



ARC Centre of Excellence
Design in Light Metals

Multi-Layered Al/Al-Sc Composite Produced by Accumulative Roll Bonding

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Motivation

Conventional metals exhibit a tradeoff between strength and ductility (Figure 1). Several nanostructured materials have been shown to exhibit increased ductility without a dramatic reduction in strength [1].

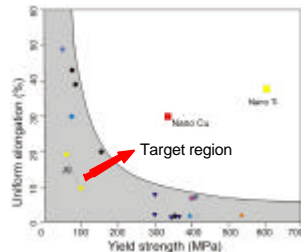


Figure 1. Properties of conventional alloys and nanostructured alloys (after [1]). The aim of this work is to produce materials beyond the grey region.

The aim is to make an Al alloy sheet that will occupy a position in the property regime that cannot be achieved by conventional processing. High purity Al is very ductile, and Al-Sc is a well examined alloy capable of sustaining strength at elevated temperatures [2]. In this work, a novel process combines these two types of Al in a layered structure in an attempt to improve mechanical properties.

Multi-layered structure formed by roll bonding

A multi-layered structure containing alternate layers of Al and a super saturated Al-0.3 wt% Sc alloy was produced by successive stacking and accumulative roll bonding (Figure 2). A stack of one sheet of each material was rolled to 50% reduction to bond the layers. The composite sheet was then cut and two pairs of layers were roll bonded. This process was repeated to create a multi-layered structure of total thickness of 0.5 mm.

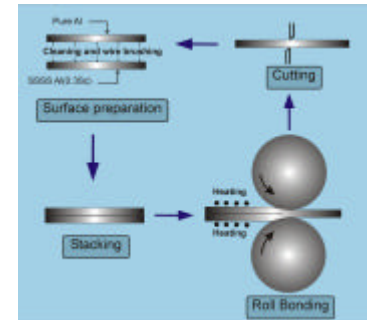


Figure 2. Roll bonding process, including surface cleaning, stacking and roll bonding at 200 °C.

Deformation microstructure

Figure 3a shows several layers of the deformation microstructure of Al and Al-Sc. The substructures in the Al layer are aligned along the rolling direction (RD) and resemble typical lamellar band structures. They are highly fragmented with boundaries of more than 15° misorientation. The Al-Sc layers are less fragmented. However, it can be seen that the upper layer contains a classic deformation band.

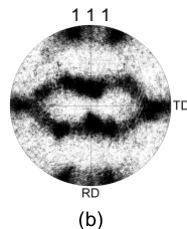
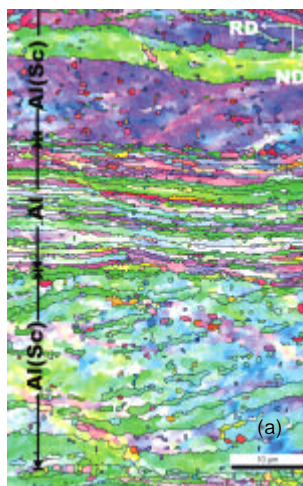


Figure 3. (a) EBSD map of several layers of the deformation microstructure. Black lines indicate high angle boundaries (more than 15° misorientation); (b) {111} pole figure of ten successive layers.

On average, the Al layers accommodate about 10% more strain than the Al-Sc layers. The {111} pole figure in Figure 3b shows that the deformation microstructure contains a typical β fibre rolling texture.

Annealed microstructures

Figures 4 and 5 show various stages of annealing at 350 °C. Annealing for 3 min results in spheroidization and continuous coarsening of the lamellar bands within the Al layers. After 6h, grains have grown to full layer thickness (Figure 5). Furthermore, annealing does not alter the deformation texture, as shown in Figures 3b, 4c and 5c. The Al layers appear to undergo **continuous recrystallization** with the Al-Sc layers only slightly recovered due to extensive Zener pinning by Al₃Sc particles [2]. The final microstructure shown in Figure 5b consists of alternate layers of ductile Al and high-strength Al-Sc.

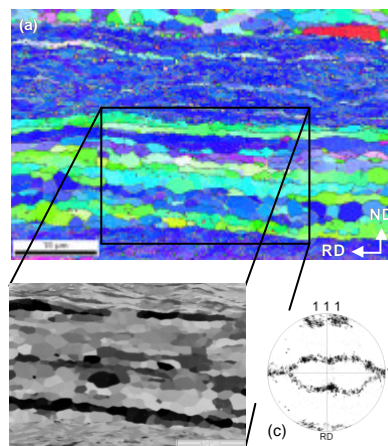


Figure 4. (a) EBSD map after annealing for 3 min at 350 °C, showing bulging of the substructure in the Al layers and retained deformation substructure in the Al-Sc layers. Black and yellow segments indicate boundary misorientations greater than 15° and 5-15°, respectively (b) Ion channeling contrast (ICC) image and (c) {111} pole figure of a typical Al layer.

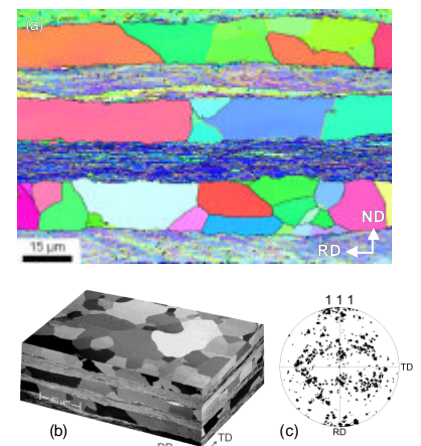


Figure 5. (a) EBSD map after annealing for 6h at 350 °C, showing alternate recrystallized and unrecrystallized layers; the latter are caused by Zener pinning from nanosized Al₃Sc particles. Boundary segments are coloured as in Figure 4; (b) three dimensional reconstruction of ICC images; (c) {111} pole figure of 84 recrystallized grains from several Al layers.

References

1. Y. Wang, M. Chen, F. Zhou & E. Ma: *Nature*, **419**, 912 (2002).
2. M. Ferry, N.E. Hamilton & F.J. Humphreys: *Acta Materialia*, **53**, 1097 (2005).

Conclusions

- A multi-layered Al/Al-Sc composite was developed with the intention to generate a material with a combination of high strength and high ductility.
- Continuous recrystallization occurs in the high purity Al layers, which retain the rolling texture after annealing.