

# Influence of through thickness shear strain on substructure fragmentation in ARB Al Sheet

K.D. Lau<sup>1</sup>, M.Z. Quadir<sup>1,2</sup> and M. Ferry<sup>1</sup>

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

## 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<sup>[1]</sup> and dissimilar metal sheets<sup>[2,3]</sup> up to many cycles. A typical ARB cycle involves four main operations, as shown in Figure 1.

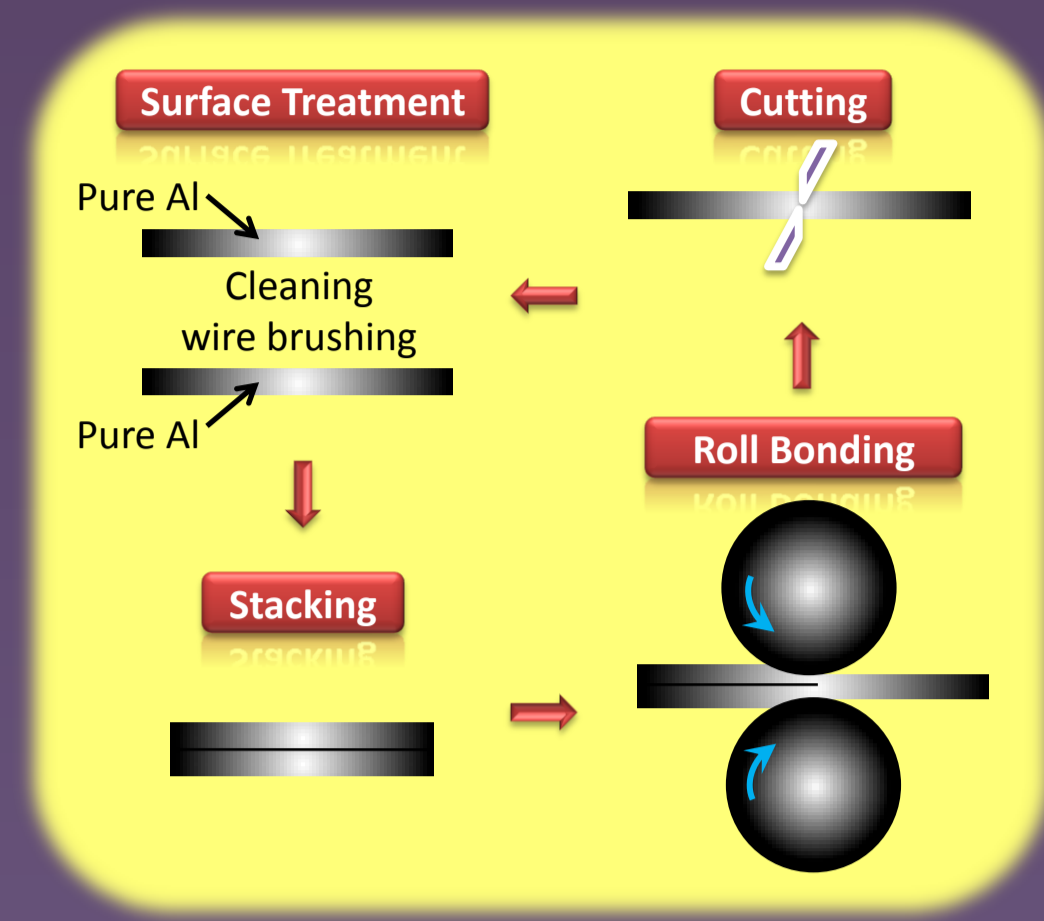


Figure 1) Four stages of Accumulative Roll Bonding process in cycle.

## Objective and Experimental Procedure

Typical ARB cycle involves a large reduction of 50%. This introduces a large inhomogeneous through-thickness shear strain in the sheet. The aim of this study is to investigate the influence of shear strain on the fragmentation of grains across the sheet thickness during ARB processing. Electron Backscatter Diffraction (EBSD) is the primary analysing technique used in this investigation. The fragmentation of grains is determined by the amount of misorientation angle and boundaries formed during ARB processing. A commercial purity Al alloy was used in this study.

