Clad Metals for Use as Connectors for Lithium Ion Batteries

Michael Haynes, Michael Hardy, Engineered Materials Solutions
Ben Schweitzer, AllCell Technologies

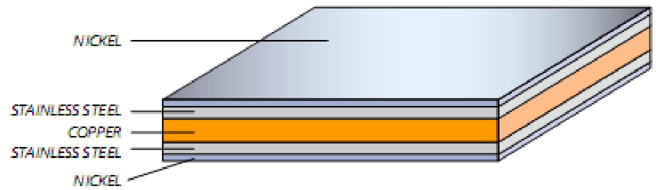
Problem Statement

Nickel is commonly used as connectors for Lithium Ion Batteries, due to an adequate combination of conductivity, solderability, strength, formability, weldability, and corrosion resistance. But as the number of individual 18650 cells in a pack increase, one issue with nickel is heat generation (particularly at the busbar) which reduces efficiency of cells and poses a risk of overheating.

The limited thermal and electrical conductivity of Nickel results in some unfavorable consequences. First, high amperages contribute to Joule heating at the busbar, and to temperature rises in the cell that are damaging to the performance and life of the battery. Second, higher impedance in the connector material leads to more IR drop, and consequently significantly less voltage in the cell. Third, hot spots can develop due to insufficient thermal conductivity and inferior heat spreading. Clad metal connectors offer electrical and thermal conductivity advantages to address these concerns, and they are characterized below.

Materials and Procedures

Clad connector material is a metallic laminate composite which includes 5 layers: 1) a central copper layer, variable in thickness, to design the desired electrical and thermal conductivity; 2) two layers of Austenitic stainless steel, sandwiching the central copper layer, to enable resistance welding with good to excellent pull strengths; and 3) thin nickel layers on the outside surfaces for surface corrosion resistance and solderability. This system is designated as SIGMA_{CLAD}-XX, where XX represents the nominal electrical conductivity in %IACS. SIGMA_{CLAD} materials were characterized and compared to pure nickels such as N02201 and N02270 (899M and 899A). Select copper alloys {C7035-TM06, C50710-H02, and Sn-Plated C19025 (NB109)} were also evaluated.



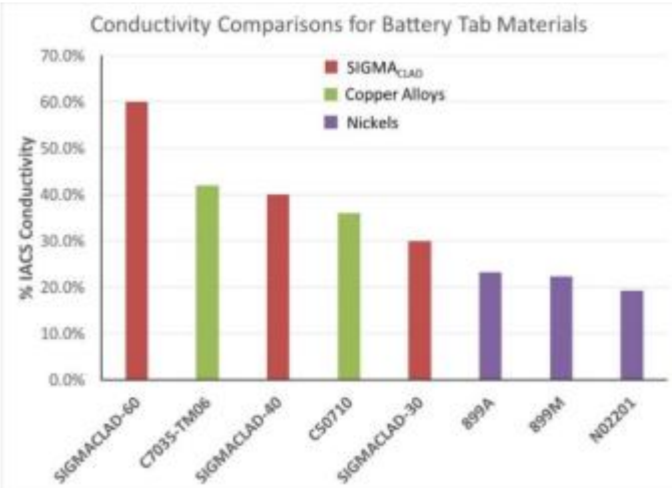
Layer Configuration of SIGMA_{CLAD}

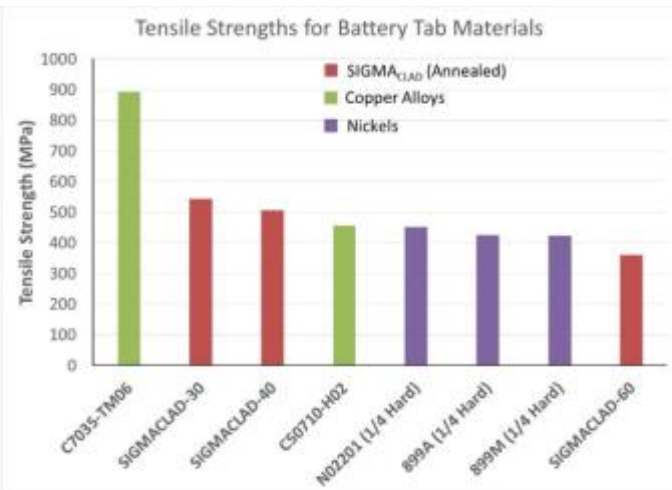
Characterization included measurements on the electrical conductivity, tensile properties, and formability. These measurements followed ASTM standards. Further characterization consisted of atmospheric corrosion testing, solderability testing, and welding trials. The corrosion testing was exposure to a corrosive dip in ASTM 2570 water, followed by 16 hours exposure in a condensing humidity chamber (100% RH, 37.7ºC), and 8 hours of drying. ASTM D2570 water is composed of 148 mg Sodium Sulfate, 165 mg Sodium Chloride, and 138 mg Sodium Bicarbonate; dissolved in 1 liter of distilled or deionized water. Sixty cycles of testing were completed. Welding simulations were performed on selected clad material systems at Amada Miyachi, using a 300ADP (advanced dual pulse) power supply. Welding techniques included the introduction of anti-shunting slots and/or weld projections to the clad strip, as well as the use of a step-welding process when required.

