165	1.5486080647	2.0144696045	0.2650000388	PS170112	SF	EPAG
4329	6882	10	1484228789	1400	2.6	0.8596240282	1.7096816301	2.0085056152	0.1620000112	PS170112	SF	EPAG
4330	6882	11	1484228789	1356	2.0	0.7570567131	1.2211813927	2.0133121338	0.2680000325	PS170112	SF	EPAG
4331	6882	12	1484228789	1398	2.5	0.8929188251	1.5638101101	2.0115679932	0.183000011	PS170112	SF	EPAG
4332	6882	13	1484228789	1341	2.7	0.8332665563	1.8208827972	2.01418396	0.2110000205	PS170112	SF	EPAG
4333	6882	14	1484228789	1244	2.0	0.6860777736	1.2715365887	2.0110170898	0.2350000286	PS170112	SF	EPAG
4334	6882	15	1484228789	1464	2.3	0.8249878287	1.4508116245	2.0141676025	0.2040000254	PS170112	SF	EPAG
4335	6882	16	1484228789	1311	2.9	0.8533605337	2.0163273811	2.0082023926	0.2160000149	PS170112	SF	EPAG
4336	6795	1	1484126592	1166	1.5	0.6326046586	0.8591676354	0.8962542725	0.3050000232	PS170111	SF	NiPdAu
4337	6795	2	1484126592	1162	1.2	0.5109914541	0.7320914268	0.898171814	0.2900000254	PS170111	SF	NiPdAu
4338	6795	3	1484126592	1519	2.8	0.9086602926	1.8471997976	0.8986861572	0.5540000275	PS170111	SF	NiPdAu
4339	6795	4	1484126592	1090	2.4	0.4396002889	1.9515662193	0.8995822144	0.5400000373	PS170111	SF	NiPdAu
4340	6795	5	1484126592	1013	2.4	0.6666644812	1.7285174131	0.8998928223	0.5430000601	PS170111	SF	NiPdAu
4341	6795	6	1484126592	1211	2.1	0.3740683198	1.7422966957	0.8990944214	0.5690000253	PS170111	SF	NiPdAu
4342	6795	7	1484126592	1047	1.2	0.3194817305	0.8714680672	0.9006490479	0.2880000393	PS170111	SF	NiPdAu
4343	6795	8	1484126592	1391	3.7	0.9680181742	2.7630710602	0.9021064453	0.5340000498	PS170111	SF	NiPdAu
4344	6795	9	1484126592	1101	1.1	0.4778065383	0.6299083233	0.8994814453	0.23900003	PS170111	SF	NiPdAu
4345	6795	10	1484126592	1282	3.1	0.7342248559	2.3700144291	0.8979545288	0.5540000275	PS170111	SF	NiPdAu
4346	6795	11	1484126592	1083	1.9	0.6403104067	1.2161068916	0.8961484375	0.5800000508	PS170111	SF	NiPdAu
4347	6795	12	1484126592	1119	1.1	0.4603401124	0.6551667452	0.8999275513	0.2330000279	PS170111	SF	NiPdAu
4348	6795	13	1484126592	1175	2.2	0.5214776993	1.6688234806	0.8995775146	0.565000053	PS170111	SF	NiPdAu
4349	6795	14	1484126592	1205	1.7	0.6538833976	1.0597748756	0.8994814453	0.6200000644	PS170111	SF	NiPdAu
4350	6795	15	1484126592	1085	0.9	0.3342804015	0.5338554382	0.8978254395	0.2060000261	PS170111	SF	NiPdAu
4351	6795	16	1484126592	1069	0.6	0.3339164853	0.3135589957	0.897909729	0.1610000181	PS170111	SF	NiPdAu

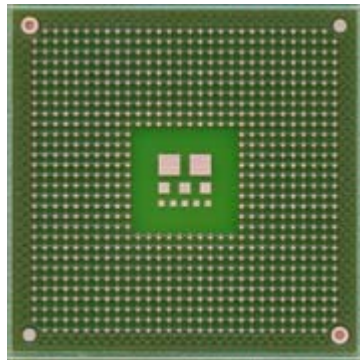
Data is HSS based for SJR evaluation

IMC evaluation

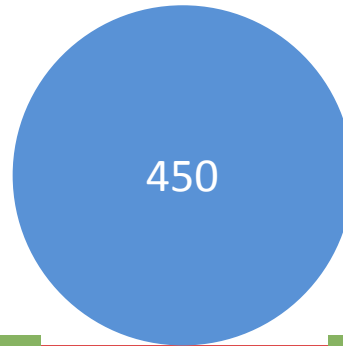
Physical test parameters



Test Vehicle



Description



SMD 380µm

Ageing

ASR
As Received Condition "ASR"

Sequence:
Plating → ball attachment → HSS → IMC analysis

Aged
Substrate and IMC Aging

Sequence:
Plating → Pre-aging → Ball attachment → Post Aging → HSS → IMC analysis

Pre ageing

- Baking 2hours @175°C
- 5 min DI water@ 60°C
- Cold air dry

Ball attach

- TSF 6502 Linear Lead-Free Reflow Profile
- Flux: Kester TSF 6502

Post Ageing

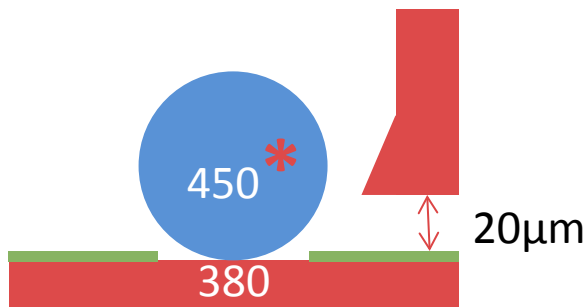
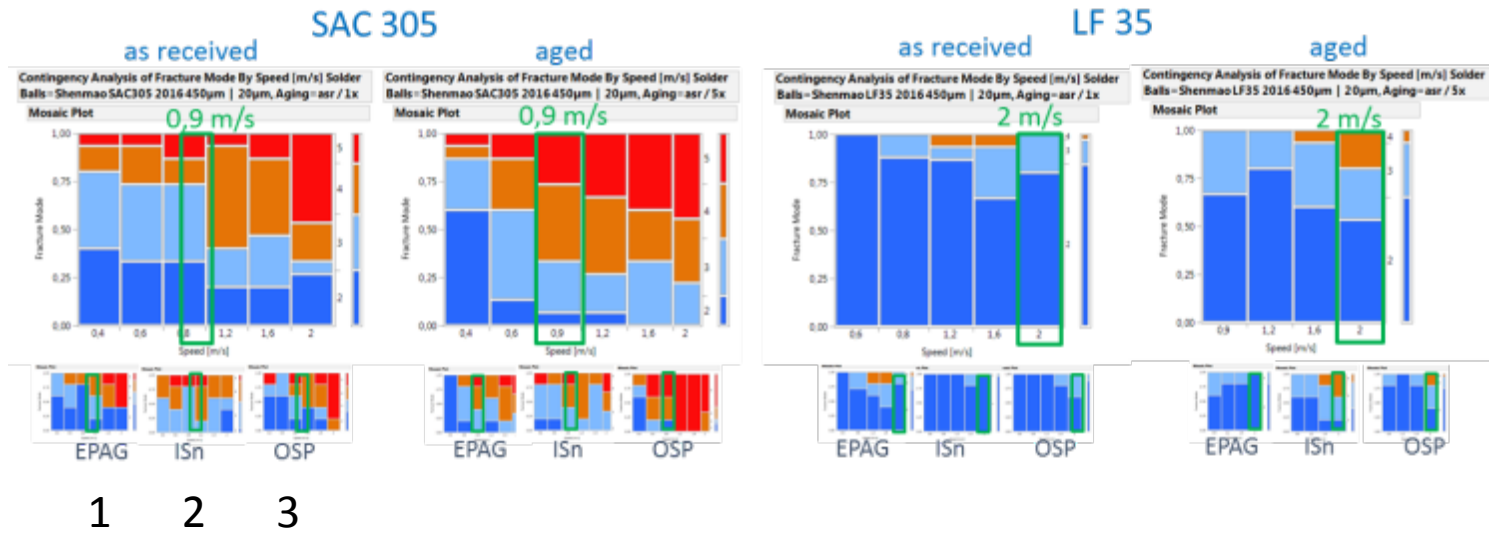
- 120 hours @ 60°C with 60% Relative Humidity
- 5 x reflow (Ball attach + 4 ageing reflows)

Test Vehicle	Handling
TV3_V4 KSG	Pummed

Solder	Metal %		
	Ag	Cu	Ni
SAC 305	3	0,05	0
LF35	1,2	0,05	0,05

IMC evaluation

Cliff finding for HSS



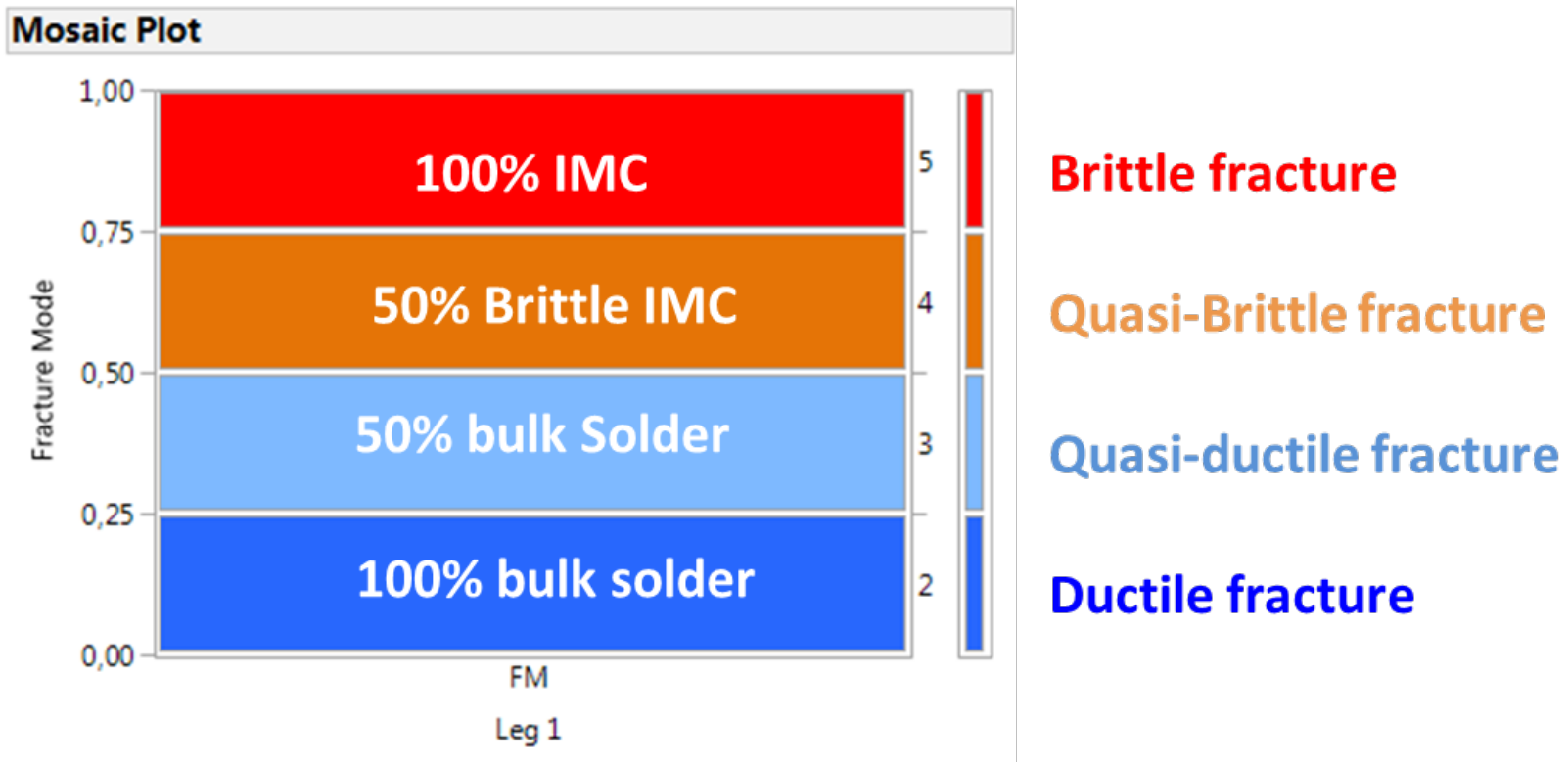
SAC 305:
0.9 m/s ($\varnothing 450\mu\text{m}$)

LF 35:
2.0 m/s ($\varnothing 450\mu\text{m}$)

LF 35:
1.2 m/s ($\varnothing 250\mu\text{m}$)

IMC evaluation

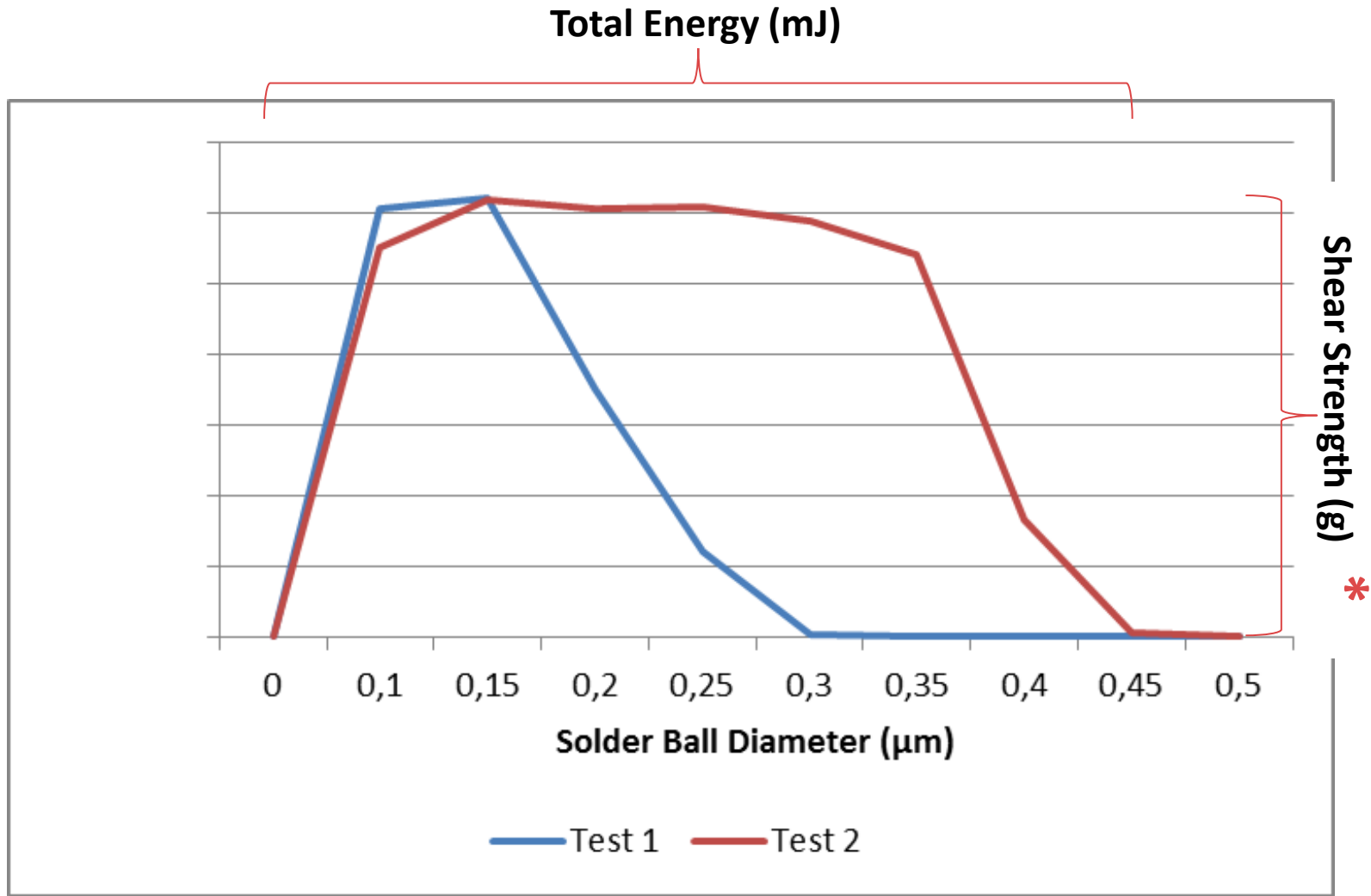
Fracture mode classification



Ductile fracture modes are better for mobile devices

IMC evaluation

Why Total Energy (mJ) ?



