Texture Evolution of High Purity Aluminium Sheets Produced by ARB

K.D. Lau[1], O. Al-Buhamad[1], M.Z. Quadir[1,2] and M. Ferry[1]

1) School of Materials Science & Engineering, University of New South Wales
2) Electron Microscope Unit, University of New South Wales

ARC Centre of Excellence
Design in Light Metals

Accumulative Roll Bonding (ARB)

ARB is a severe plastic deformation process for sheet metals. The process can produce ultra-fine-grained structures by repeatedly joining and rolling of similar[1] and dissimilar metal sheets[2,3] up to many cycles. A typical ARB cycle involves four main operations, shown in Figure 1.

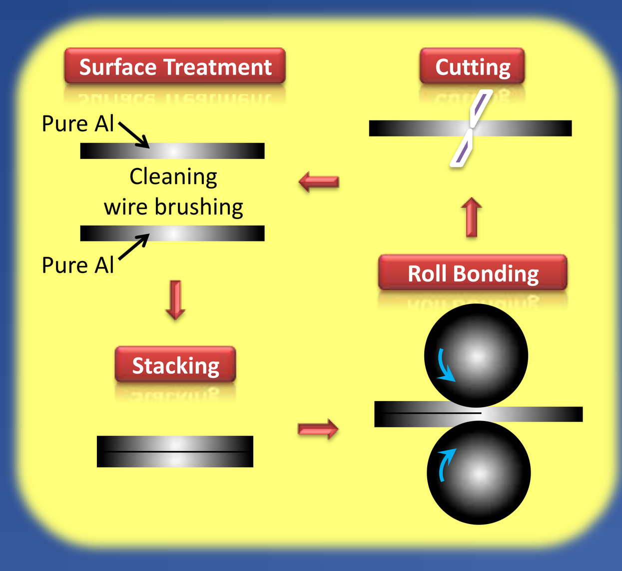

Figure 1) Four stages of Accumulative Roll Bonding process in one cycle.

The aim of this study is to investigate the shear strain distribution in ARB sheets during rolling and its influence on the development of the through-thickness crystallographic texture. The strain distribution was determined by measuring the deflection of an embedded scratch which was introduced prior to roll bonding and the resulting texture was measured by EBSD. A commercial purity Al alloy was used in the work that was roll bonded up to five ARB cycles.

Shear Strain Monitoring Technique

Two similar sized samples of 1 mm thickness were polished in RD-ND sections and carefully stacked together. Several fine, straight scratches (along ND) were scribed onto the polished surfaces and placed into half of a rectangular slot of an aluminium holder (Figure 2a). The thickness of the holder was maintained equal to the stack (2 mm). In the remaining half of the slot, a pre-polished dummy aluminium (2 mm thick) sample was placed facing the polished surfaces of the stack in contact (Figure 2b). Any gaps of this assembly were filled with fine aluminium swarf to generate pre-polished, tightly-fitted mating surfaces on a microscopic scale. The purpose of this rig was to simulate the plane strain deformation condition of the surface containing the scratches. The arrangement shown in figure 2c was subsequently rolled to 50% reduction in a single pass without lubrication.

