Supporting Information

New Opportunities in Metallization Integration in Co-fired Electroceramic Multilayers by the Cold Sintering Process

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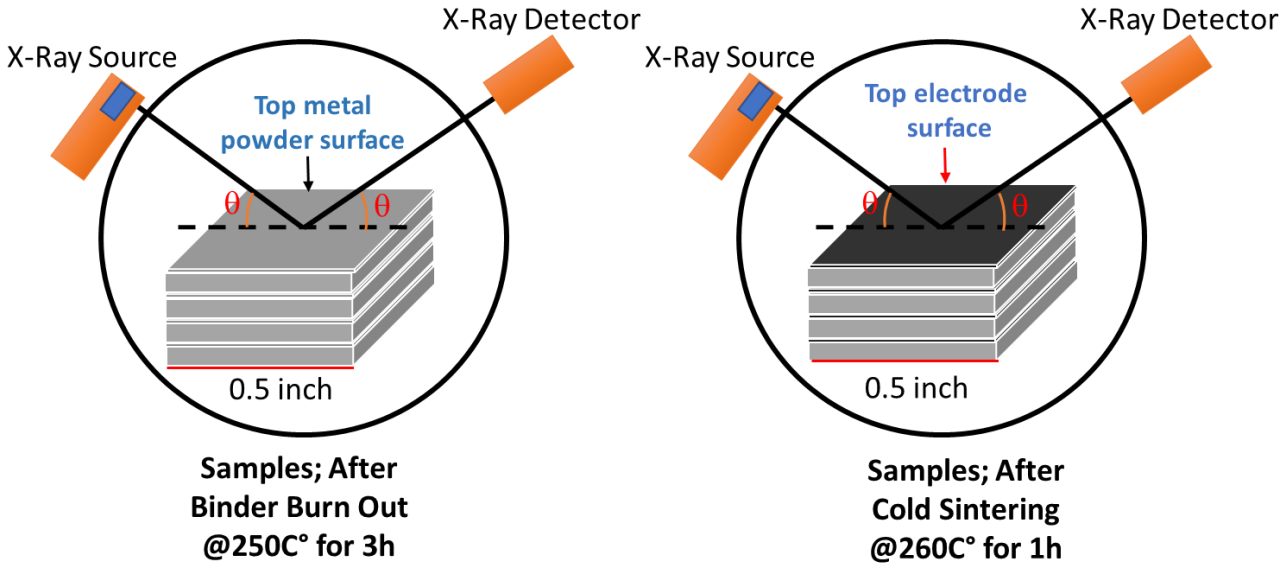

Figure S1. Schematic representation of XRD on the multilayer samples.

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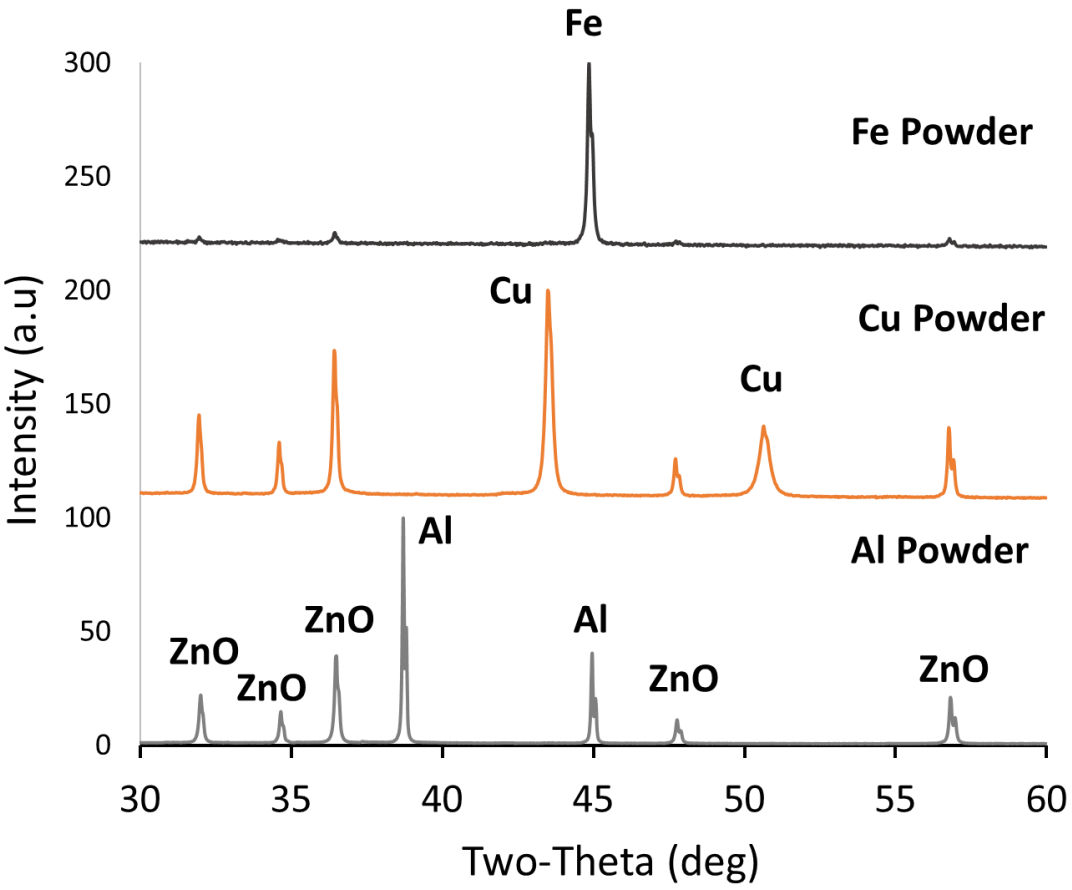

