Aluminum WrapUp

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Providing Aluminum Answers™ for the Industry

SECAT

PROVIDING ALUMINUM ANSWERS™

Secat News

Welcome Dr. Cui

Dr. Baozhi Cui joined Secat as a Materials Engineer in August 2015. He received his PhD in Materials Science and Engineering at the Institute of Metal Research (IMR), Chinese Academy of Sciences (CAS) in 2000. Before joining Secat Dr. Cui worked as a Senior Materials Engineer at Electron Energy Corporation, PA, where he developed and characterized magnetic materials, semiconducting metal oxides and metal matrix composites for energy storage and conversion, gas sensors, water treatment, and solar energy harvesting applications. Dr. Cui authored/co-authored 80 peer-reviewed journal papers on Acta Materialia, Applied Physics Letters, Carbon, Journal of Alloys and Compounds, Journal of Applied Physics, Scripta Materialia, etc. He also authored/co-authored 5 patents and delivered more than 30 presentations at international conferences. Dr. Cui successfully completed twenty R&D projects funded by DOD, DOE, EPA, and NSF. Please welcome Dr. Cui to the Secat team.

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Featured Capabilities

Ridging or Roping

The phenomenon of "ridging" or "roping" is a cosmetic appearance defect commonly found in automotive sheet alloys. When present, the alloy is not acceptable for use in outer body panel applications because the ridges that develop from part forming will be visible underneath the paint layer of the sheet on the vehicle. Roping is specifically, the resultant surface roughness of peaks and valleys present after a sheet has been strained along the transverse direction (TD, LT, or 90° to the rolling direction). The ridges are typically on the order of millimeters in spacing along TD, extending tens of millimeters in length along the rolling direction with a peak/valley depth of tens of microns. Research into the causes and remedies for roping is very active and much of what has been characterized has been a relationship to banding of the crystallographic orientation of grains on the sheet surface. The grains in a banded pattern will tend to deform together to accommodate the strain imposed on the sheet. Some groupings of crystallographic orientations or texture will deform more in the thickness direction from the imposed strains and some will deform less giving rise to the ridges observed.

To test for roping, a sheet coupon is subjected to a predefined strain along the TD. Once strained, the surface is painted with a permanent ink of dark color and good flow to cover into the ridges and valleys. After painting, the surface of the test coupon is subjected to a very light stoning which removes the paint from the ridges but leaves the valleys untouched. Care must be taken to be light in the stoning operation to prevent removal of the peaks causing a widening in the observed ridge size. In the figure below, an example of a roping evaluation as carried out by Prillhofer et al[i]. and analyzed digitally with a scanner and a roping analysis system, Audi Roping Tool v.054 (Audi AG, Neckarsulm, Germany). The system then rates the roping after the coupon was subjected to a 15% strain and a stoning of the inked coupon with P800 abrasive paper. As can be seen in the figure, the roping lines are clearly visible on a painted surface and the visibility of the pattern is enhanced with the stoning so that it can be scanned on a scanner with 300 dpi resolution.