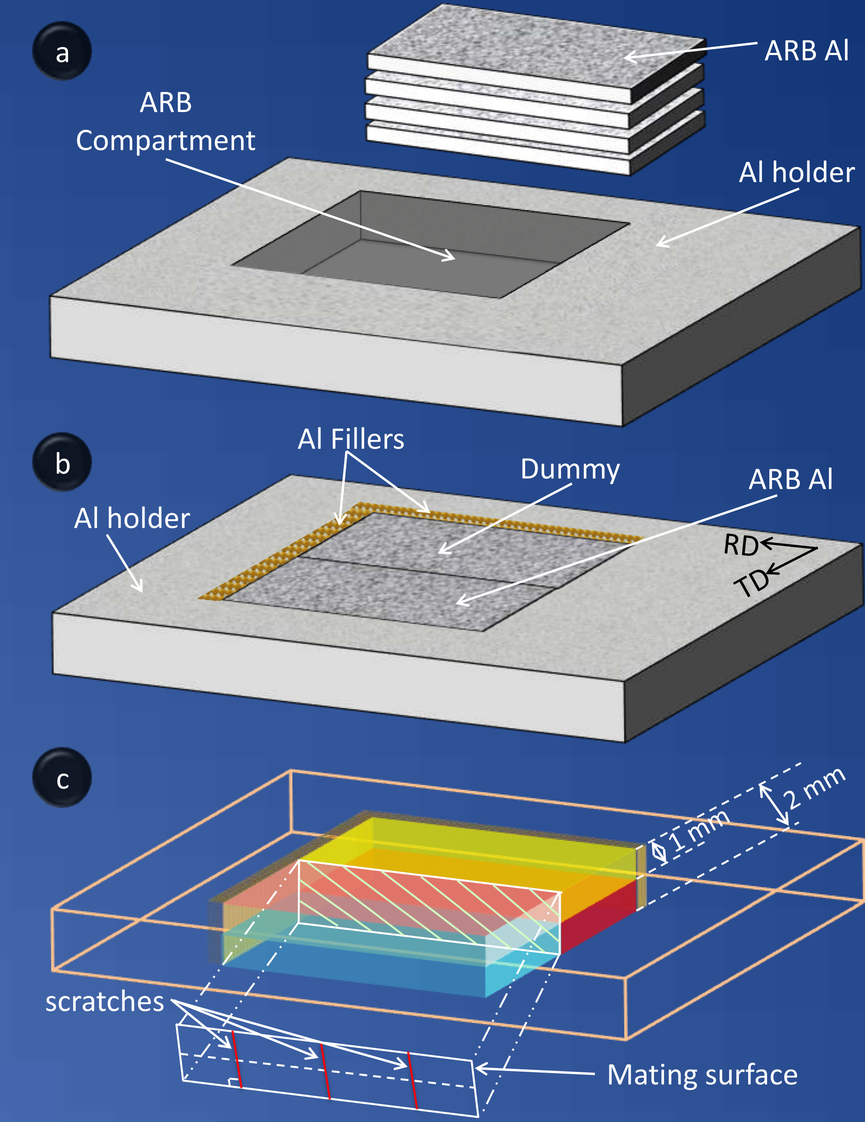

Figure 2) A Schematic arrangement showing the shear strain monitoring technique after a single pass rolling; a) an overview of the setup b) the fitting of the samples and the dummy inside the holder; c) The stacking arrangement of the ARB samples.

Through-thickness Shear Strain Distribution

Figure 3a is an optical micrograph of a deflected scratch after rolling; this represents the degree of shear strain introduced during deformation. The shear strain is largest at the surface region adjacent to the rolls (top of the image), then decreases to zero followed by a slight increase at the bonded interface (bottom of the image). The shear strain, γ, was calculated from the rolling reduction, r, and the shear angle, Θ, at each thickness location using:[4]

$$\gamma = \frac{2(1-r)^2}{r(2-r)} \tan\theta \cdot \ln\frac{1}{1-r} \qquad \text{---------- (1)}$$

and the equivalent strain ε_{eq} was calculated using:

$$\varepsilon_{eq} = \sqrt{\frac{4}{3}\left(\ln\frac{1}{1-r}\right)^2 + \frac{\gamma^2}{3}} \qquad \text{---------- (2)}$$

Figure 3b shows the distribution of shear strain throughout half the sample. The best fit of the data is given by the yellow curve which corresponds to the following empirical relation:

$$y = -503.9x^5 + 750.3x^4 - 422.4x^3 + 112.9x^2 - 14.6x + 1.5 \qquad \text{---------- (3)}$$

If the distribution given in figure 3c is accumulated over the next four cycles, the distribution showed in figure 3d. A homogeneous distribution over the entire thickness is achieved.