Figure S2. XRD data of the multilayer device with Al, Cu, Fe powders were carried out after BBO at 275 for 3h for the 2θ for 30°-60° angle range.

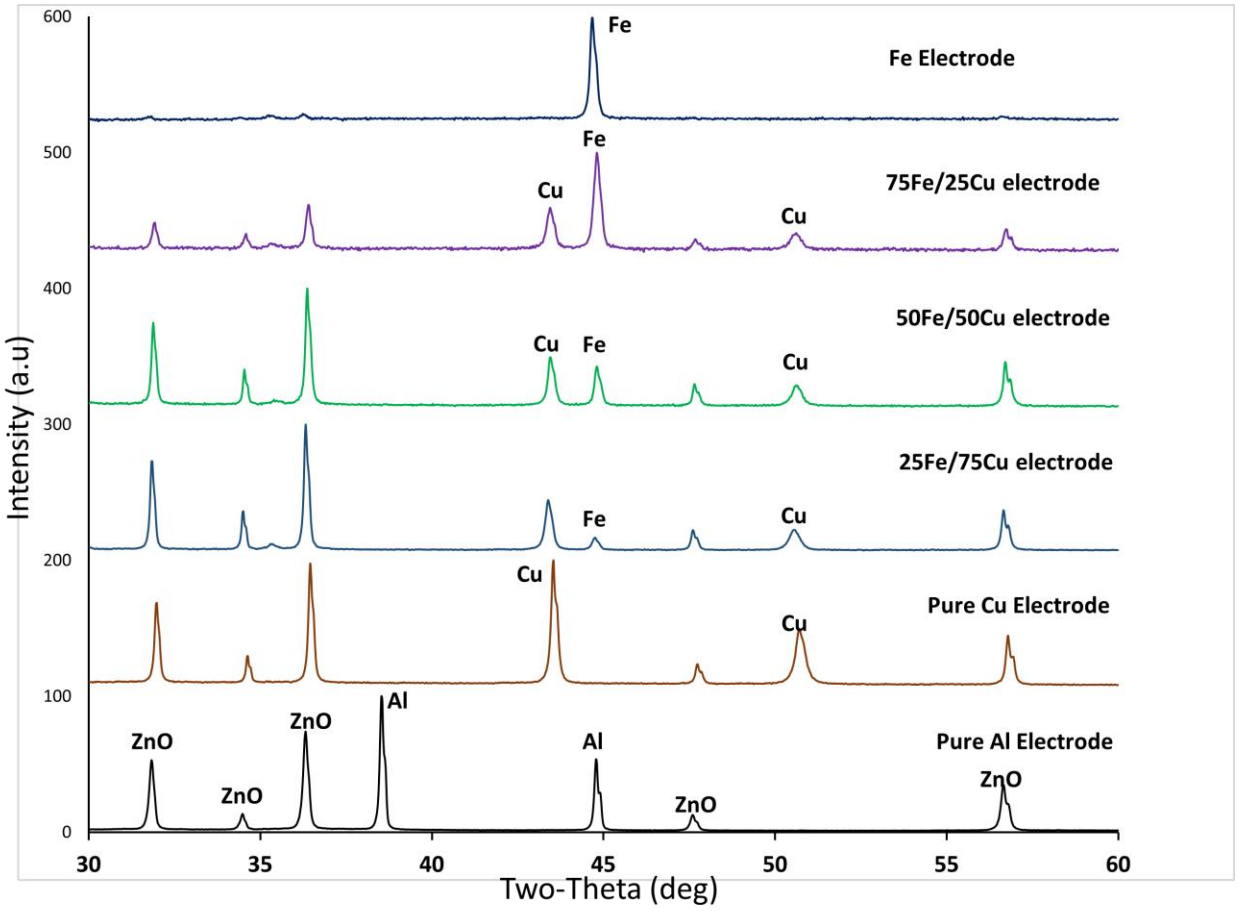

Figure S3. XRD data of the multilayer device the Al, Cu, Fe electrode metals were carried out after cold sintering at 260 for 3h for the 2θ for 30°-60° angle range.

Table S1. Activity series of metals and their oxidation reaction and energy data (Kilocalories per gram equivalent weight at 25°C)[1]

Metal	Oxidation reaction	Normal electrode Potential	Sublimation energy	Ionization energy	Hydration energy	Total (net) energy
Li	$Li \rightarrow Li^{+} + e^{-}$	3.02	37.1	125.8	-229.4	-66.6
K	$K \rightarrow K^{+} + e^{-}$	2.92	21.5	101.6	-183.1	-60.0
Ba	$Ba \rightarrow Ba^{2+} + 2e^{-}$	2.90	21.0	176.9	-262.2	-64.3
Ca	$Ca \rightarrow Ca^{2+} + 2e^{-}$	2.87	23.0	208.8	-296.1	-64.9
Na	Na$\rightarrow Na^{+} + e^{-}$	2.71	26.0	120.0	-203.3	-57.3
Mg	$Mg \rightarrow Mg^{2+} + 2e^{-}$	2.34	18.0	262.9	-336.1	-55.2
Al	$Al \rightarrow Al^{3+} + 3e^{-}$	1.67	25.0	410.8	-477.6	-41.8
Zn	$Zn \rightarrow Zn^{2+} + 2e^{-}$	0.76	15.6	316.9	-350.7	-18.2
Fe	$Fe\rightarrow Fe^{2+} + 2e^{-}$	0.44	48.3	276.7	-335.5	-10.5
Cd	$Cd \rightarrow Cd^{2+} + 2e^{-}$	0.40	13.5	300.1	-322.3	-8.7