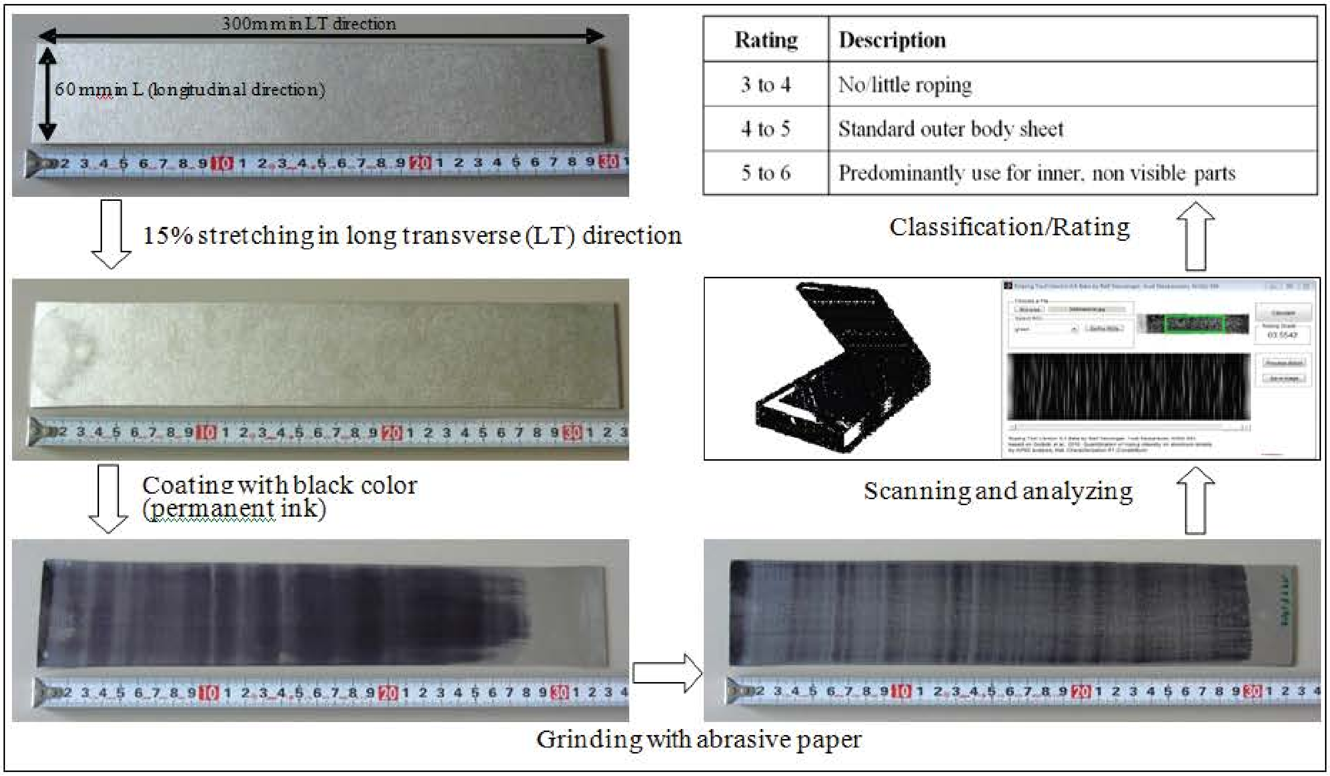

Figure 1 – Roping procedure as outlined by Prillhofer et al.

[i]Prillhofer, R., Rank, G., Berneder, J. Antrekowitsch, H., Uggowitzer, P., Pogatscher, S.; "Property criteria for automotive Al-Mg-Si sheet alloys"; Materials 2014, 7, 5047-5068; doi:10.3390/ma7075047

Accumulative Roll-Bonding Technique to Fabricate Ultrafine Grained Metallic Materials

Accumulative Roll-Bonding (ARB) is one of the severe plastic deformation (SPD) processes used to fabricate ultra-fine-grain (UFG) structured metallic materials. ARB is the only SPD process applicable to continuous production of bulky materials. Various metals and alloys including aluminum and aluminum alloys have been successfully processed by the ARB technique. The principle of ARB is illustrated in Figure 1. In the ARB process, two or more sheets are roll-bonded together in the same way as those in the normal roll bonding process, but the bonded sample is then cut and stacked and roll-bonded again for designed circles. In order to obtain one-body solid material, the rolling in ARB is not only a deformation process but also a bonding process (roll-bonding). By repeating this procedure, SPD of bulky materials can be realized. Since the above mentioned procedures can be repeated limitlessly, it is possible to impose very large plastic strain on the materials in the ARB process. The bonding quality can be affected by a number of factors, including the amount of deformation, the temperature of rolling, the surface preparation conditions and the layer thickness.