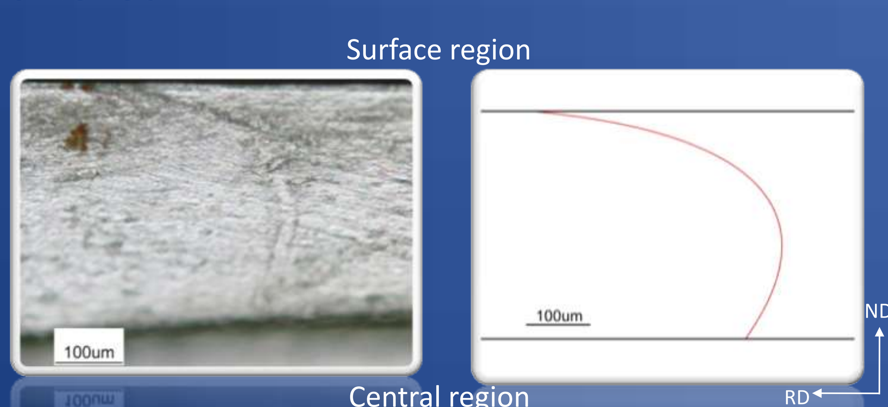

Figure 3a) The deflected stretch after 1 ARB cycle.

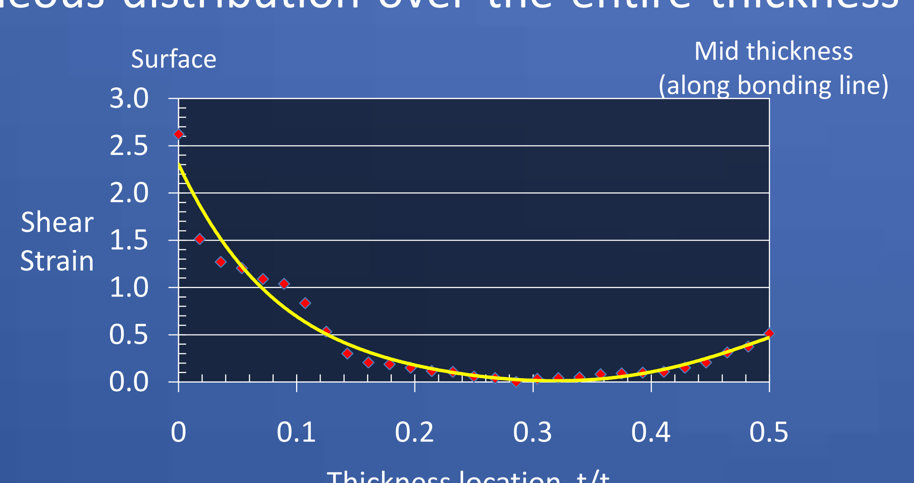

Figure 3b) Half thickness shear Strain distribution after 1 ARB cycle.

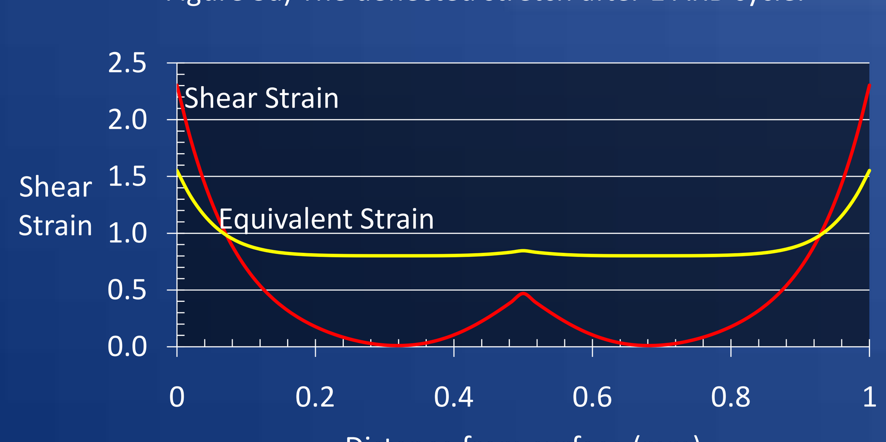

Figure 3c) Through-thickness shear Strain distribution after 1 ARB cycle.