Co	$Co \rightarrow Co^{2+} + 2e^{-}$	0.28	52.5	291.4	-351.9	-8.0
Ni	$Ni \rightarrow Ni^{2+} + 2e^{-}$	0.25	50.8	299.6	-358.1	-7.7
Pb	$Pb \rightarrow Pb^{2+} + 2e^{-}$	0.13	23.2	260.2	-283.2	0.2
Cu	$Cu \rightarrow Cu^{2+} + 2e^{-}$	-0.34	40.8	324.2	-357.3	7.7
Ag	$Ag \rightarrow Ag^{+} + e^{-}$	-0.80	69.1	176.2	-220.0	25.3

Table S2. Heat of Oxidation for Potential Electrode Chemistries[2]

Electrode Material	Heat of Oxidation (-kJ/mol)
Al	1626
Fe	823
Ni	240
Cu	162
Pd	116
Ag	31
W	843
Pt	-169
Au	-3

Table S3. Comparison of the ESR of different metal type reported for deposition and/or traditional thick film.

Electrode Type	**Method**	**Metal Layer Thickness** (μm)	**Firing Temperature (°C)**	**ESR** $(m\Omega/\square)$	**Ref.**
Cu	Deposition	0.16	-	179	3

Al	Deposition	0.21	-	$2.4x10^3$	4
Ag/Pd	Printed and Fired	-	900	5	5
Cu	Printed and Fired	25	925-950	<3.0	6
Ag/Pd/Pt	Printed and Fired	15-17	850	32-42	7
Silver	Printed and Fired	12	850	1.5-2.5	8
Cu	Printed and Cold Sintered	5-6.5	260	6.50	In this Work
Fe	Printed and Cold Sintered	4-5.5	260	114	In this Work
Al	Printed and Cold Sintered	4-5.5	260	$2.3x10^4$	In this Work

References

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