## Results

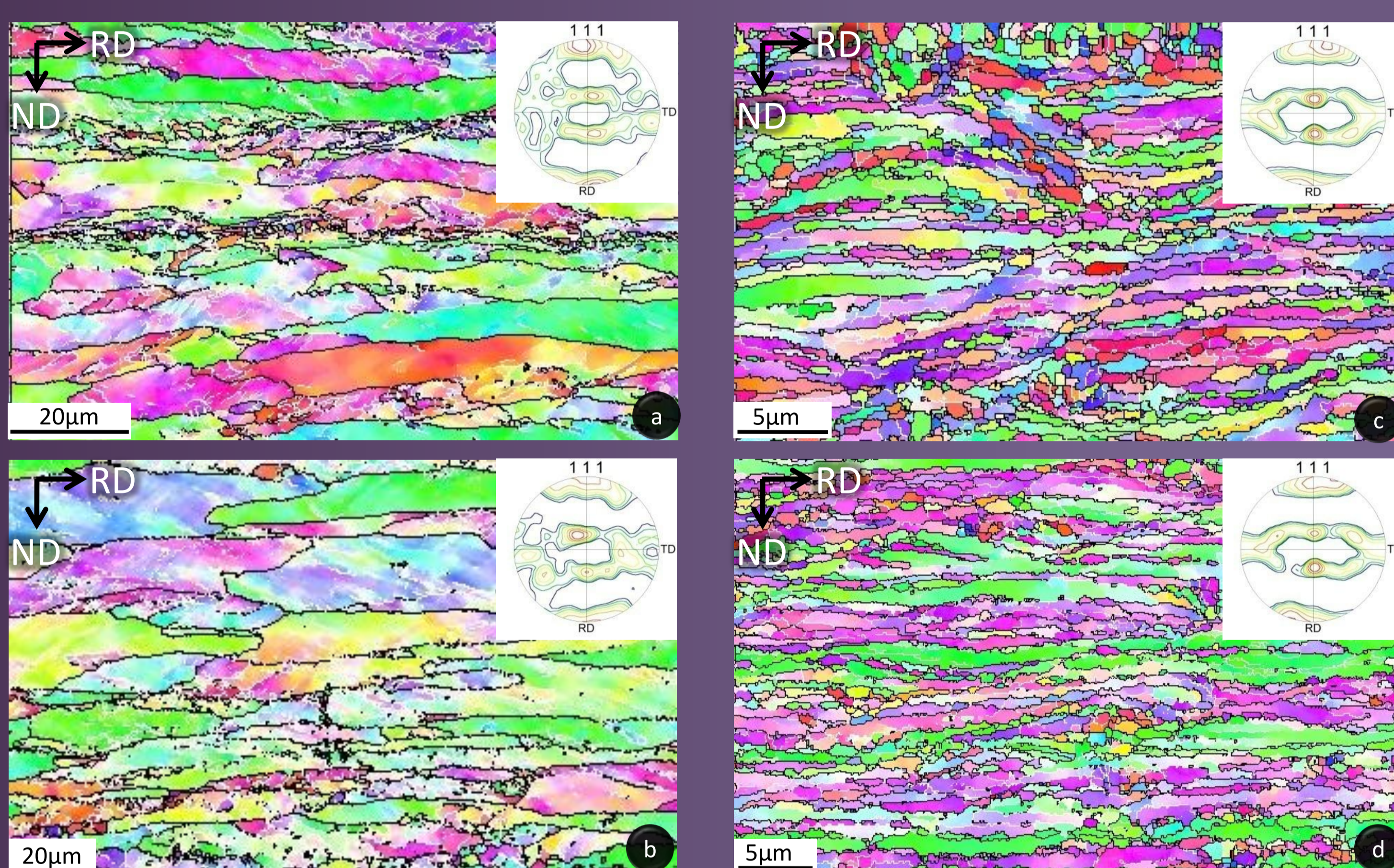


Figure 2) EBSD map and  $\langle 111 \rangle$  pole figure at various thickness location. Black lines are grain boundaries  $\geq 15^\circ$  white lines are grain boundaries between  $2^\circ$  to  $15^\circ$ ; a) at the centre, after 1 ARB cycle; b) at the surface, after 1 ARB cycle; c) at the centre, after 5 ARB cycle; d) at the surface, after 5 ARB cycle.