Total Energy is an expression of ductility drop test simulation

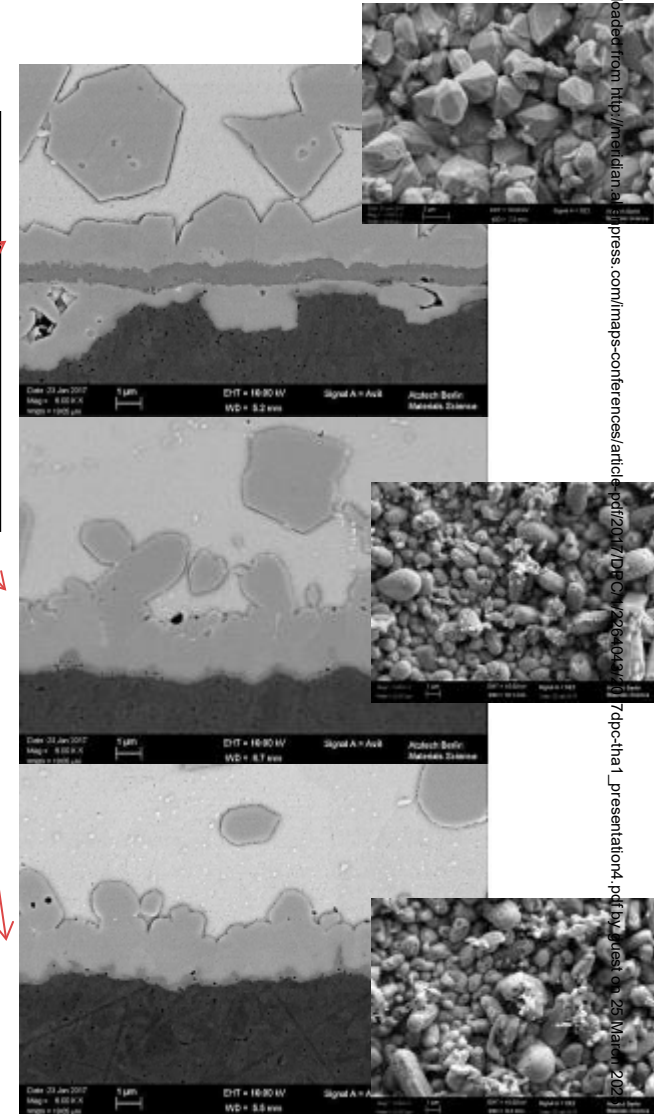
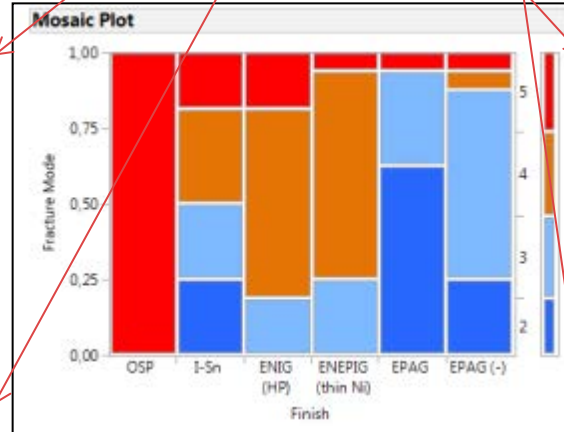
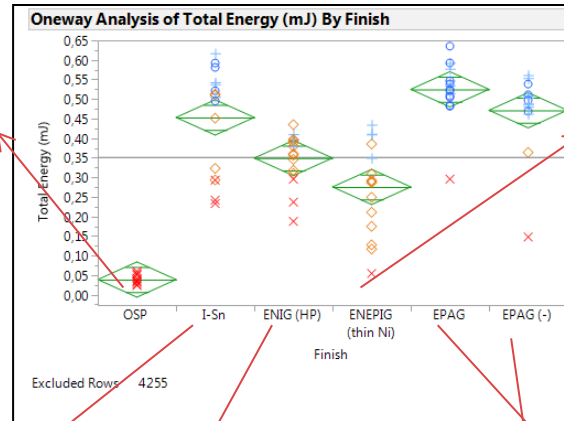
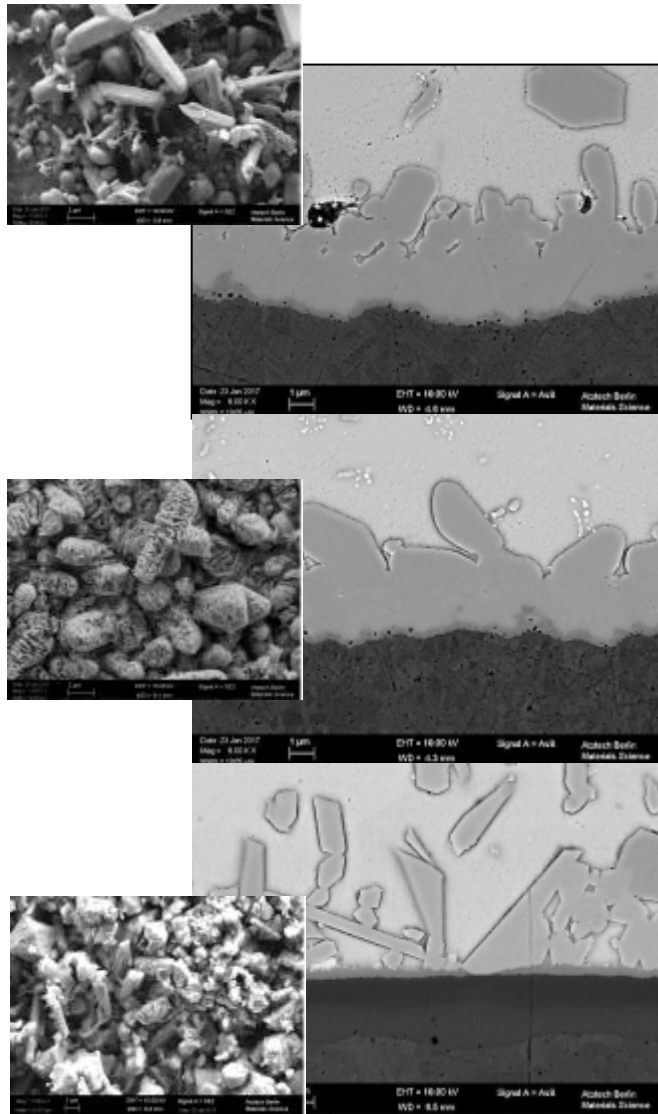
IMC evaluation

Why Total Energy (mJ) ?

Total Energy is an expression of ductility drop test simulation

IMC evaluation

Scope of evaluation (250µm LF 35 - AGED)



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High Speed Shear Testing

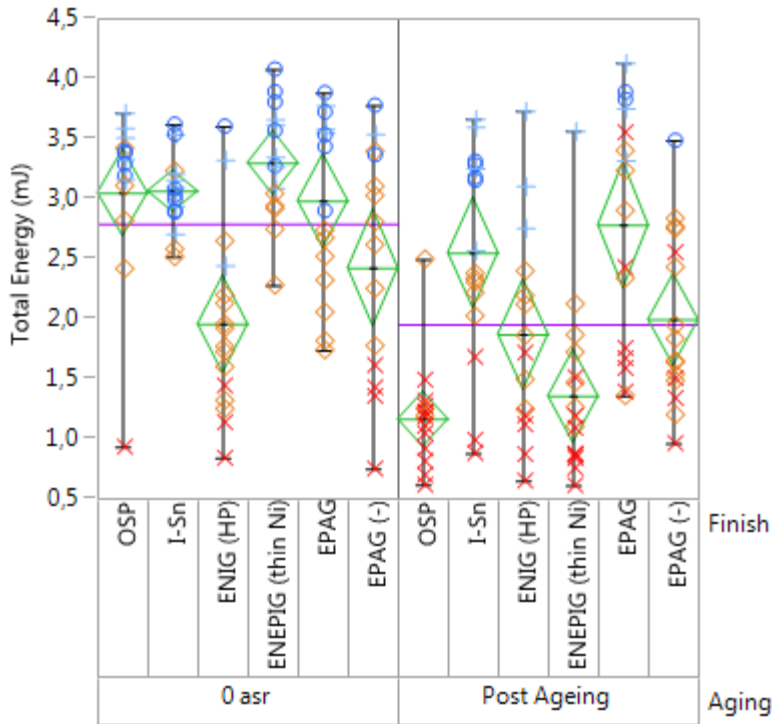
Comparison of different surface finishes

vs solder alloys

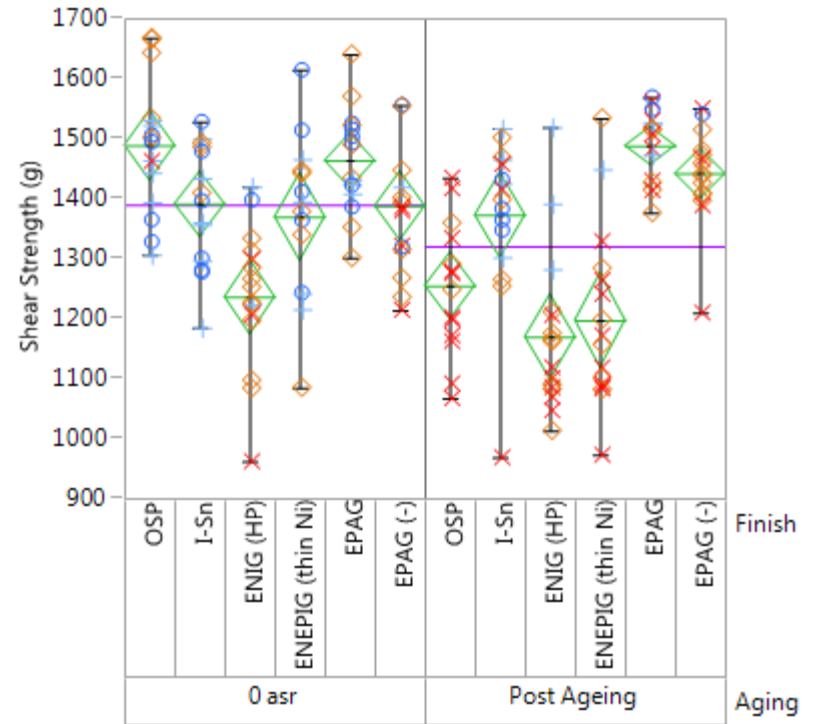
High Speed Shear Testing

SAC 305 450 μ m

Variability Chart for Total Energy (mJ)



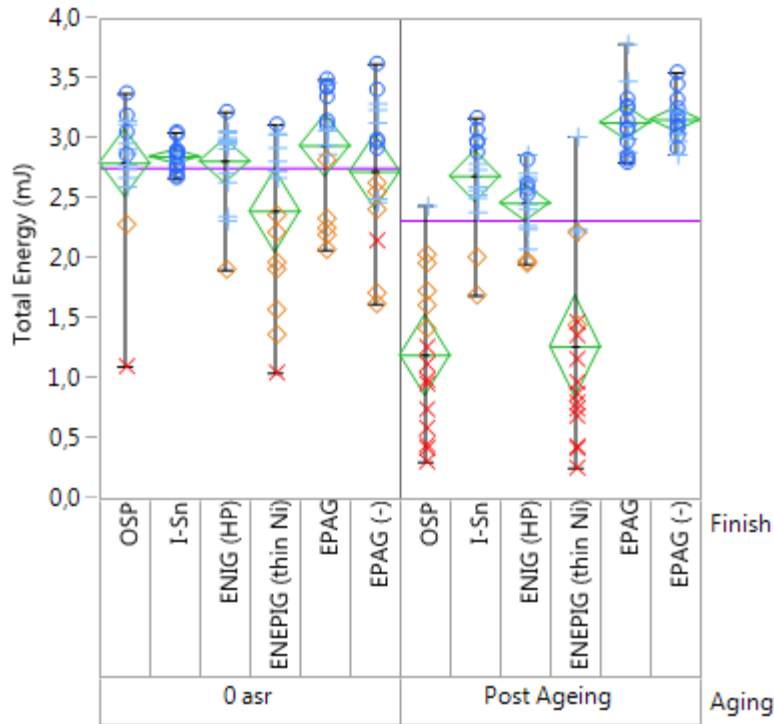
Variability Chart for Shear Strength (g)



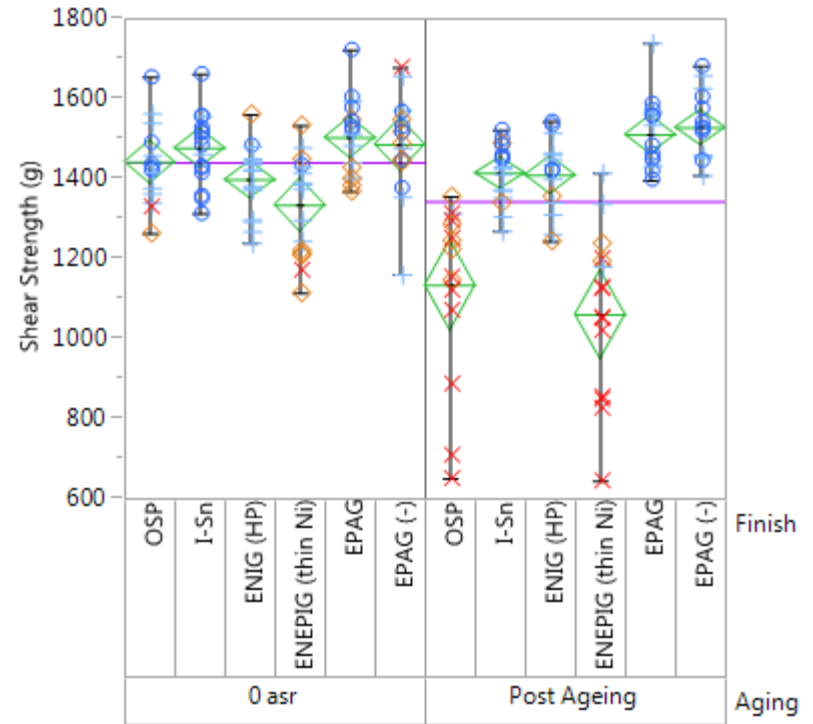
High Speed Shear Testing

LF35 450 μm

Variability Chart for Total Energy (mJ)



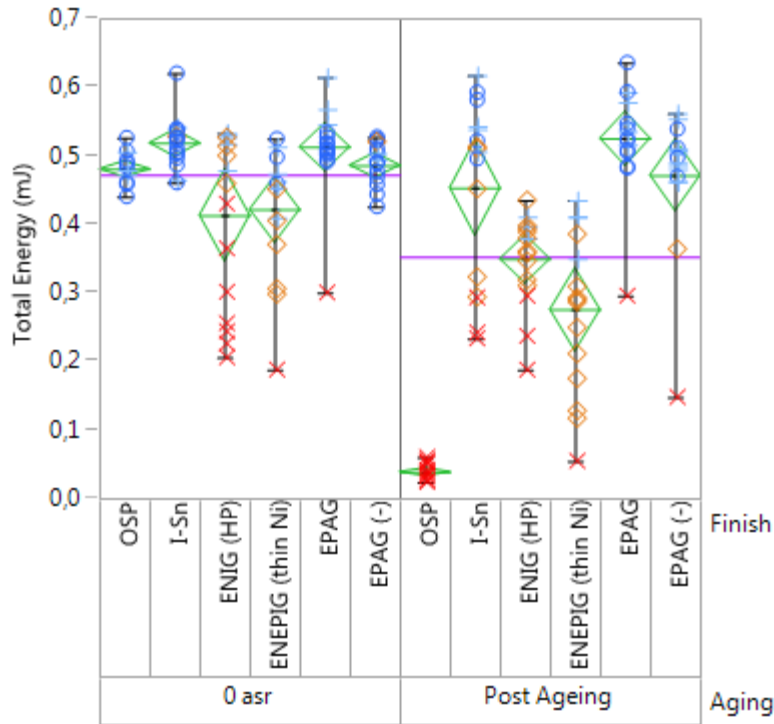
Variability Chart for Shear Strength (g)



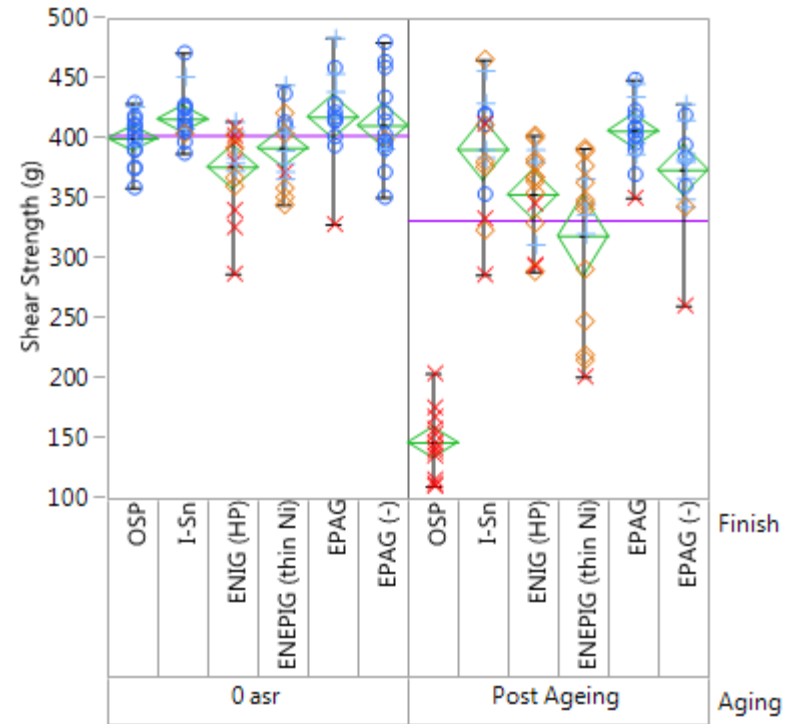
High Speed Shear Testing

LF35 250 μm

Variability Chart for Total Energy (mJ)



Variability Chart for Shear Strength (g)