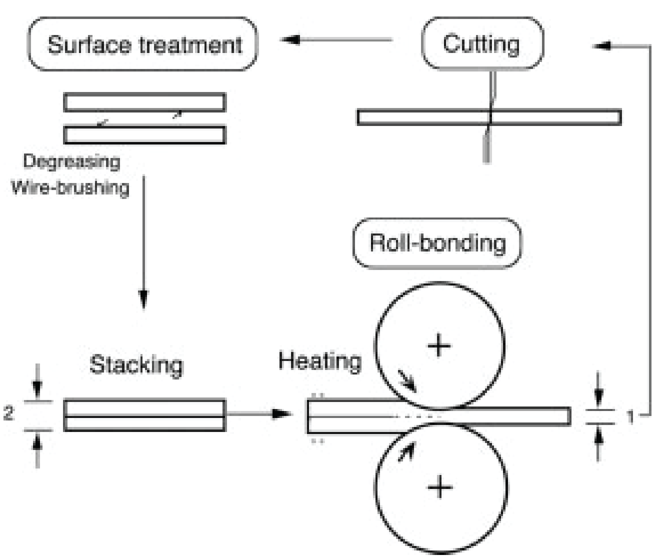

Fig 1 Schematic illustration showing the principle of the accumulative roll-bonding process.

It has been found that bonding in the ARB process is generally, not difficult. However, surface treatment is indispensable for bonding. Furthermore, there is a critical rolling reduction in one pass roll-bonding, below which it is difficult to achieve sufficient bonding. Though the critical reduction depends on the materials and the processing temperatures, more than 35% reduction by one pass is necessary in general, so that the rolling force is larger compared to conventional rolling. The main problem with the ARB process is fracture of the material; this is due to accumulation of large amounts of total plastic strain in the material and the fact that rolling is not a hydrostatic process. This results in edge cracks sometimes occurring in the sheets, especially at higher cycles. In some materials, the edge cracks can propagate into the center of the sheet. In that case, it becomes impossible to proceed to the subsequent cycle. In cases of relatively ductile materials, for example, pure aluminum and iron, the UFG sheets having a dimension of 1^T x 50^w x 300^L mm can be fabricated without cracking by the ARB process.

The ARB materials processed through several cycles are filled with ultra-fine grains (UFG). Figure 2 shows the typical UFG