The deformation microstructure near core and surface thickness of 1 – 5 ARB cycles is shown in Fig.2 using orientation imaging microscopy (OIM). The 1 cycle OIM shows the elongation of original grains with subtle amount of high angle ( $>15^\circ$ ) boundary generation. The subsurface grains, at the bottom of Fig. 2b, are thinner than the remaining core region. This indicates the accommodation of high strain. In the 5 cycle ARB sample, the identity of the original grains is lost and it is composed of fine lamellar bands, divided by high angle grain boundaries, which are aligned parallel to the rolling direction. The overall microstructure throughout the sheet's thickness become more homogenous after 5 ARB cycles. The corresponding  $\langle 111 \rangle$  pole figures in the series show that after 5 cycles, the texture is toward  $\beta$  fibre.

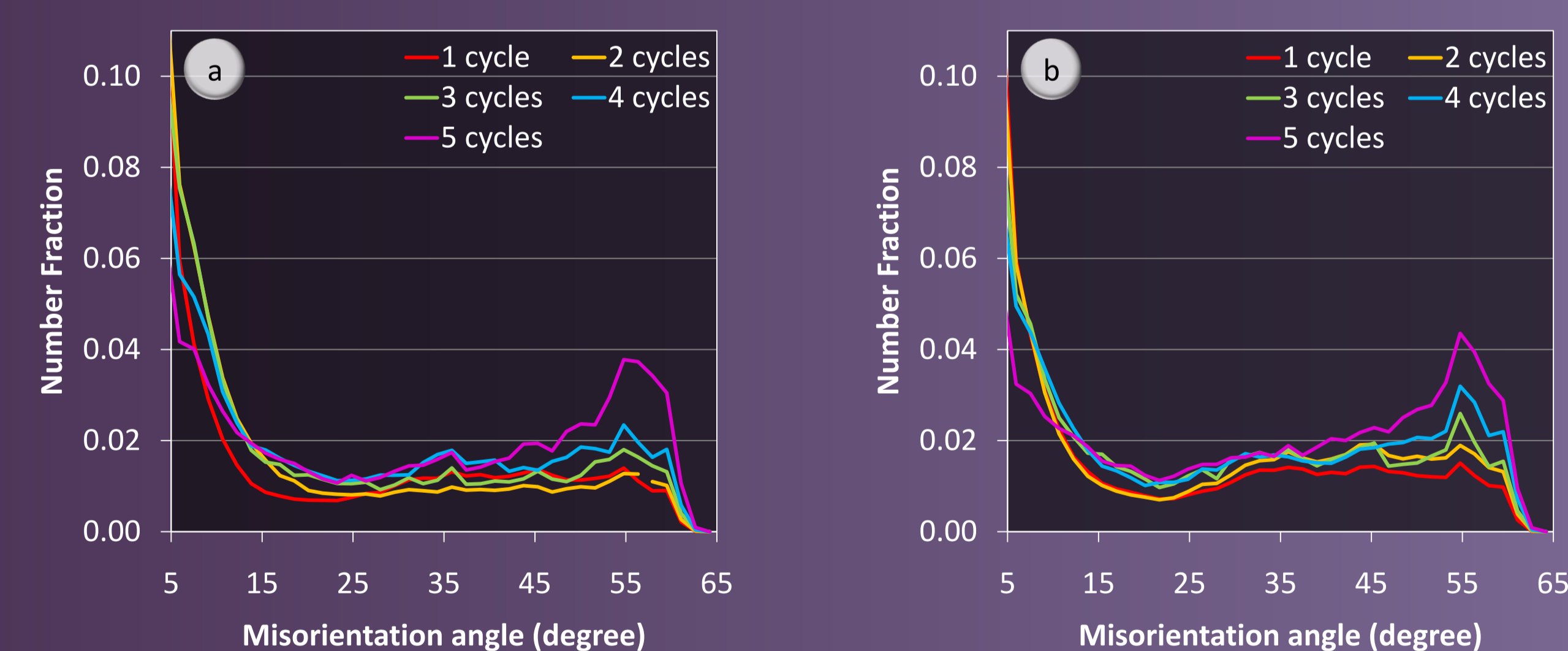


Figure 3) Misorientation distribution from 1 to 5 ARB cycle; a) surface; b) centre.