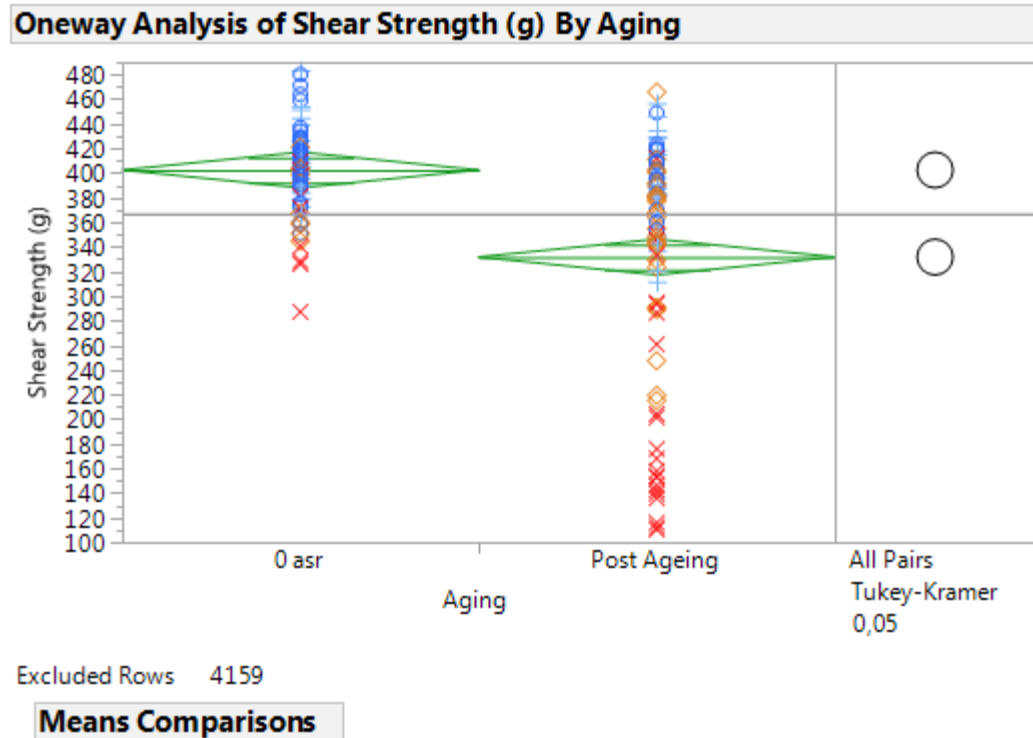


IMC Evaluation

OSP, ENPIG (thin Ni) and EPAG

IMC evaluation

Slide structure

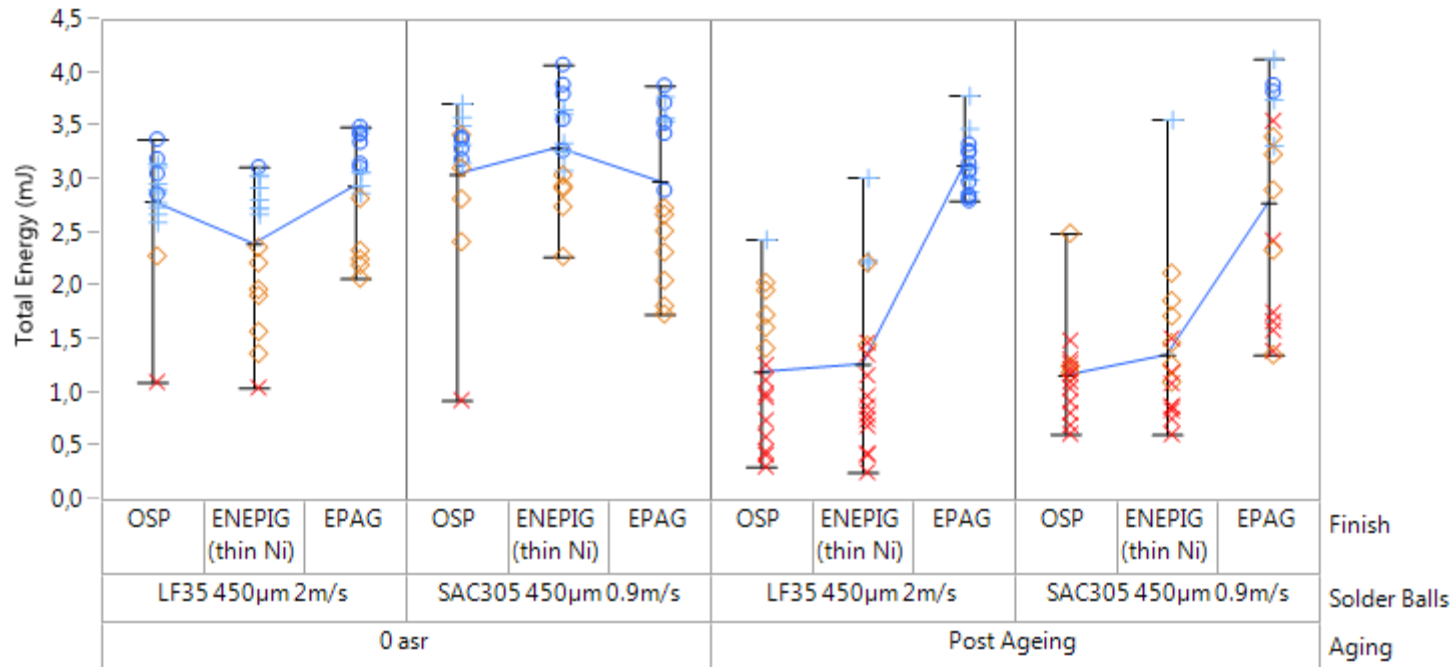


Ageing results will follow ASR

IMC evaluation

Final finishes selection at **450µm**

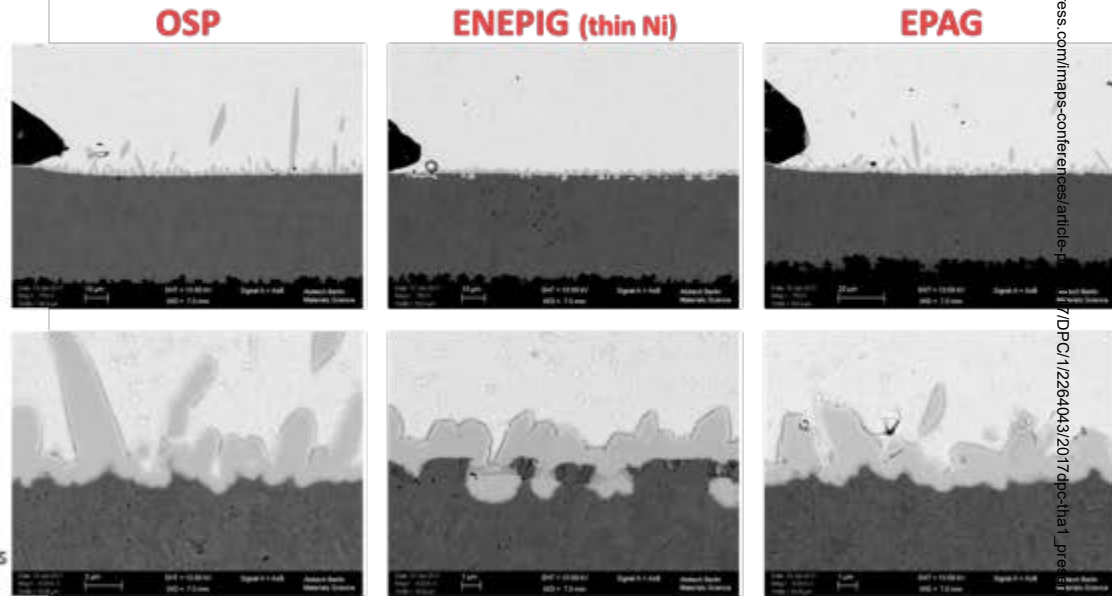
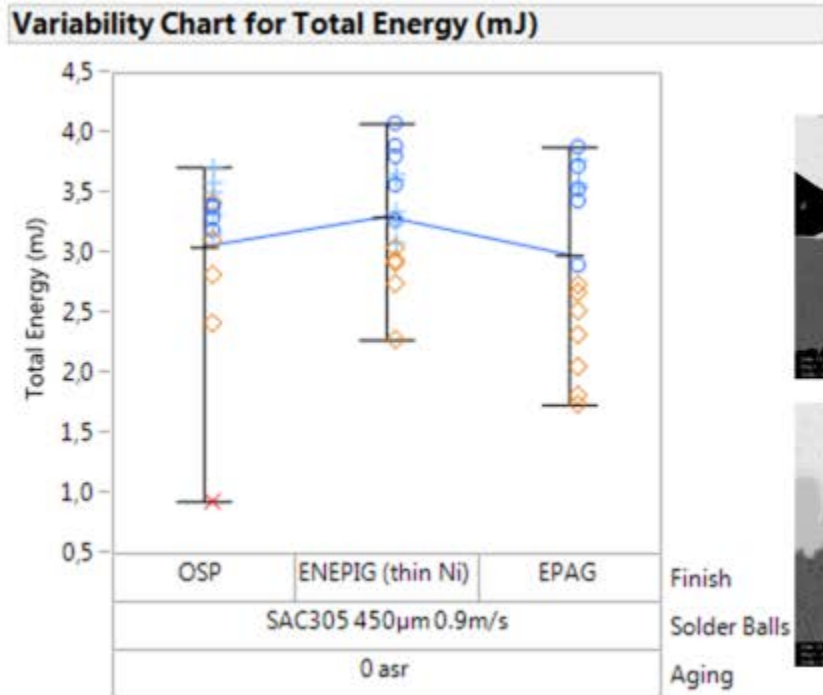
Variability Chart for Total Energy (mJ)



Market significant final finishes occupying representative niche

IMC evaluation

SAC 305, 450 μ m, ASR

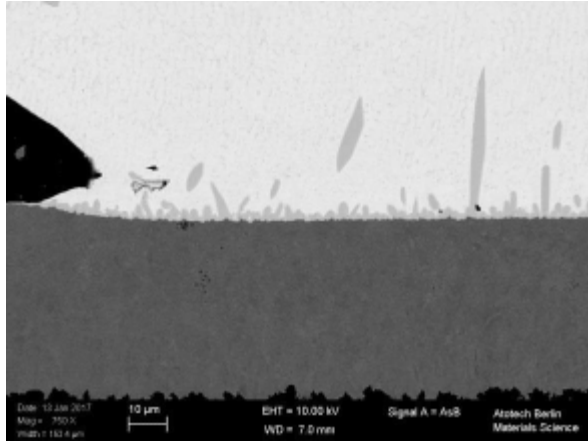


ENEPIG = High nickel corrosion

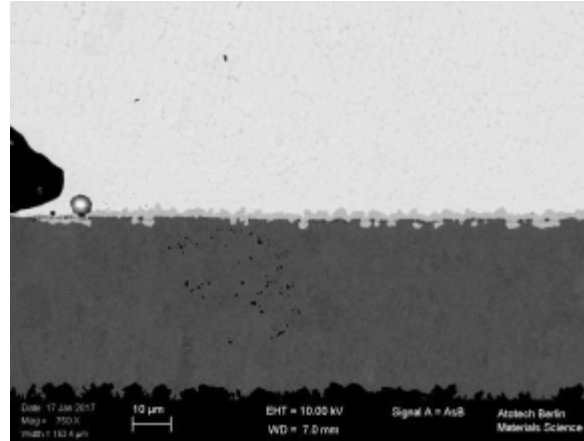
IMC evaluation

SAC 305, 450 μ m, ASR

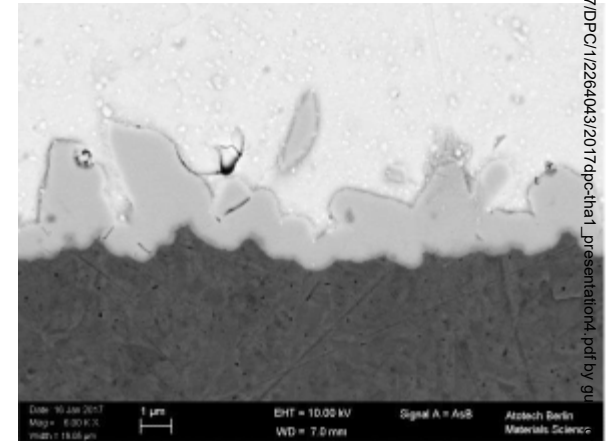
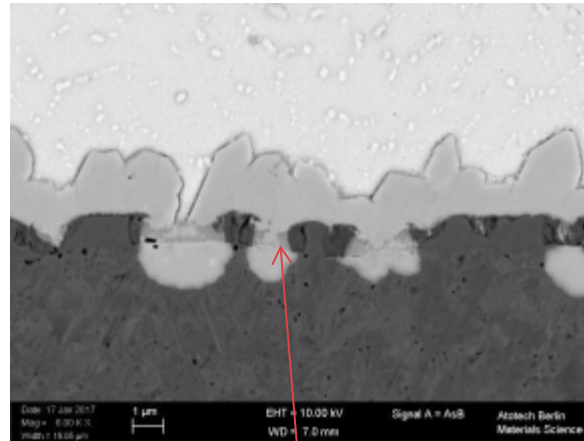
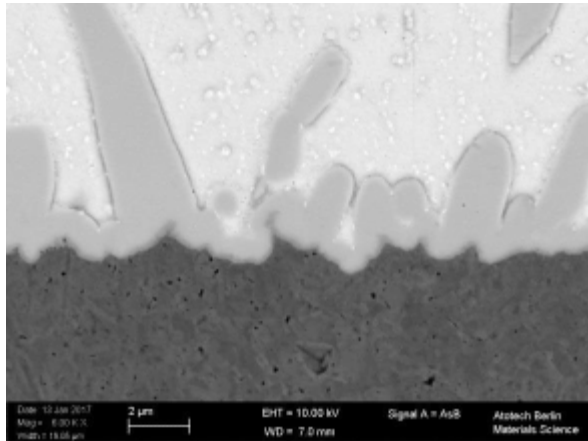
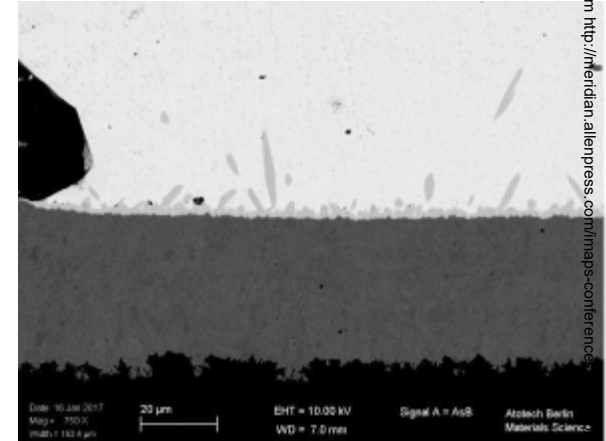
OSP



ENEPIG (thin Ni)



EPAG



Needle like structure?

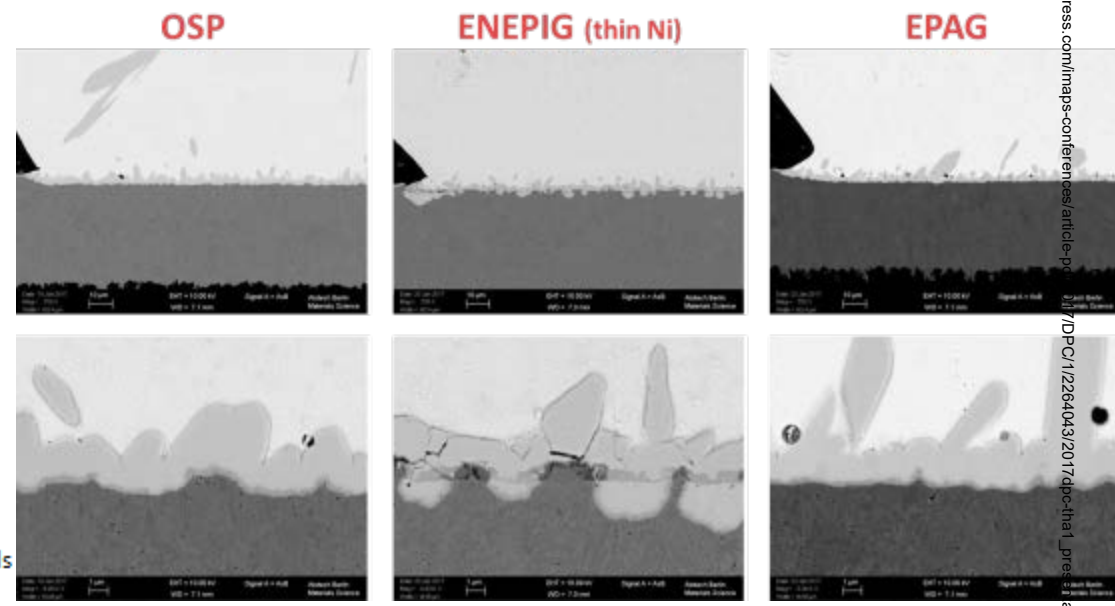
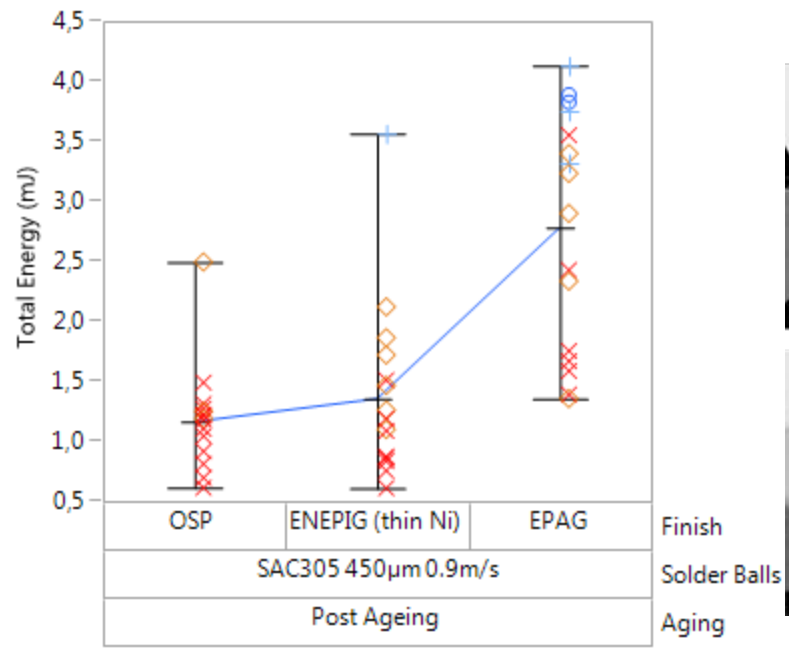
P Enrichment & Ni corrosion

Needle like structure?