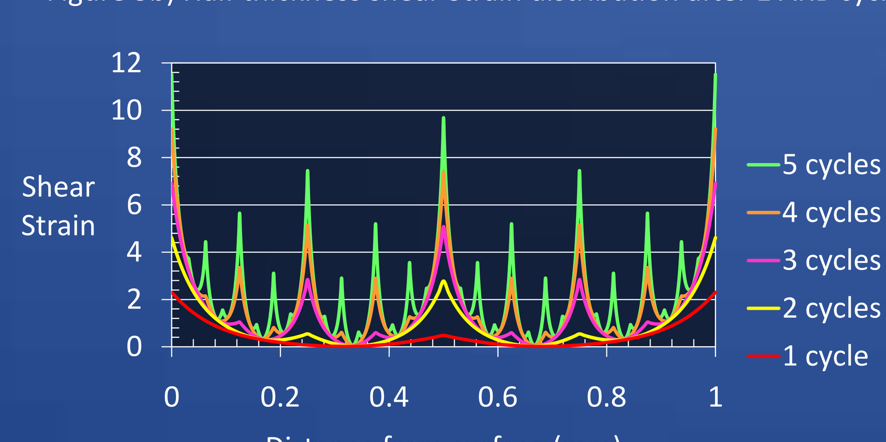

Figure 3d) Shear Strain distribution after 1-5 ARB cycles.

Microstructure and Texture Analysis

Using RD-ND sections, orientation imaging microscopy (OIM) was carried out on the central and (sub)surface regions of the roll-bonded sheets. The EBSD micrographs and textures (<111> pole figures) of the material are given in figure 4 showing very little difference in the texture after five ARB cycles. This is probably due to the homogenization of the shear strain distribution throughout the thickness, as demonstrated in figure 3. However, in the vicinity of the roll-bonded interface (shaded region in figure 4), the microstructures and the textures were less homogeneous compared to material away from this region. This has been found to have a significant influence on the recrystallization behaviour during subsequent annealing.