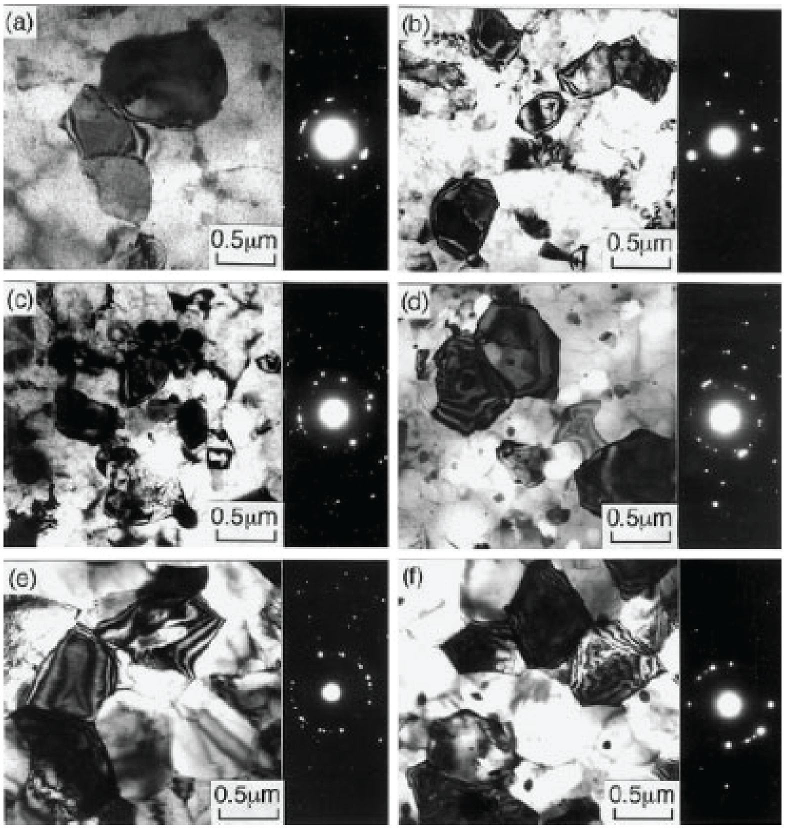

Fig 2 TEM microstructures of the typical UFGs in various kinds of ARB processed materials. Observed from normal direction (ND).
a) 1100-Al (99 %Al) ARB processed by 8 cycles (ε = 6.4) at 473 K.
b) 5083-Al (Al-4.5 %Mg) ARB processed by 7 cycles (ε= 5.6) at 573 K.
c) 6061-Al (Al-1.1 %Mg-0.4 %Si) ARB processed by 6 cycles (ε = 4.8) at RT.
d) 7N01-Al (Al-4.4 %Zn-1.8 %Mg) ARB processed by 5 cycles (ε = 4.0) at 523 K and then annealed at 473 K for 900 s.
e) IF steel ARB processed by 5 cycles (ε = 4.0) at 773 K, then annealed at 773 K for 600 s.
f) Plain low-carbon steel (SS400; Fe- 0.13 %C-0.37 %Mn) ARB processed to a total strain of 4.0 at RT., and annealed at 833 K for 1.8 ks.

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Accumulative Roll-Bonding Technique to Fabricate Ultrafine Grained Metallic Materials cont. from page 3

structures in some ARB processed Al alloys and steels. Independent of material type, UFGs with diameters smaller than 1 μm are observed. The UFGs are surrounded by clear but irregular shaped boundaries, and the number of dislocations inside the grains appear to be small. These features are similar to those observed in materials heavily deformed by other SPD processes. The microstructures in Figure 2 were observed from the normal direction (ND) of the sheets. The most characteristic feature of the UFGs in the ARB processed materials is the elongated morphology.

Figure 3 is a typical microstructure of the elongated ultrafine grains in ultra-low-carbon IF (interstitial free) steel processed by ARB through seven cycles ($\varepsilon = 5.6$) at 500 °C. The grains are elongated along rolling direction (RD). In most cases, the mean grain thickness of the pancake-shaped UFGs or the ultrafine lamellar structures are 100 - 200nm for the ARB processed materials (Fig.3 and Table 1). The ARB at lower temperature results in smaller grain size within the similar materials. Similar microstructures appear in the ARB processed aluminum alloys. These microstructures resemble the lamellar boundary structures observed in heavily deformed materials. The formation process of the UFGs during the ARB process is suggested via a continuous recrystallization (or in-situ recrystallization) characterized by ultrafine grain subdivision, recovery to form UFGs, and short range grain boundary migration.

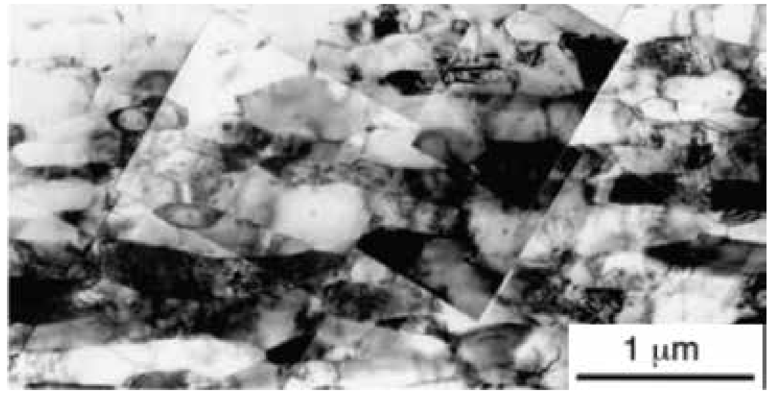

Fig 3 TEM image of interstitial free (IF) steel ARB processed by 7 cycles ($\varepsilon = 5.6$) at 773 K. Observed from transverse direction (TD).