IMC evaluation

SAC 305, 450 μ m, Aged

Variability Chart for Total Energy (mJ)

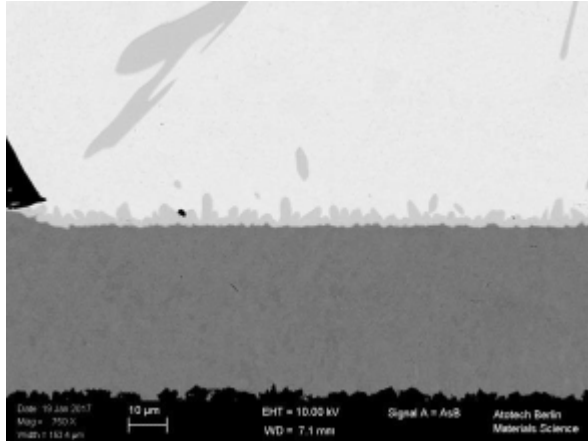


ENEPIG = High nickel corrosion and enrichment demarcation

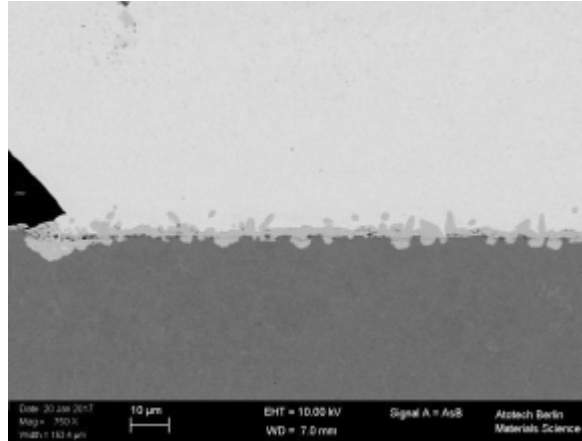
IMC evaluation

SAC 305, 450 μ m, Aged

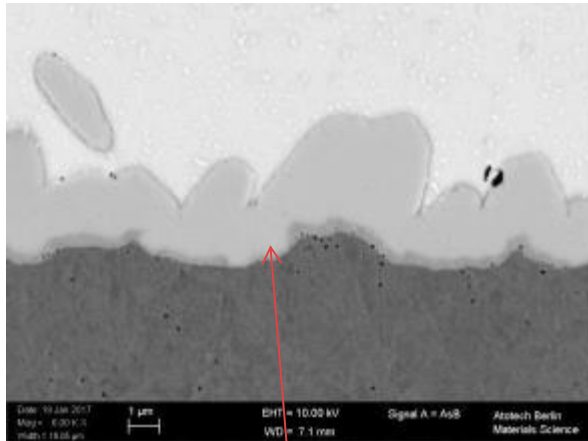
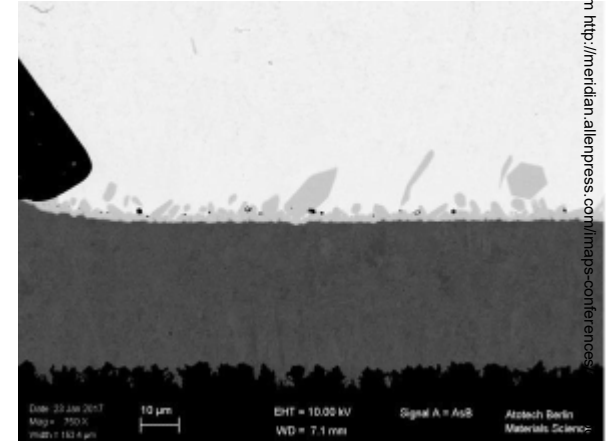
OSP



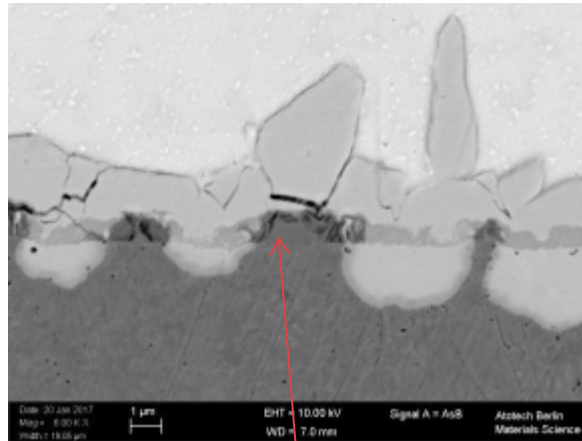
ENEPIG (thin Ni)



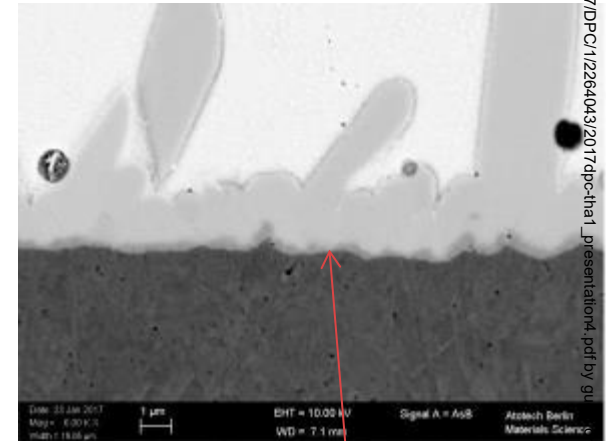
EPAG



Cu rich IMC



Strong Ni corrosion & P Enrichment



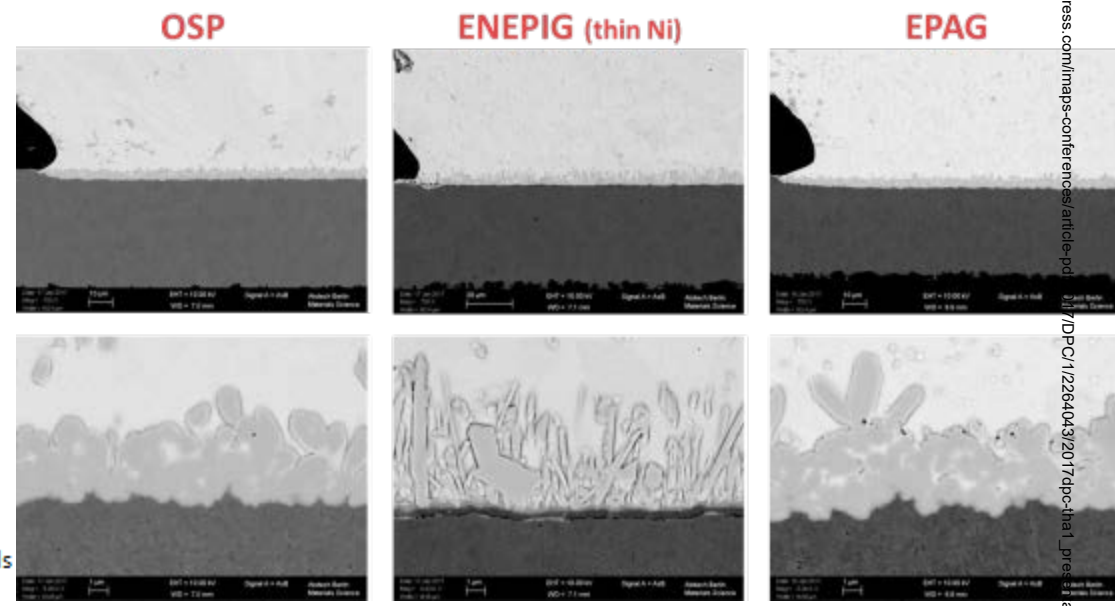
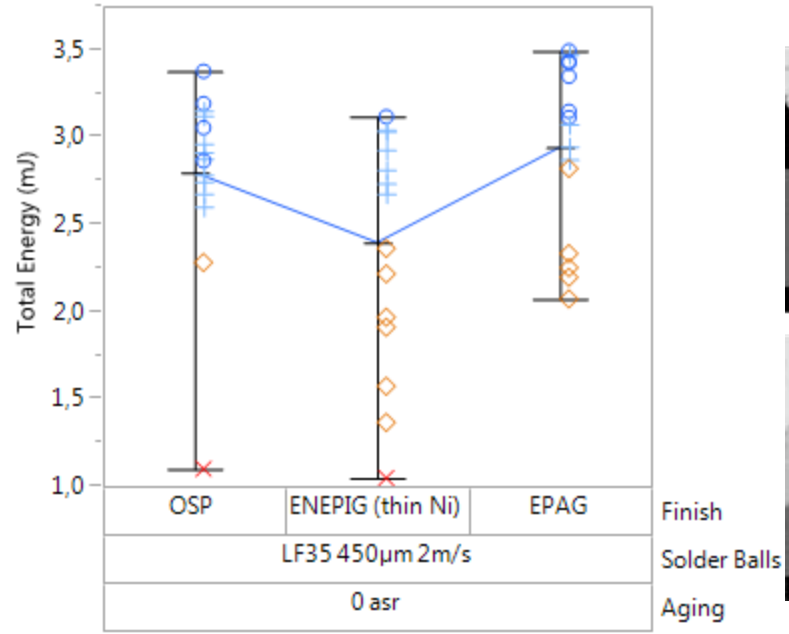
Cu rich IMC

IMC evaluation

LF 35, 450 μ m, ASR

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Variability Chart for Total Energy (mJ)

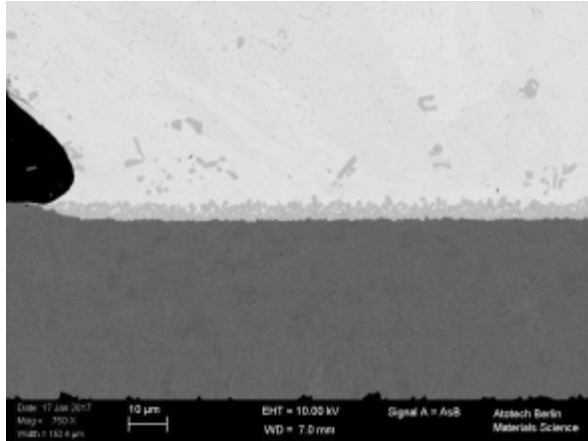


ENEPIG = needle like IMC

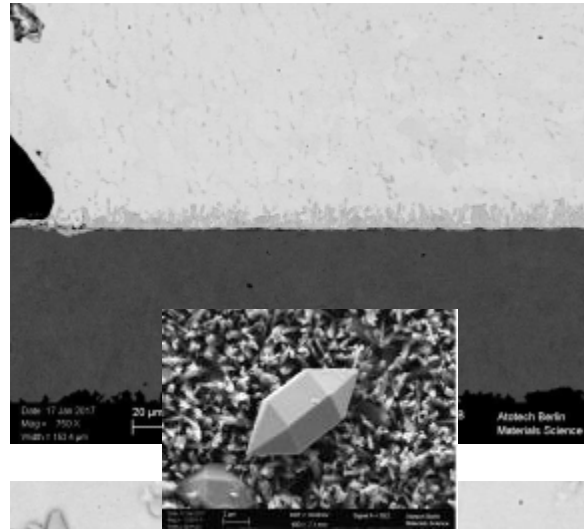
IMC evaluation

LF 35, 450 μ m, ASR

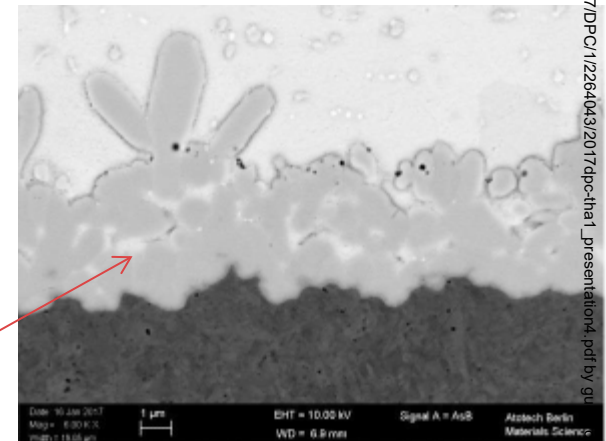
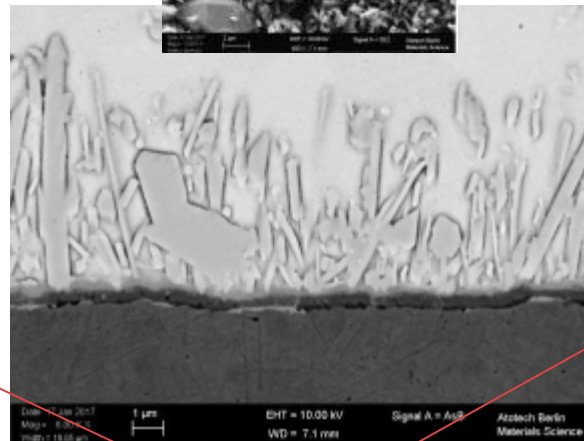
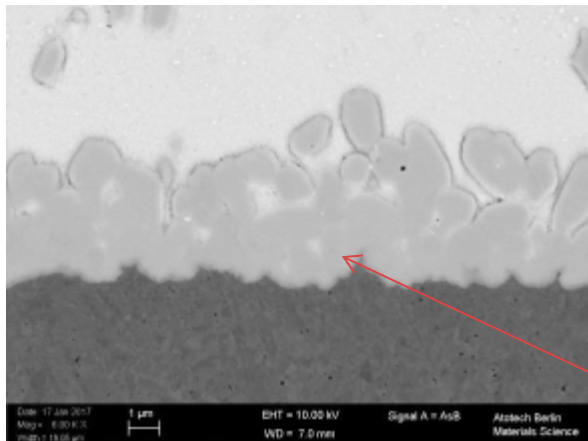
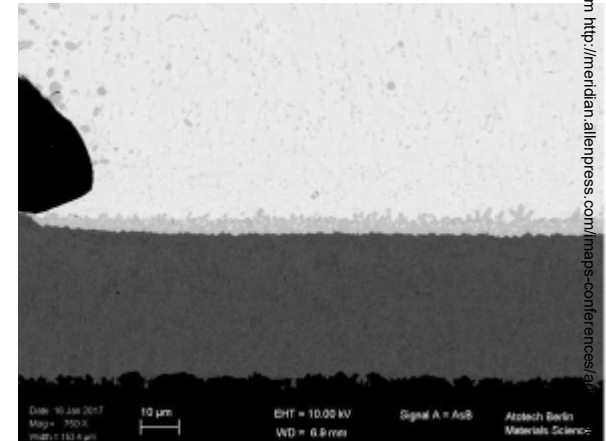
OSP



ENEPIG (thin Ni)