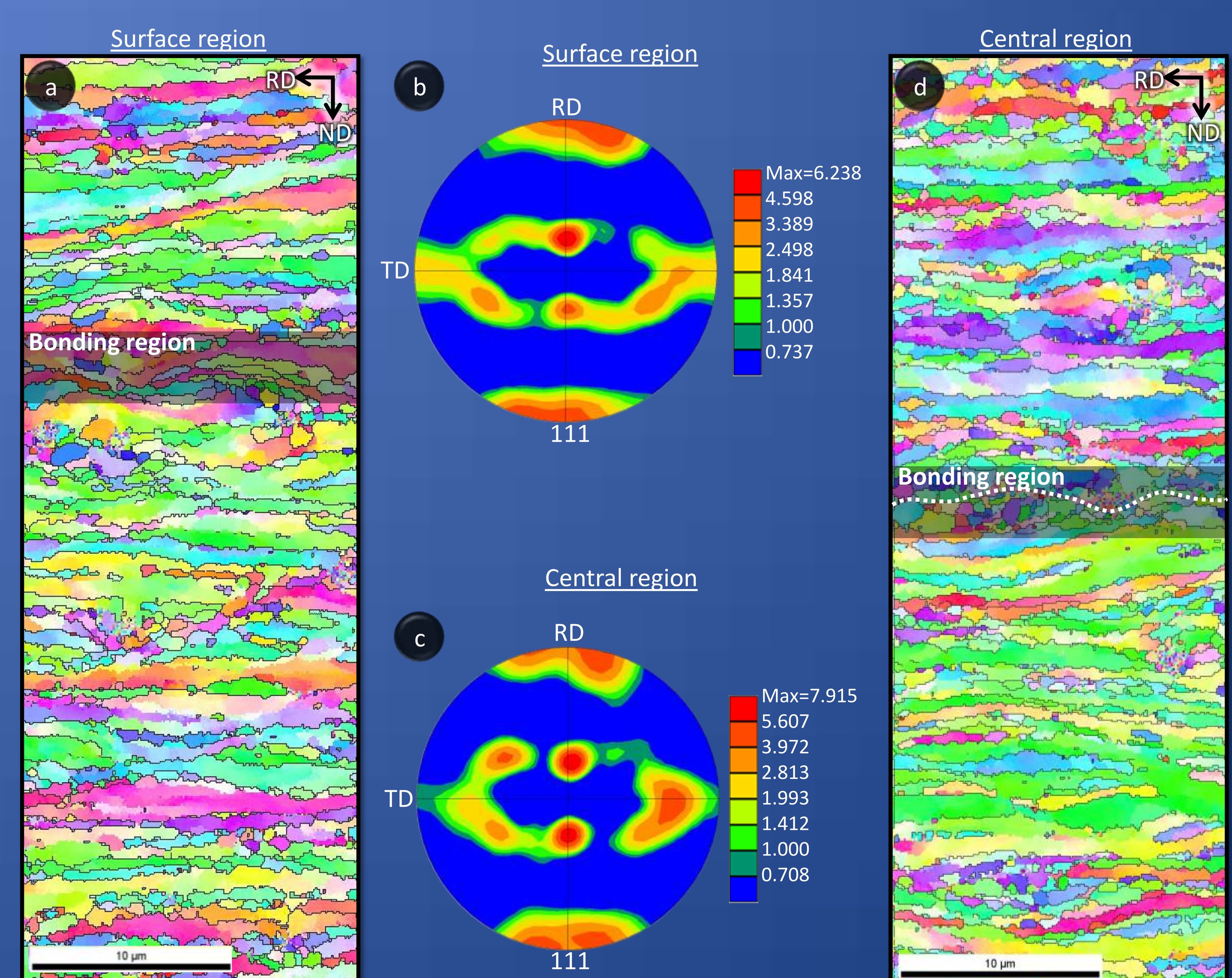

Figure 4) microstructure and texture analysis after 5 ARB cycles at different regions; a, d) EBSD map at the surface/central region of the deformed structures. Black lines indicate the high angle boundaries (>15° misorientation); b, c) <111> pole figure from the surface/central region.

Conclusion

A homogeneous through-thickness shear strain and texture distribution was generated by ARB after several cycles of cold rolling. While surface shearing was significant after a single rolling pass, the shear texture components did not dominate after several cycles.

References

[1] Y. Saito, H. Utsunomiya, N. Tsuji, T. Sakai, Acta Materialia 47 (1999) 579-583.
[2] M. Z. Quadir, M. Ferry, O. Al-Buhamad, P. R. Munroe, Acta Materialia 57 (2009) 29-40.
[3] M. Z. Quadir, O. Al-Buhamad, L. Bassman, M. Ferry, Acta Materialia 55 (2007) 5438-5448.
[4] T. Sakai, Y. Saito, K. Hirano, K. Kato, Transactions of the Iron and Steel Institute of Japan 28 (1988) 1028-1035.

Australian Government
Australian Research Council
MONASH University
THE UNIVERSITY OF NEW SOUTH WALES SYDNEY · AUSTRALIA
THE UNIVERSITY OF MELBOURNE
THE UNIVERSITY OF QUEENSLAND AUSTRALIA
DEAKIN UNIVERSITY
The University of Sydney

www.arclightmetals.org.au