The ARB processed materials having the elongated UFG structures show very high strength. The UFG materials have tensile strength two to four times higher than the starting material with conventional grain size. On the other hand, the ARB processed materials have limited tensile elongation owing to early plastic instability. It has been also clarified that the ARB processed 5083-Al alloy with UFG microstructure shows low-temperature superplasticity at 200 °C. The grain size and the tensile strength of the various UFG materials fabricated by the ARB are summarized in Table 1.

Table 1. Microstructure, grain size and tensile strength of some ARB processed metals and alloys

Materials [mass %]	ARB Process	Microstructure	Grain size [μm]	Tensile strength [MPa]
4N-Al	7 cycles at RT	pancake UFG	0.67	125
100-Al (99 % Al)	8 cycles at RT	pancake UFG	0.21	310
5052-Al (Al-2.4Mg)	4 cycles at RT	ultrafine lamellae	0.26	388
5083-Al (al-4.5Mg+0.57Mn)	7 cycles at 100°C	ultrafine lamellae	0.08	530
6061-Al (Al-1.1Mg-0.63Si)	8 cycles at RT	ultrafine lamellae	0.10	357
7075-Al (Al-5.6Zn-2.6Mg-1.7Cu)	5 cycles at 250°C	pancake UFG	0.30	376
OFHC-Cu	6 cycles at RT	ultrafine lamellae	0.26	520
Cu-0.27Co-0.09P	8 cycles at 200°C	ultrafine lamellae	0.15	470
Ni	5 cycles at RT	ultrafine lamellae	0.14	885
IF steel	7 cycles at 500°C	pancake UFG	0.21	870
0.041P-IF	5 cycles at 400°C	pancake UFG	0.18	820
SS400 steel (Fe-0.13C-0.37Mn)	5 cycles at RT	ultrafine lamellae	0.11	1030
Fe-36Ni	7 cycles at 500°C	ultrafine lamellae	0.087	780

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Ron Lane
VP of Operations, Aleris

Ron joined Aleris this year as VP of Operations. Aleris is a global leader in the manufacture and sale of aluminum rolled products, with 14 facilities in three geographically aligned business units in North America, Europe and China serving a variety of end-use industries, including aerospace, automotive, defense, building and construction, transportation, packaging, and consumer goods. Ron is accountable for over-all performance of 8 USA manufacturing sites and has a record of tangible improvements in a variety of disciplines: general management, strategy development, manufacturing, supply chain, project management, engineering, management of change, health/safety & environment and human resources. Ron has lived and worked in North America, Europe and Asia and most recently held the position of VP of Global Operation for the Flavor Division of Firmenich.

What brought you to the Board of Directors of Secat?

Aleris has had a long-standing relationship with both the University of Kentucky and Secat which began in the late 1980s. Aleris was a founding member of Secat and has had a representative on the Board of Directors since Secat's inception. As I started my career with Aleris earlier this year, and learned more about our successful collaborative history and the forward-looking opportunities, I was eager to join Secat's Board.

In your opinion, what makes Secat unique/special in the industry?

Secat is one of the few organizations that is solely focused on the research and testing of aluminum products and their applications. Secat has access to the resources of the University of Kentucky, close relationships with other universities and national laboratories, and has a diverse membership base that represents a wide spectrum of technologies for the manufacture and application of aluminum sheet products. This, combined with a well-equipped certified laboratory and experienced researchers and technicians, provides Secat with the unique capability to aid companies with testing, analysis and guidance on current issues, but also to lead more complex, long-term, strategic research projects.