EPAG



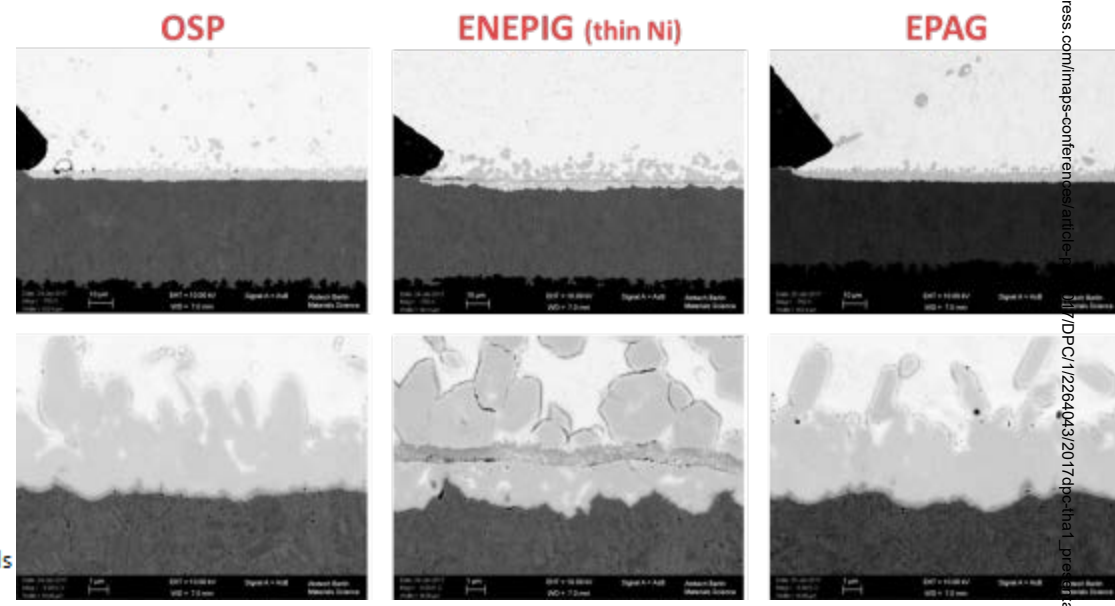
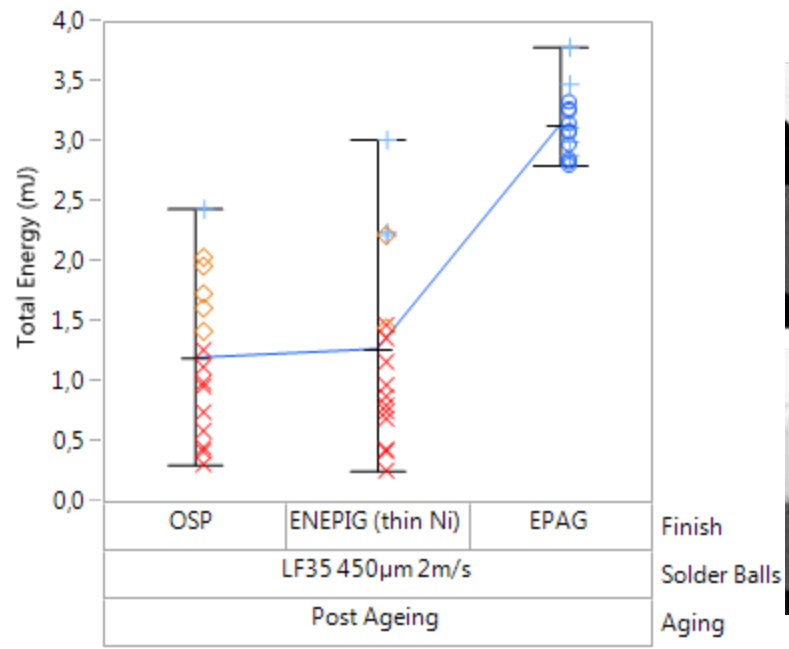
Similar IMCs

IMC evaluation

LF 35, 450 μ m, Aged

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Variability Chart for Total Energy (mJ)

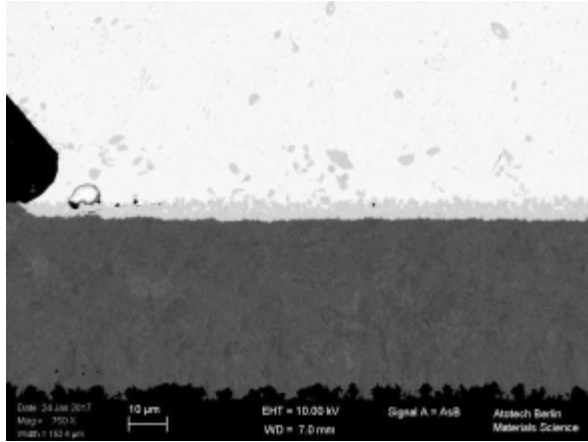


ENEPIG with p rich layer

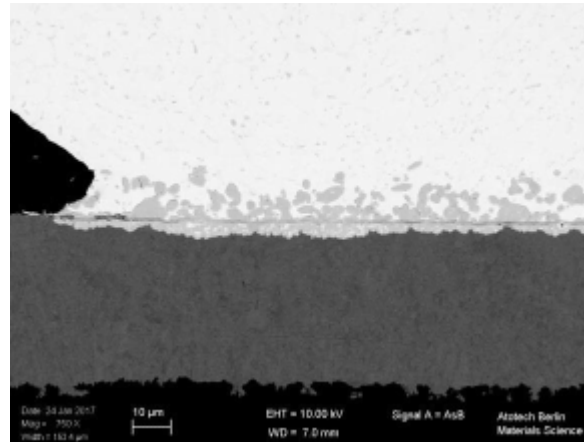
IMC evaluation

LF 35, 450 μ m, Aged

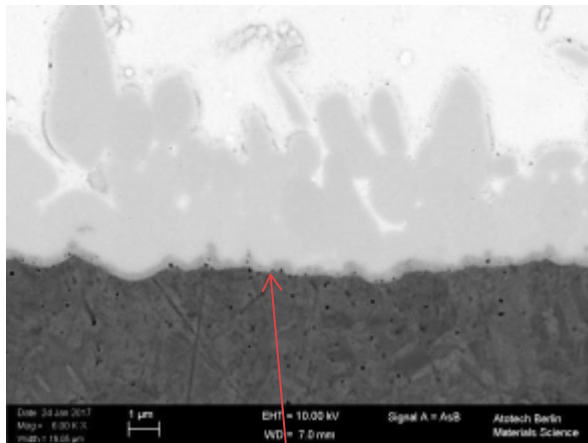
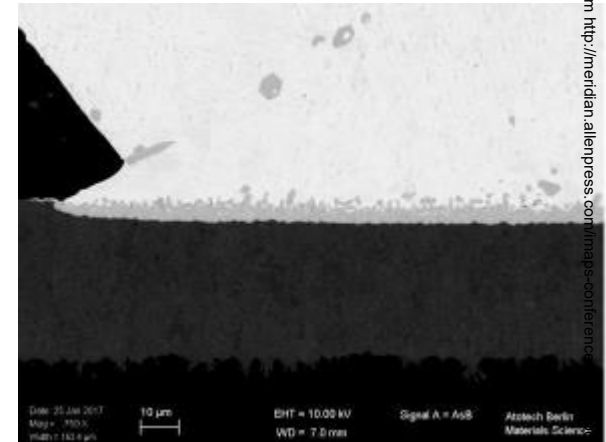
OSP



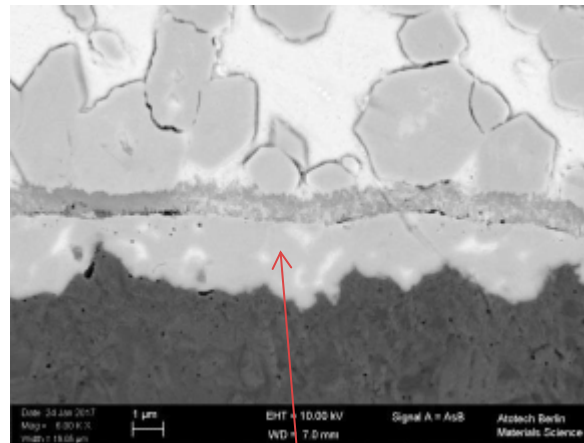
ENEPIG (thin Ni)



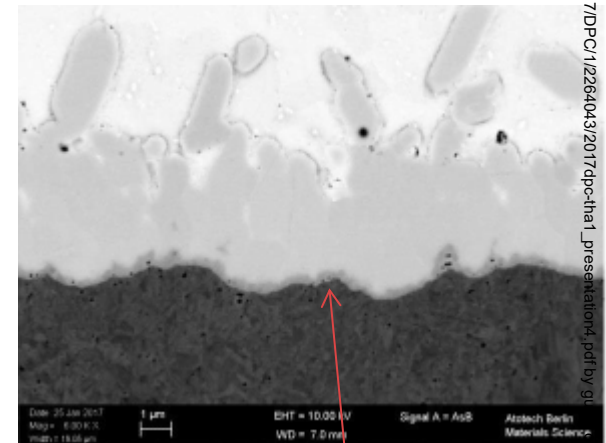
EPAG



Cu rich IMC



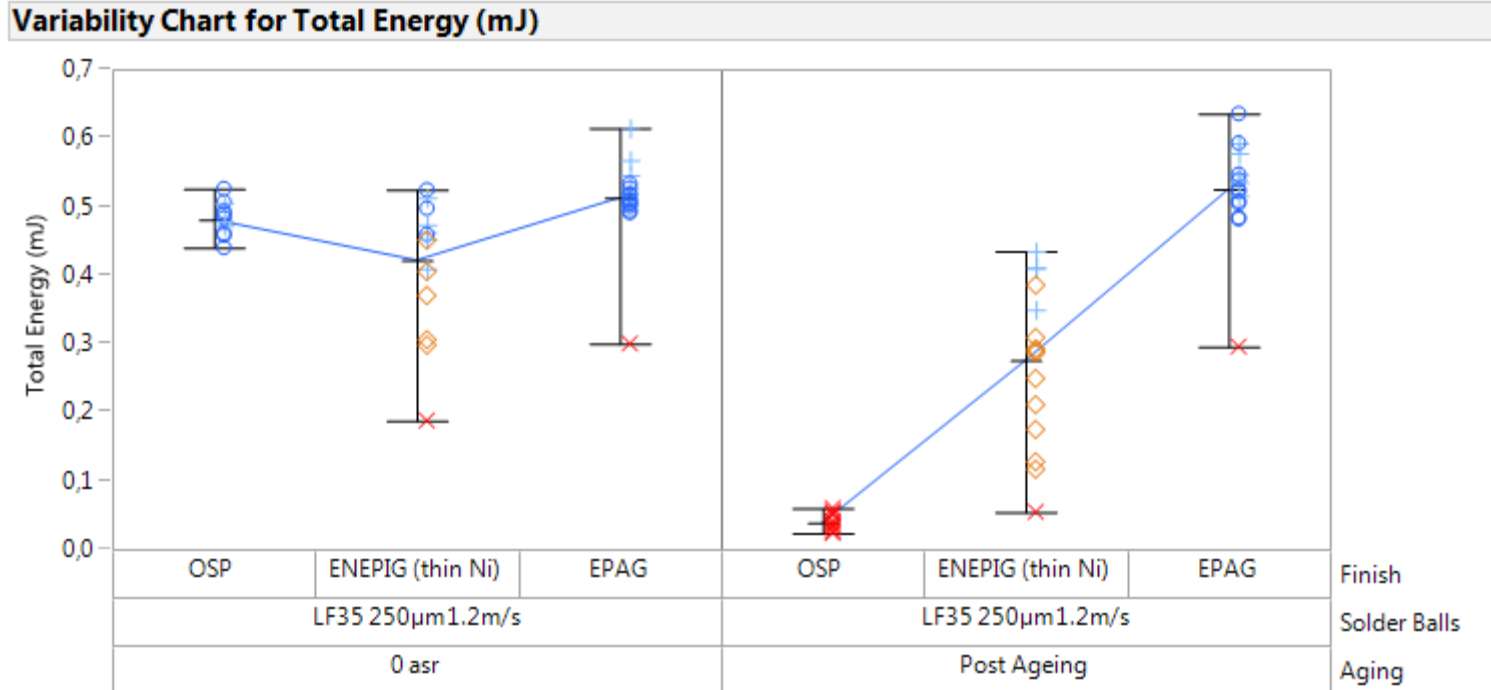
P Enrichment



Cu rich IMC

IMC evaluation

Final finishes selection at 250 μ m

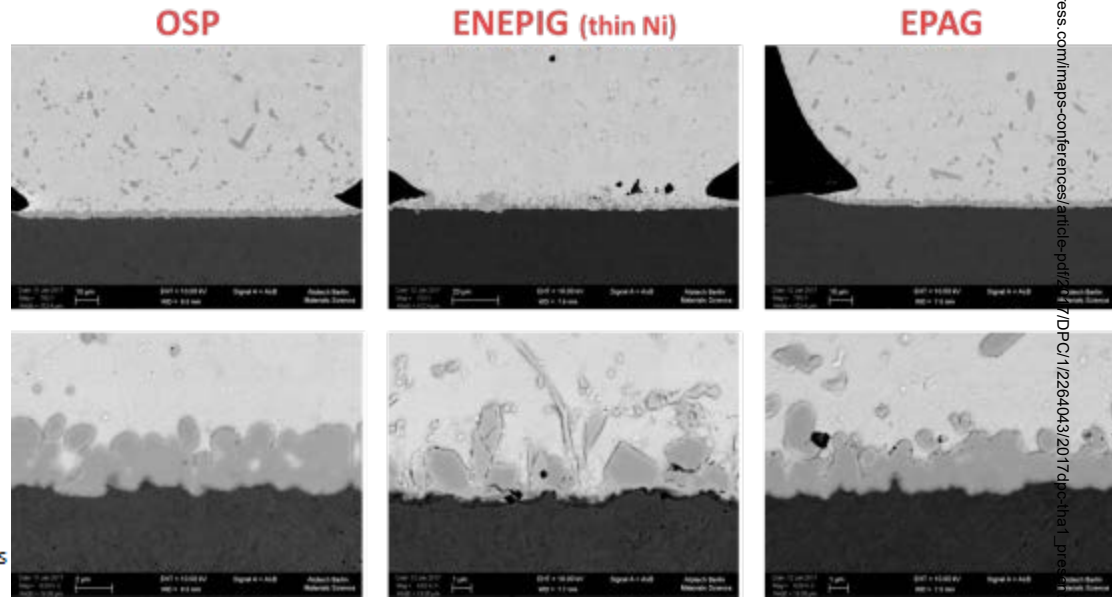
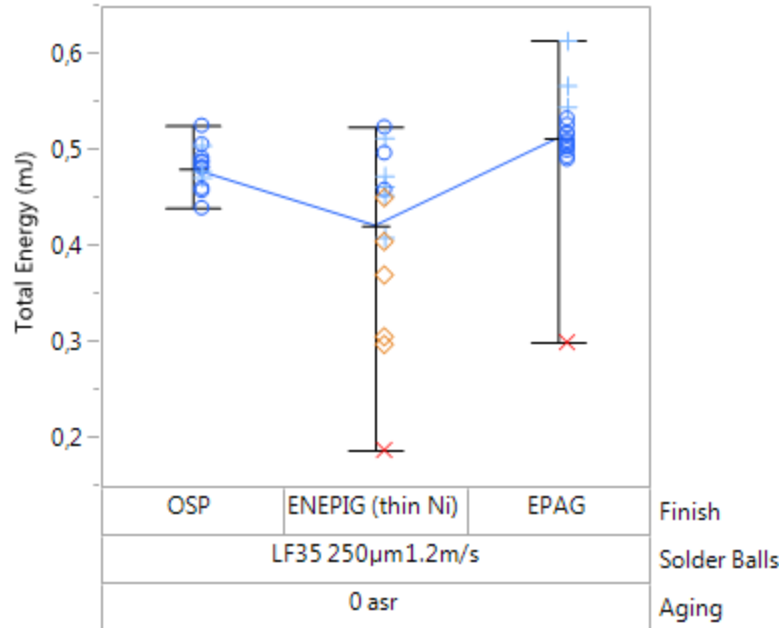


Market significant final finishes under stringent conditions

IMC evaluation

LF 35, 250 μ m, ASR

Variability Chart for Total Energy (mJ)