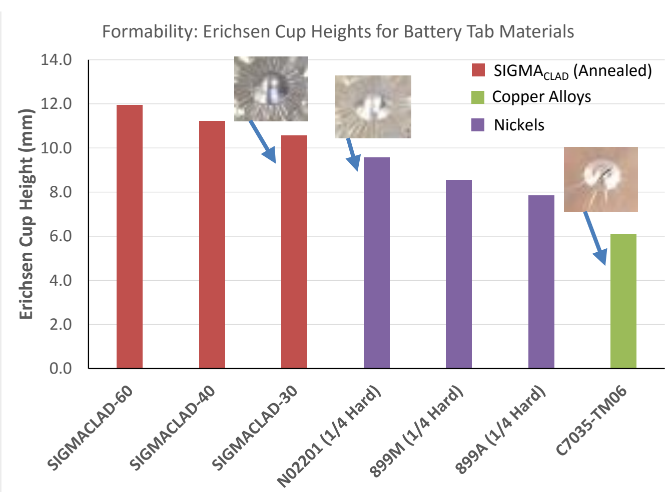
Conductivity and Mechanical Property Results

Electrical conductivity can be designed to desired conductivities, ranging from 1.3 to 3.1 fold of the conductivity of commonly available N02201 strip (~19.3% IACS). Clad conductivity compares very favorably with nickel, and is equivalent or superior to the copper alloys, depending on the variant utilized.

The combination of strength and elongation is also favorable for the clad materials. Both tensile strength and the Erichsen cup height measurement of formability exceed ¼ hard nickel strip for the SIGMA_{CLAD}-30 and SIGMA_{CLAD}-40 variants. Due to a higher copper content, the SIGMA_{CLAD}-60 in the annealed condition has a lower strength than quarter-hard nickel. However, its ductility is higher, and it can provide equivalent properties with an added small amount of cold work.

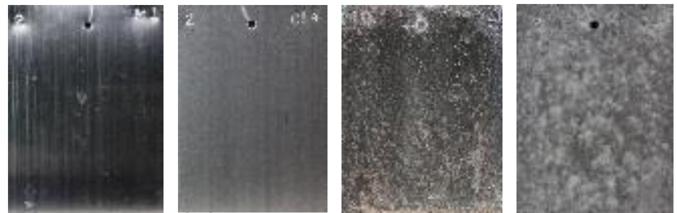






Corrosion Resistance

Clad materials displayed excellent corrosion resistance, similar to that of nickel strip, after 60 cycles of the corrosive dip test. Conversely, the copper alloys showed severe corrosion, which could lead to reliability issues in service for humid environments.



N02201 *SIGMA$_{CLAD}$-60* *C7035-TM06* *Sn-Plate C19025*

Welding

The clad connector material welds readily through the use of anti-shunt slots, weld projections, and/or a step welding process, as shown in table below. Excellent pull strengths are observed for multiple conductivity levels and strip thicknesses.

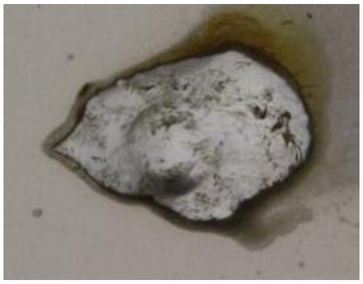
Material & Thickness	Electrode Config.	Anti-Shunt Slots? / Projections?	Ws	Pull strength (Kgs) Cathode/Anode
SIGMA$_{CLAD}$-40 0.127 mm	parallel	Yes/No	65	5.4/6.4
SIGMA$_{CLAD}$-40 0.250 mm	parallel	Yes/Yes	150	23/28
SIGMA$_{CLAD}$-40 0.400 mm	parallel	Yes/Yes	250	30/20
SIGMA$_{CLAD}$-60 0.381 mm	parallel	Yes/Yes	275	23/31
SIGMA$_{CLAD}$-60 0.508 mm	parallel	Yes/Yes	500	48/35
SIGMA$_{CLAD}$-60 0.508 mm	step	No/Yes	150	38/38

Anti-shunt slot with projections

Step welding w/projections

Solderability

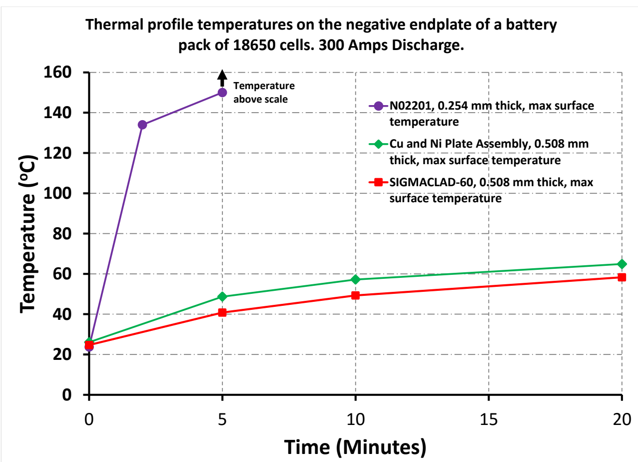
Good solderability is observed for all $SIGMA_{CLAD}$ variants using a Sn/Cu solder with a rosin core.



Soldering test showing good surface wetting

Thermal Profiles in Service

$SIGMA_{CLAD}$-60 material at 0.508 mm thickness was utilized as current collector endplates in a cell brick of 18650 cells and was characterized thermally under a 300 Amp discharge current. The temperature was monitored with an Infrared camera. The results were compared to the same battery pack and discharge with endplates comprised of 0.250 mm thick Nickel or 0.508 mm total thickness Nickel/Copper welded assembly (0.250mm Ni/0.250mm Cu). The clad endplate shows lower overall temperature and less hot spots, due to improved thermal conductivity and lower Joule heating.



For more information, contact:

N America: Dan Risner; +1 508 212 9308, drisner@emsclad.com
EMS Corporate Headquarters; +1 508 342-2100

China: C.W. Kong; +86 514 8891 6888, c.w.kong@emsclad.com.cn

Europe: James Craggs; +44 77 99 358 150, jcraggs@emsclad.com