What is the most important/exciting development you see in the future for Secat?

The shift toward aluminum-intensive automobiles, with North American demand for aluminum body sheet projected to increase significantly in the next decade, presents a very exciting opportunity for Secat. With their experienced staff and well equipped lab, they are well positioned to help the industry bridge the gaps between current supplier capabilities and future OEM application needs. The demanding requirements of the automotive products will provide Secat an opportunity to enhance their capability beyond aluminum sheet metallurgy, into more complex forming, joining and surface treatment technologies that challenge the automotive manufacturing supply chain.

Tell us something about yourself that people may not know. . . and anything else you would like to share.

I'm a marathon runner and so far have completed 6 marathons with a PB of 3:06.

SECAT PROVIDING ALUMINUM ANSWERS™

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Bring *Aluminum: Wrapped Up* to Your Company

Secat is proud to offer a new training course called "Aluminum: Wrapped Up" to companies interested in the fundamental understanding of aluminum processing. If you are interested in having this class taught at your facility, please contact Todd Boggess at tboggess@secat.net for more information.

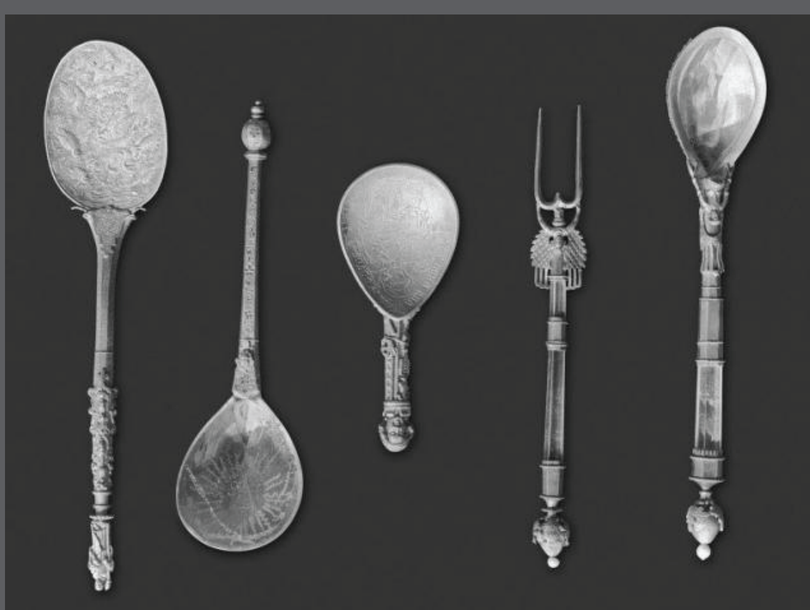
The purpose of the course is to introduce students to aluminum, its characteristics, alloys, processes, forms, and applications. Students will leave with a broad understanding of the manufacturing process – from bauxite mining to primary and secondary production to recycling. Along the way, students will also learn about the various alloys, tempers and designations of aluminum and the commercial factors that influence buying behavior.

Reference materials will be provided as a resource for professionals working in the aluminum industry. Students are encouraged to bring questions and/or samples for discussion. The course instructor has a wide variety of experience and can assist with day to day issues that are commonly faced in the industry.

THIS COURSE IS IDEAL FOR:

- Metallurgists
- Technicians
- Quality Engineers
- Management
- Purchasing
- Sales & Marketing
- Customer Service

Aluminum Art



Historically Speaking . . .

The early history of aluminum – (19th Century) finds its novelty being translated into many forms of artwork. Before the metal was mass produced, it was considered rare and precious and it was incorporated into, among other things, jewelry and decorative items. Emperor Napoleon III reserved a prized set of aluminum cutlery for special guests at banquets. (Less favored guests used gold knives and forks.) The book, Aluminum by Design, traces the history of aluminum from its beginnings through modern day as an inspiration and medium for artists, designers, architects and engineers.