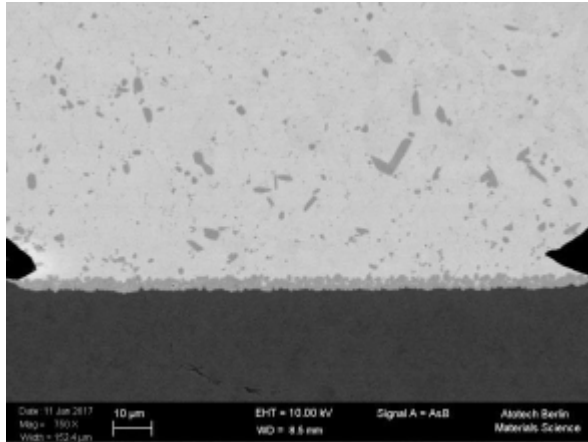


ENEPIG with some brittle fractures

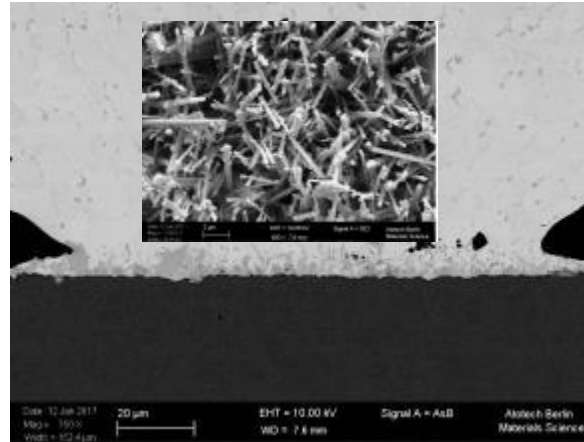
IMC evaluation

LF 35, 250 μ m, ASR

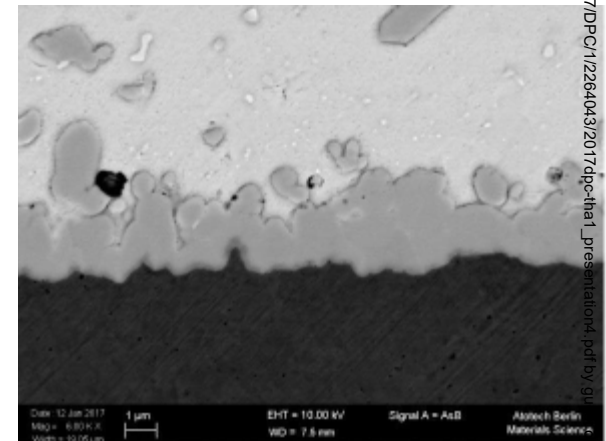
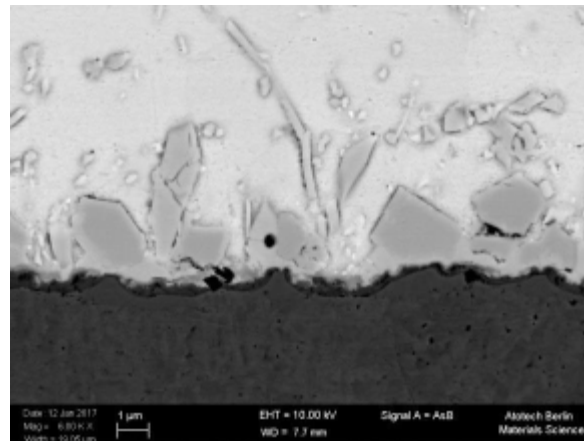
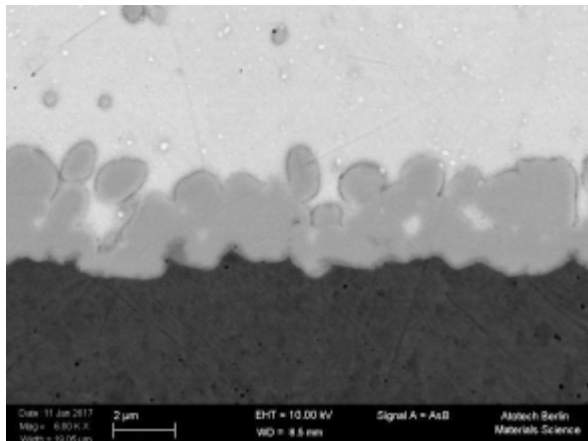
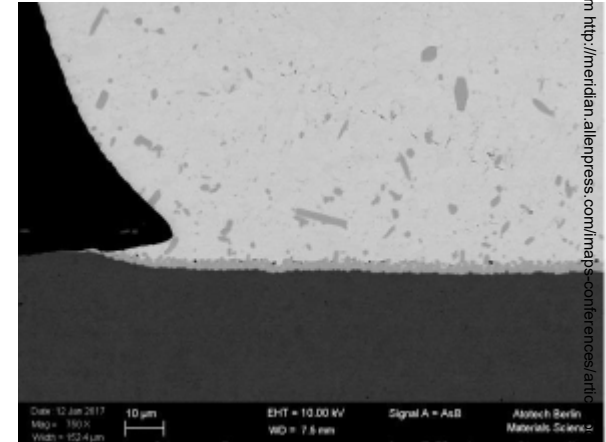
OSP



ENEPIG (thin Ni)



EPAG



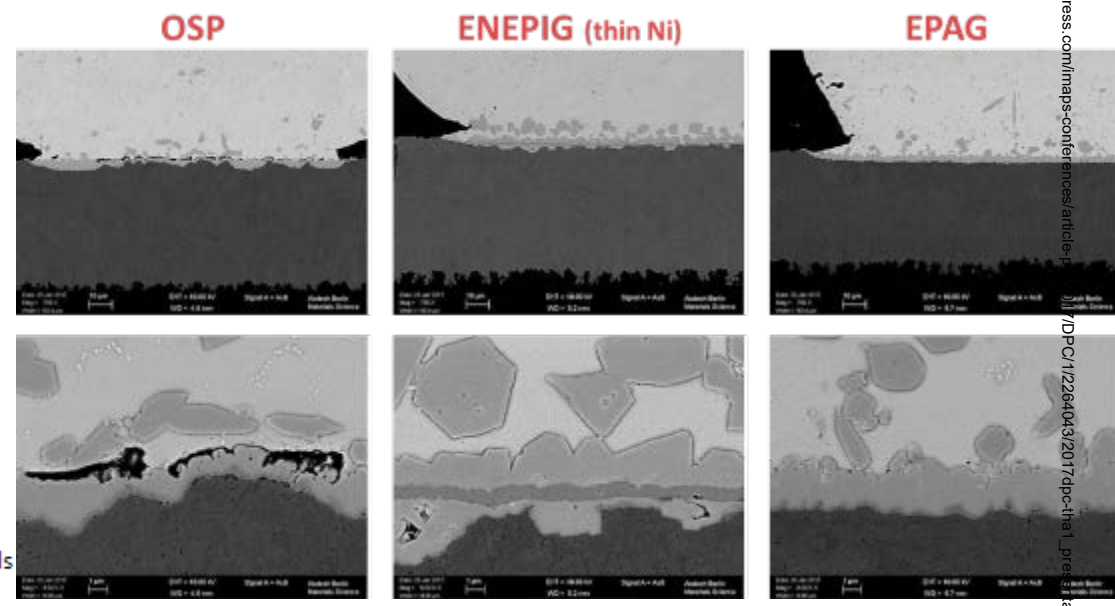
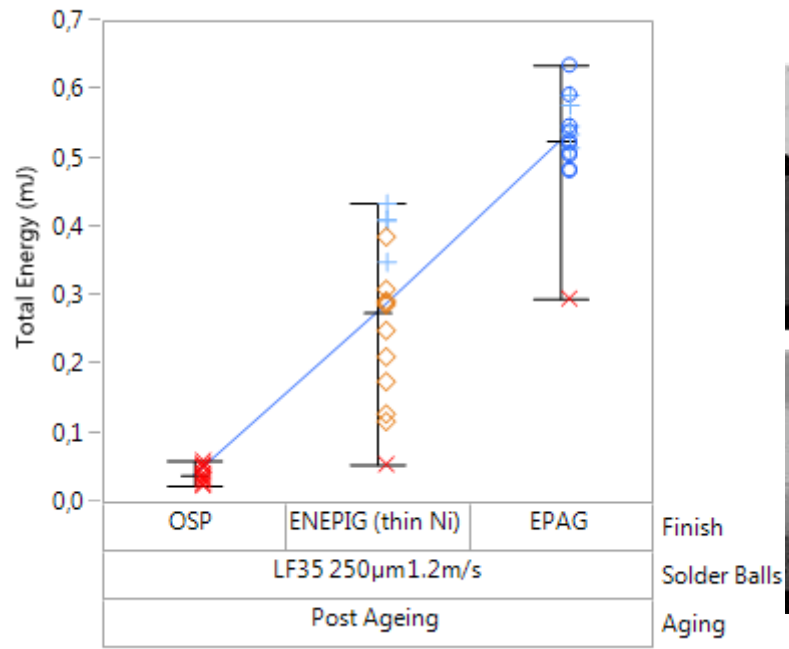
ENEPIG needle like but poorly developed IMC

IMC evaluation

LF 35, 250 μ m, Aged

Downloaded from http://imr.tandfonline.com/ on 25 March 2015

Variability Chart for Total Energy (mJ)

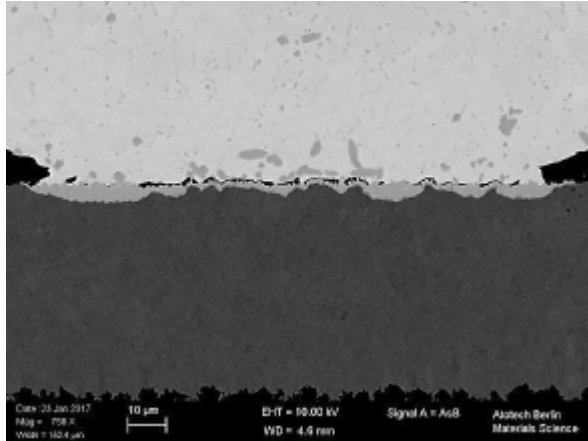


Most severe conditions – reflow conditions?

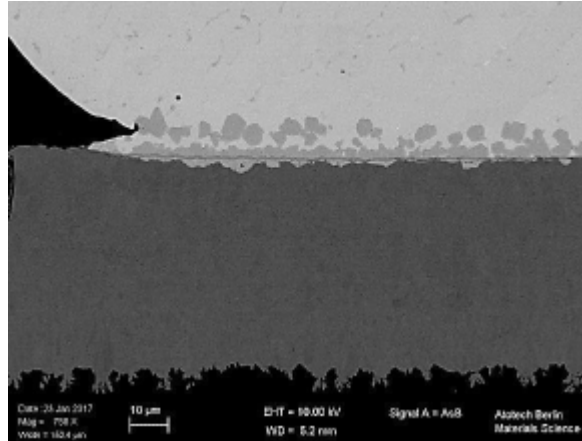
IMC evaluation

LF 35, 250 μ m, Aged

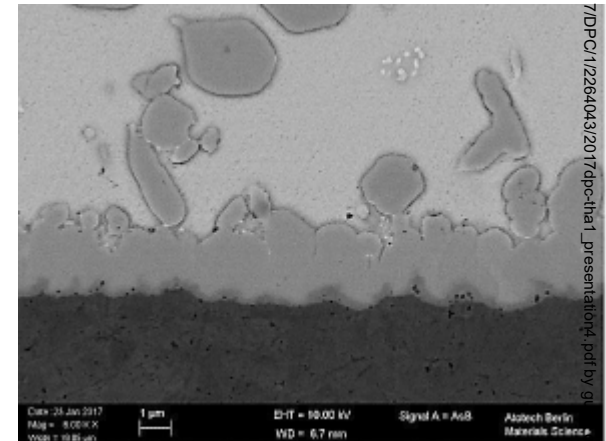
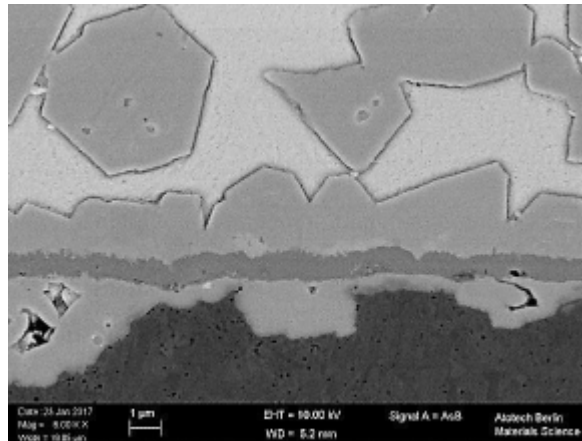
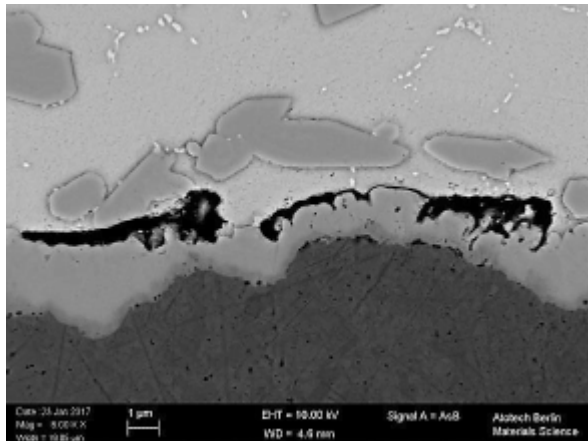
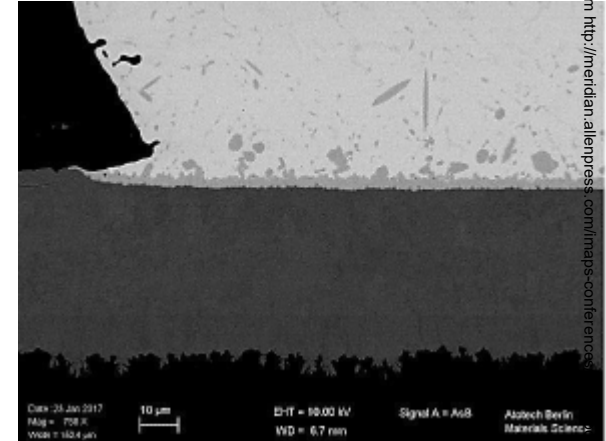
OSP



ENEPIG (thin Ni)



EPAG



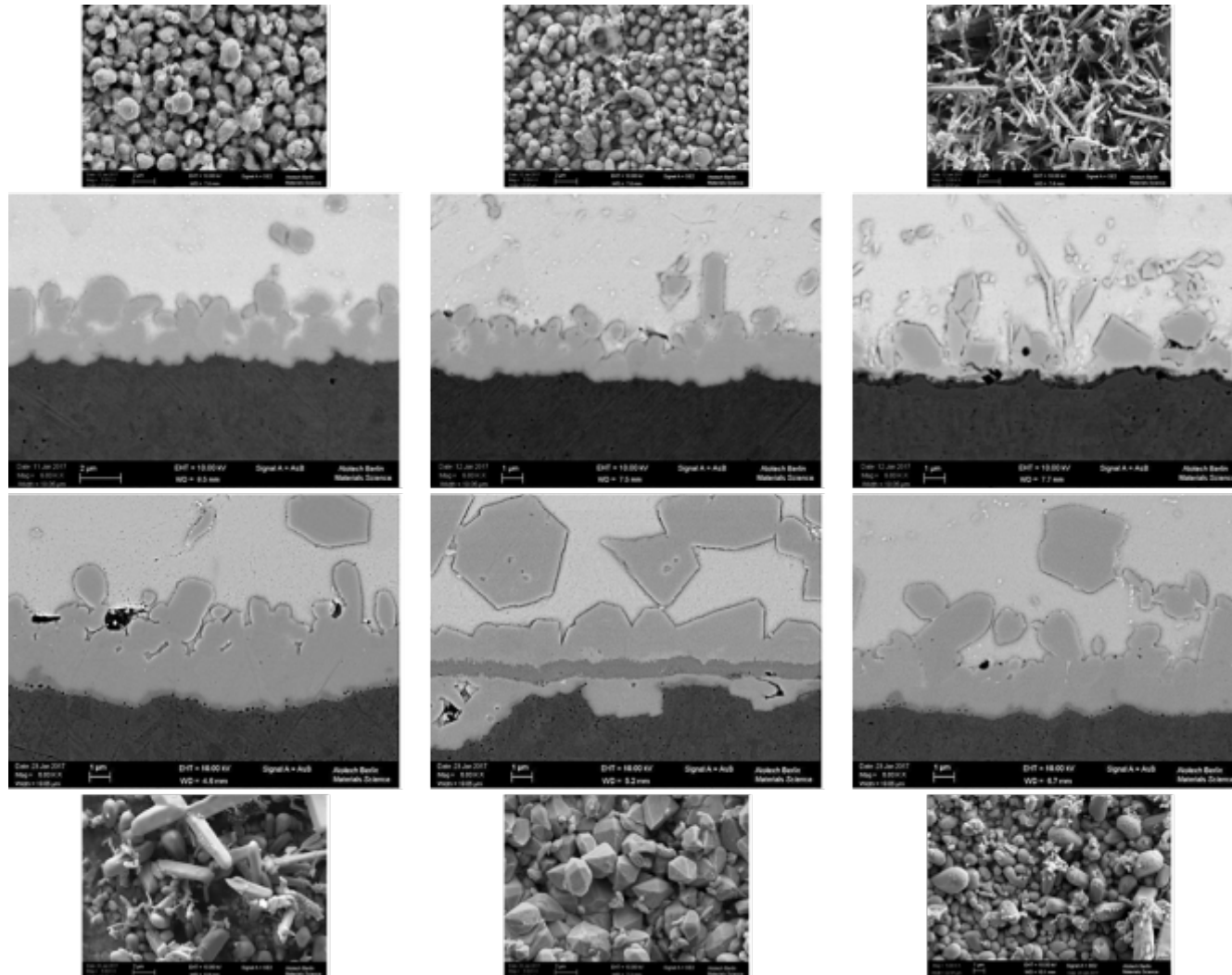
Failures clear

IMC Evaluation

Evaluation comparisons

IMC Evaluation

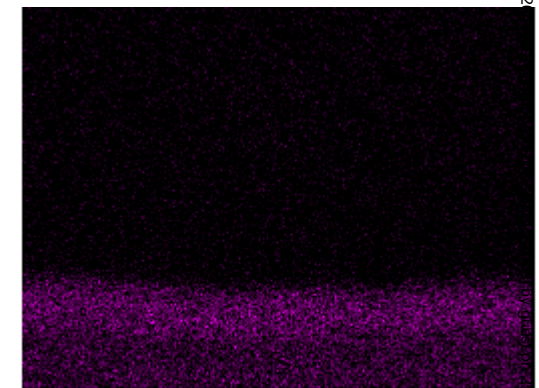
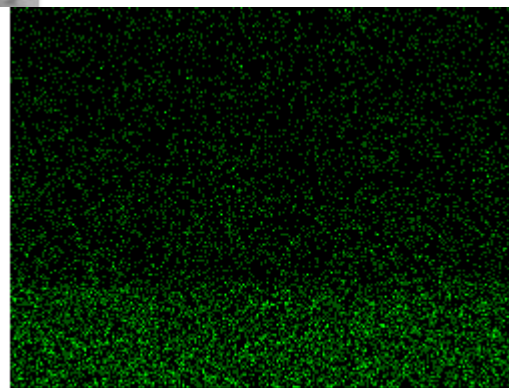
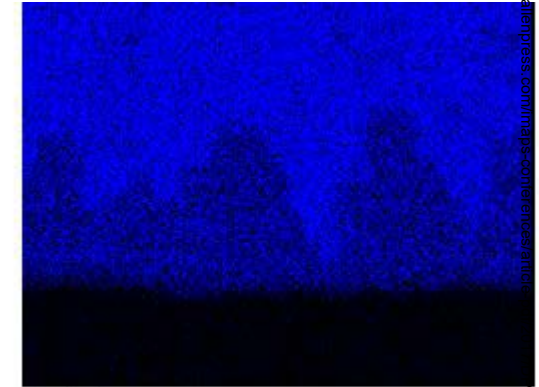
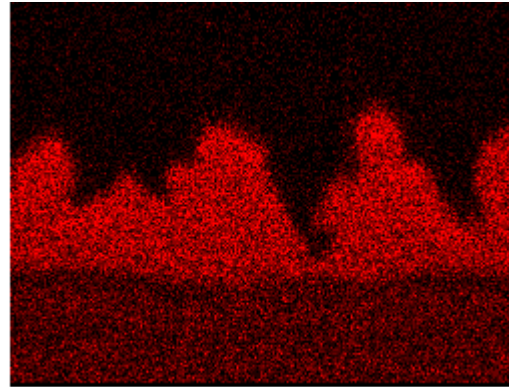
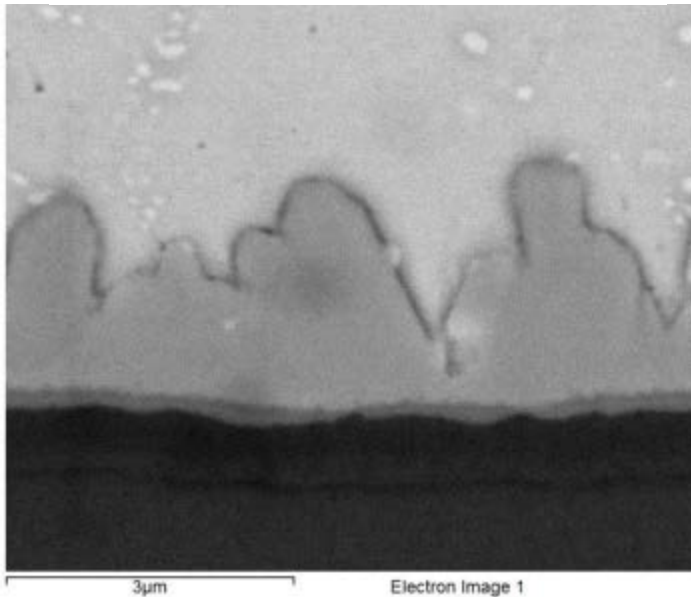
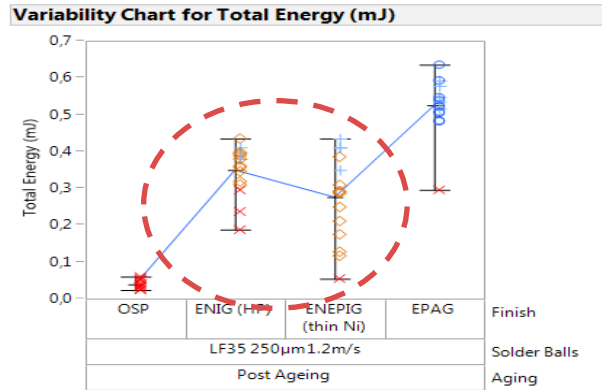
Cross sectional IMC evaluation vs surface topography (LF35 250 IMC)



The evaluation methods are mutually supportive

IMC Evaluation

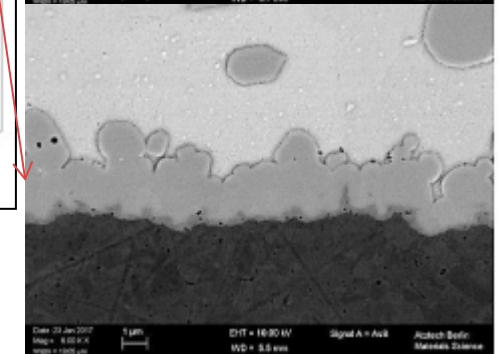
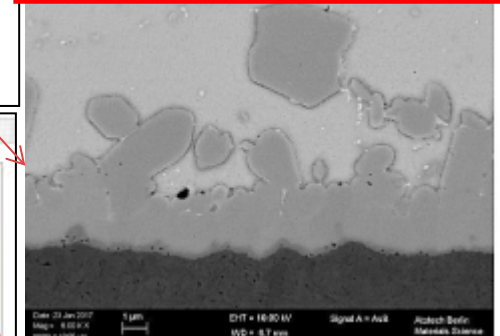
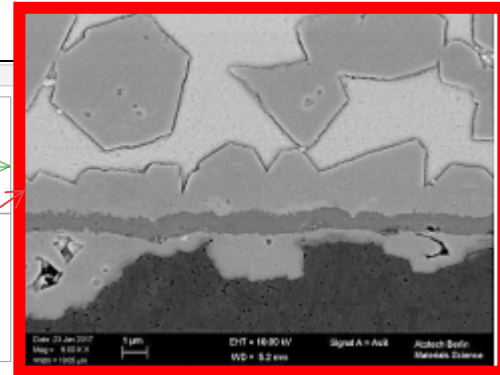
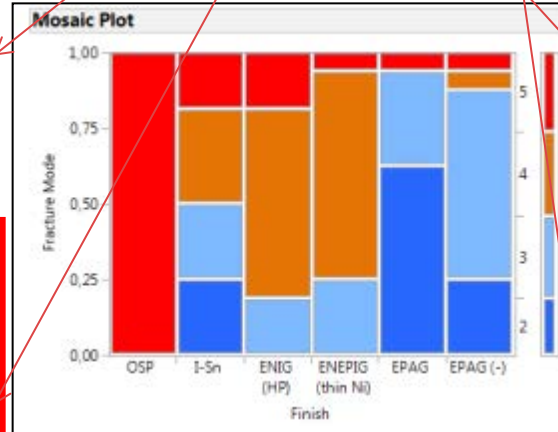
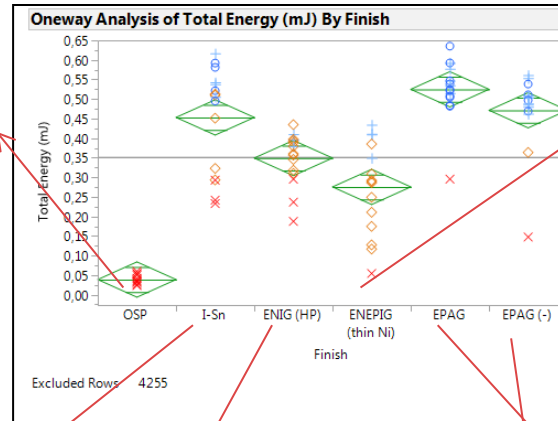
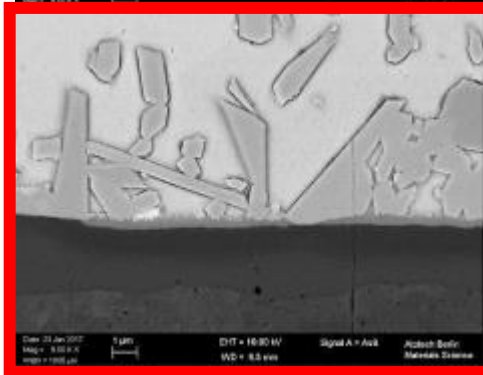
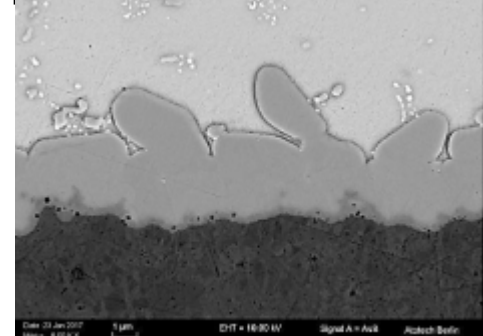
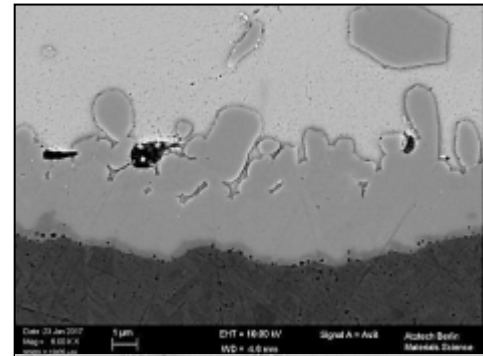
Elemental analysis - Nickel finishes vs P enrichment



Phosphor rich layer present

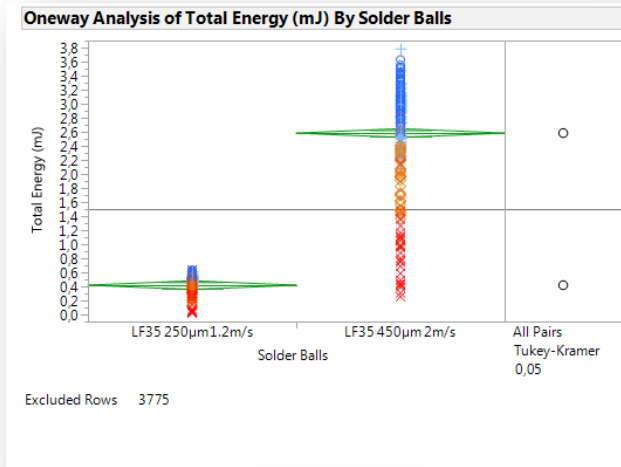
IMC evaluation

Test result overview (LF 35, 250µm – Aged)

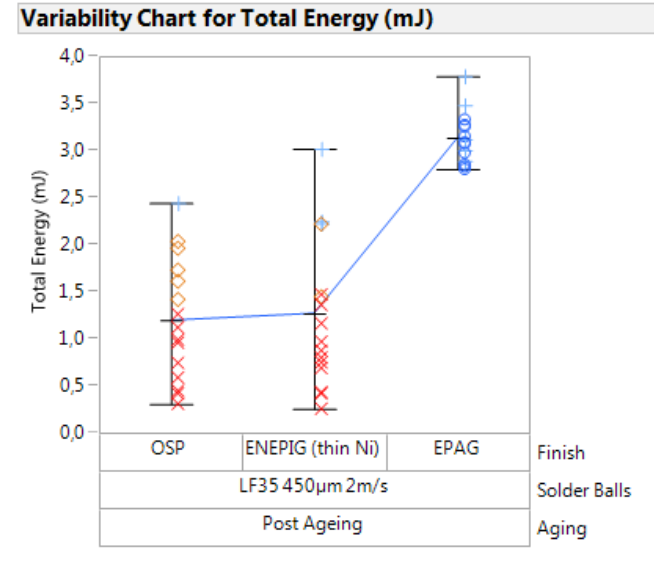
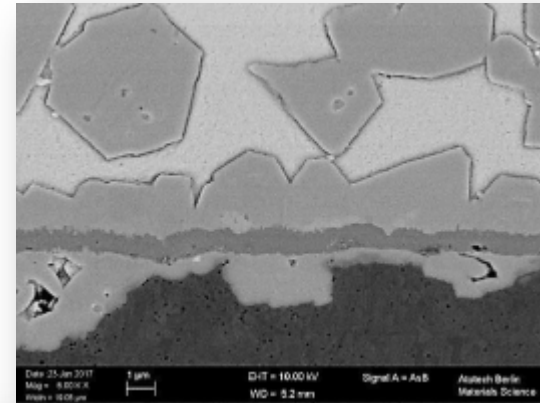
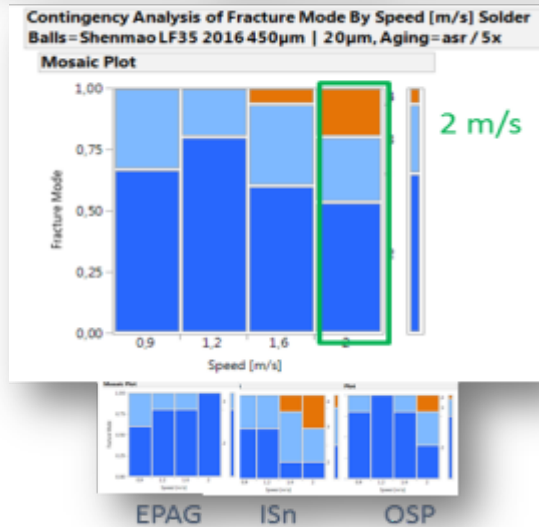


IMC Summary

Key Observations



AGED LF 35



IMC structure is correlated to SJR

Thank you

for your attention!

Contact

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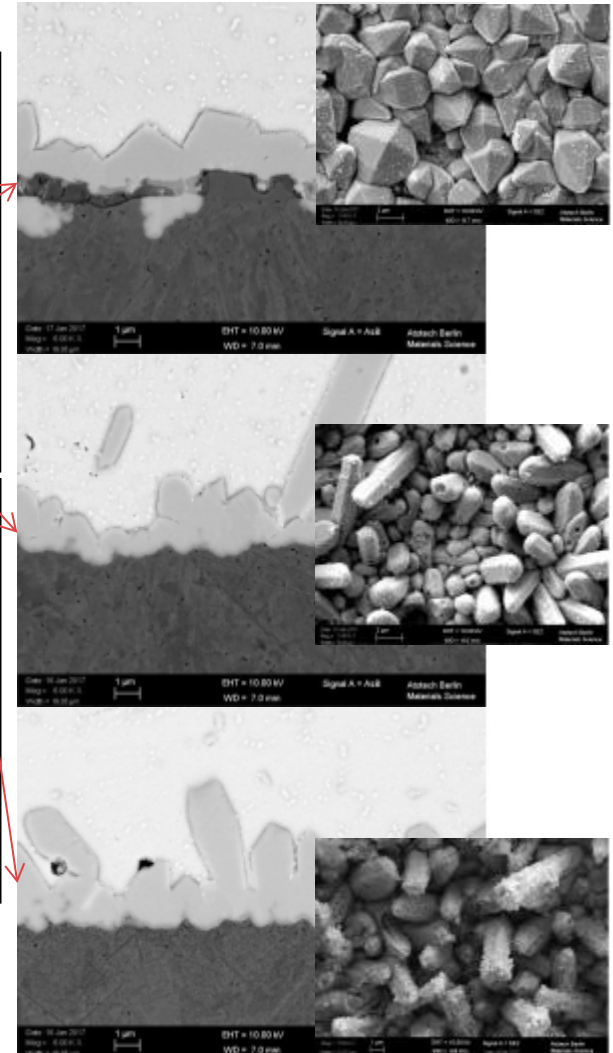
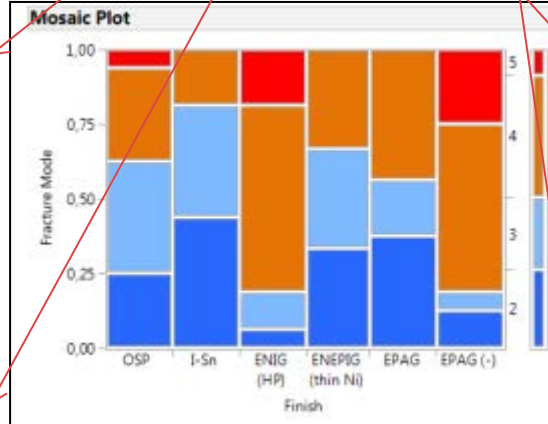
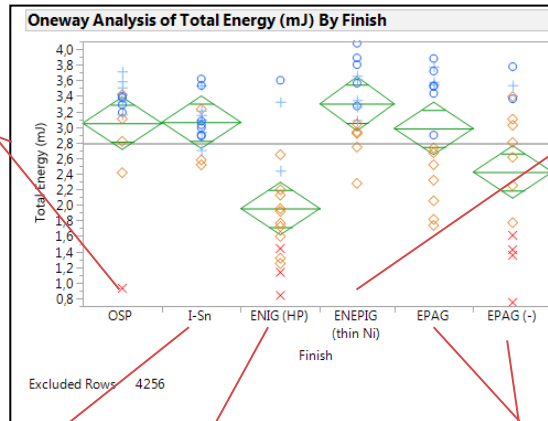
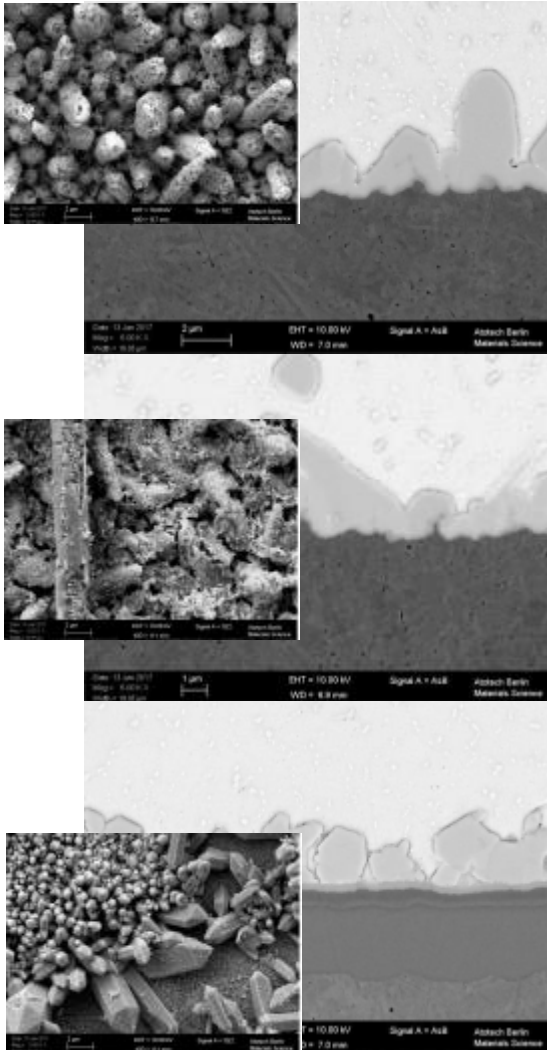
Technology for tomorrow's solutions

Appendix

All finish overview

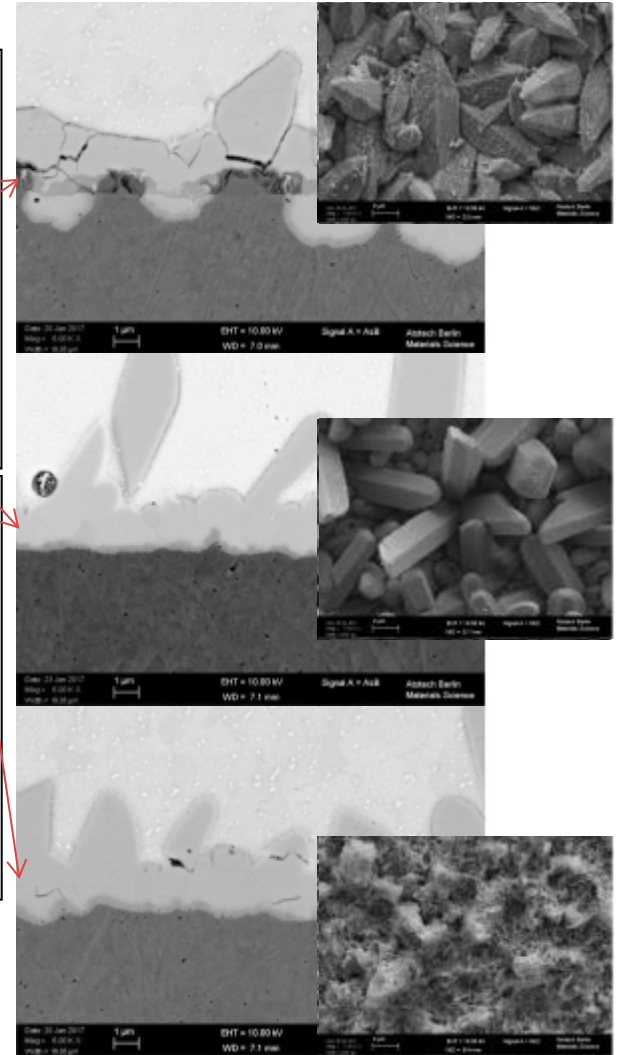
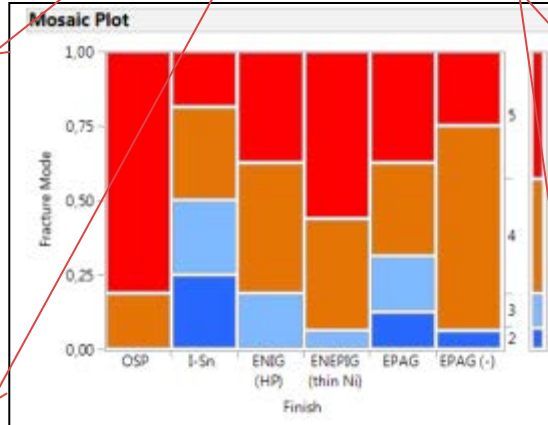
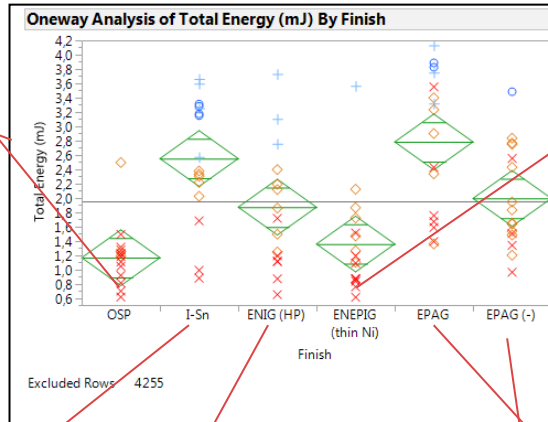
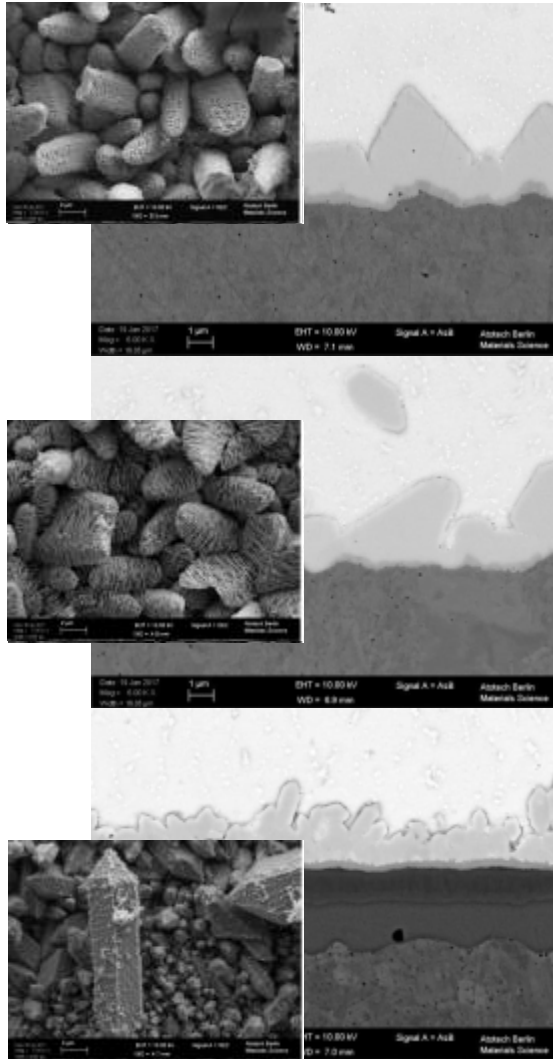
IMC evaluation

SEM – SAC 305 (450) asr



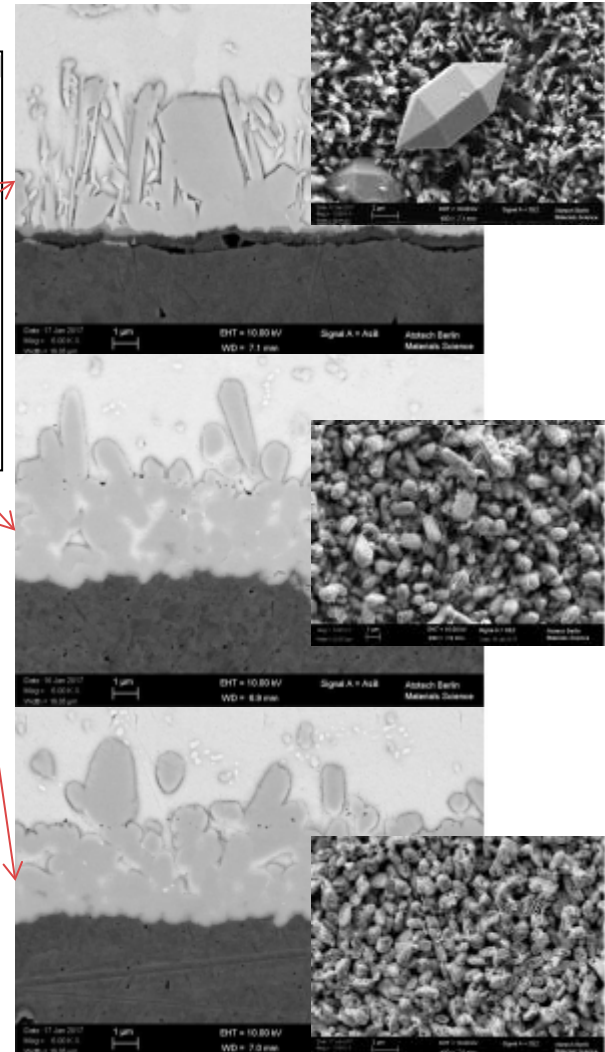
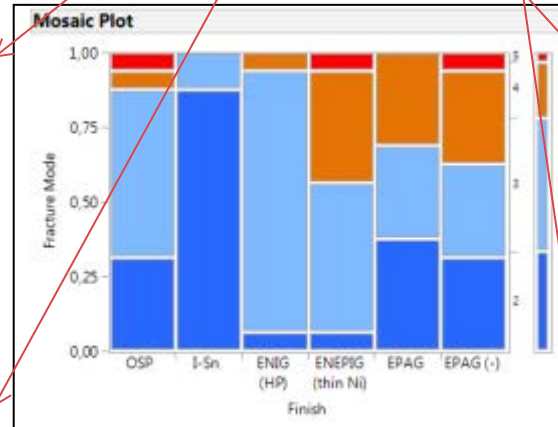
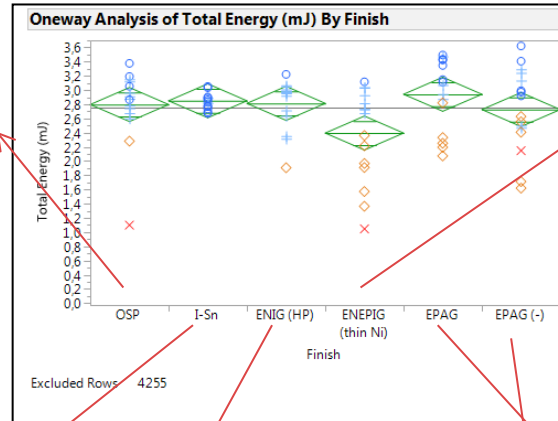
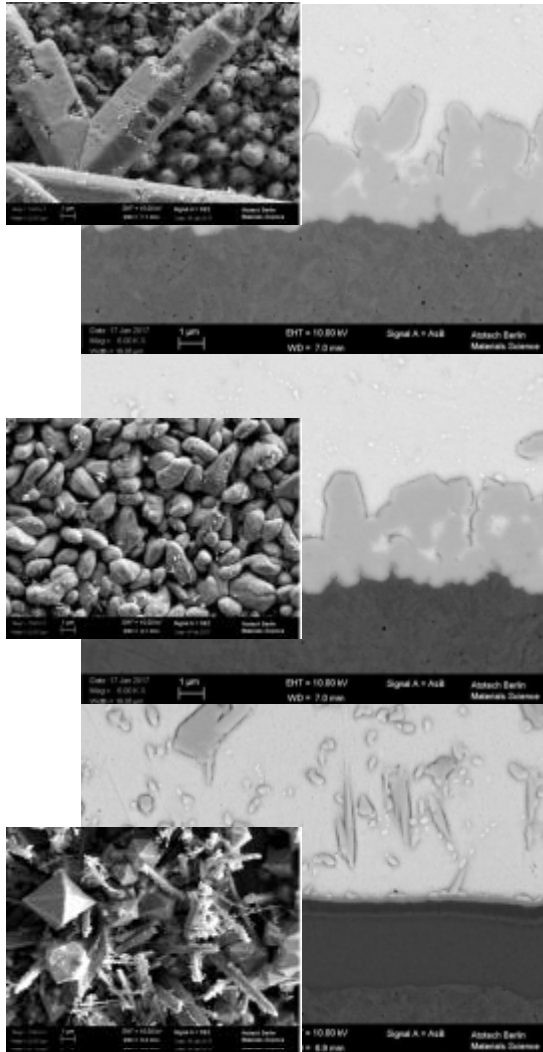
EXPT Pallabond IMC evaluation

SEM – SAC 305 (450) - aged



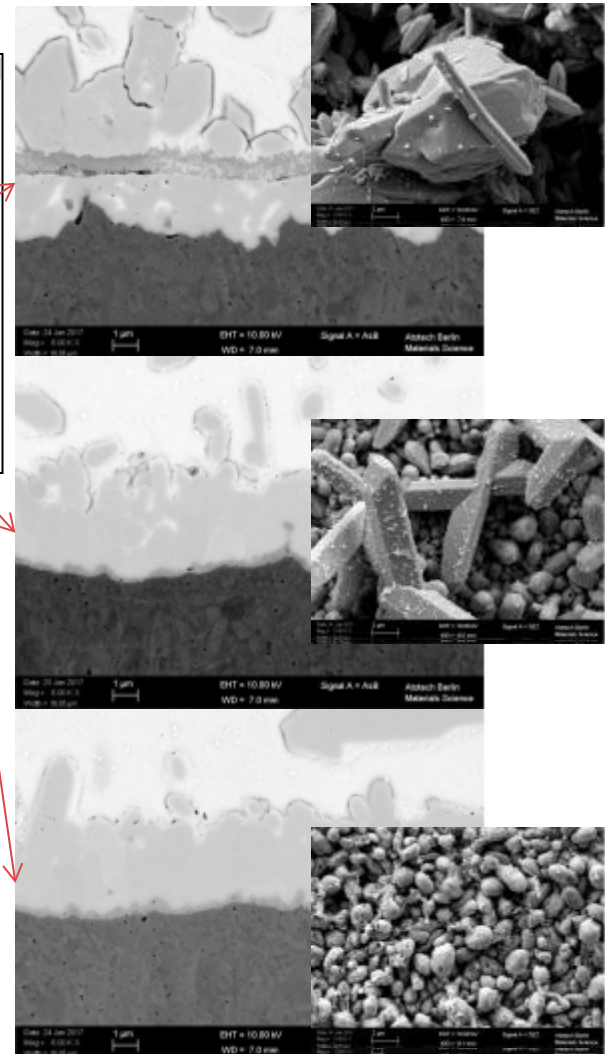
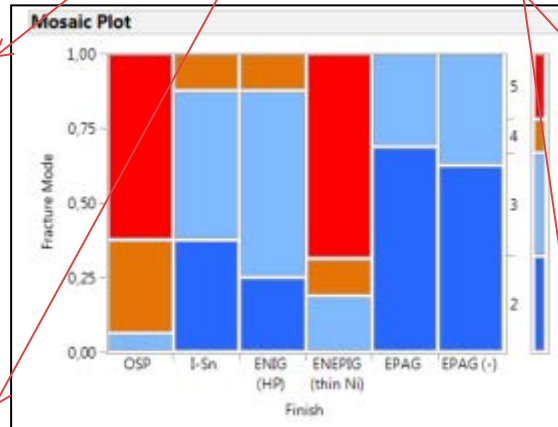
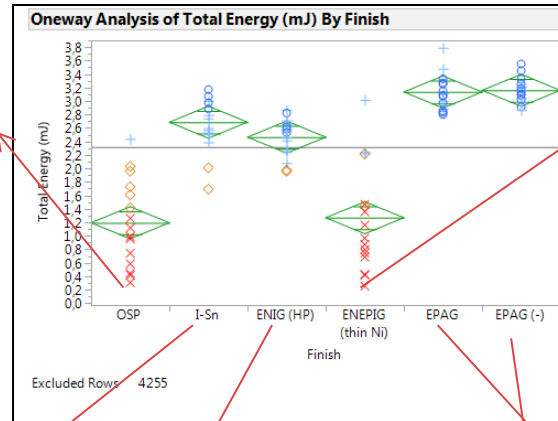
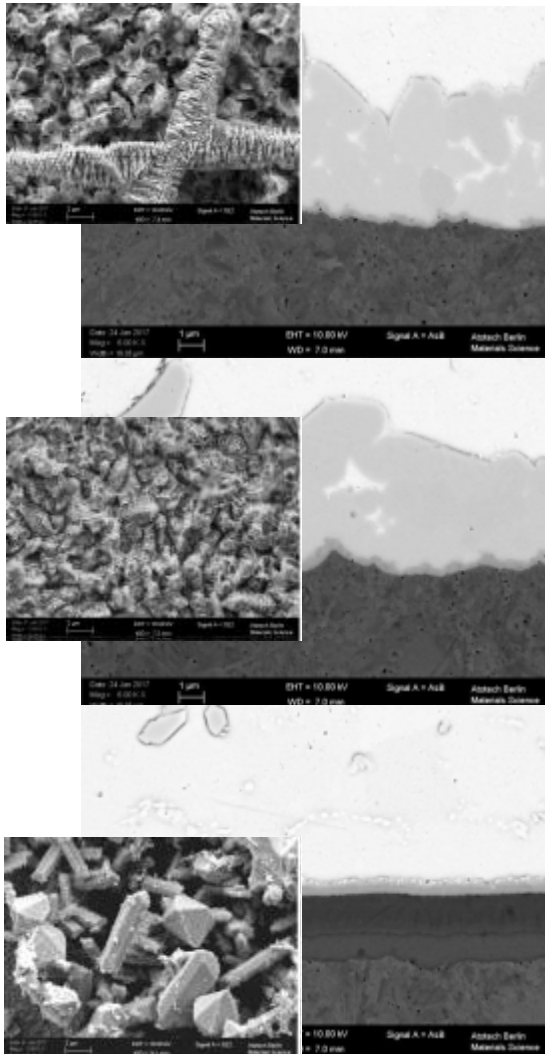
EXPT Pallabond IMC evaluation

SEM -LF 35 (450) - asr



EXPT Pallabond IMC evaluation

SEM -LF 35 (450) - aged



EXPT Pallabond IMC evaluation

SEM -LF 35 (250) - asr