The misorientation boundary distribution of 1-5 ARB cycles is shown in Fig. 3. High fraction of misorientation angle are distributed at LAGBs ( $<15^\circ$ ) and at HAGBs ( $\sim 55^\circ$ ). The fraction of HAGBs increases along with increasing cycles. The fraction of HAGBs is slightly higher at the centre region than at the surface.

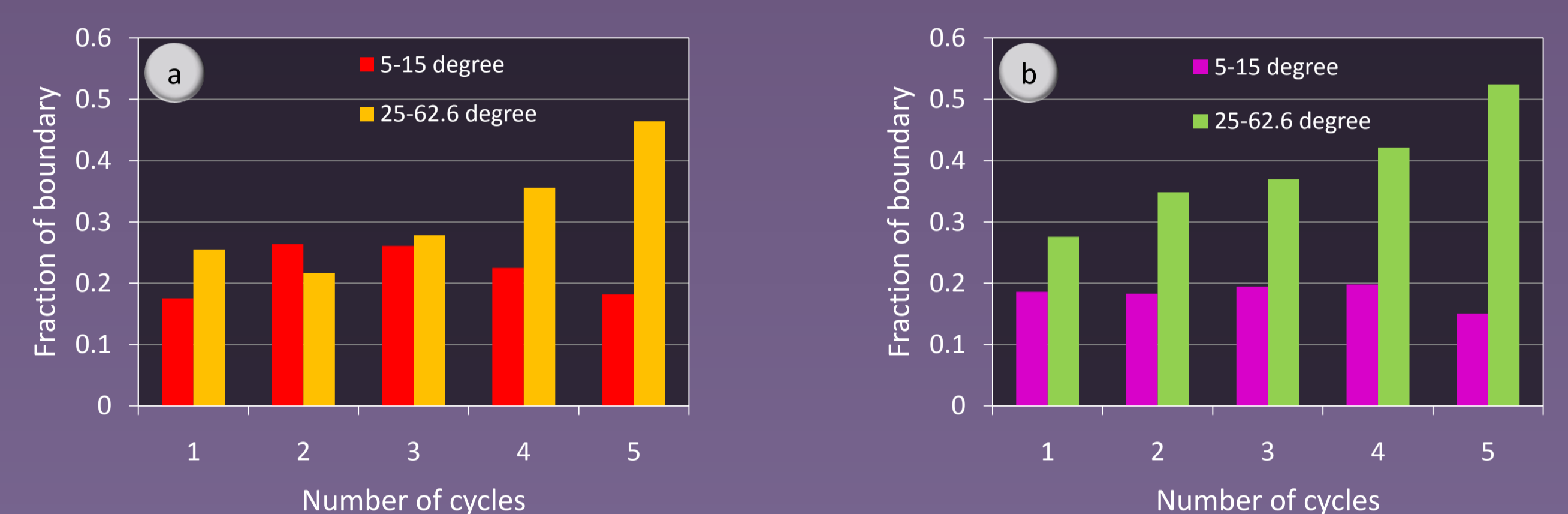


Figure 4) Fraction of high angle grain boundaries (HAGBs) ( $25^\circ \leq \theta < 62.6^\circ$ ) and low angle grain boundaries (LAGBs) ( $5^\circ \leq \theta < 15^\circ$ ) as a function of the number of ARB cycles; a) surface region; b) centre region.

Fig. 4 is an extraction of the fraction of HAGBs and LAGBs from Fig. 3 to further focus on their change as the number of ARB cycles increases. Both the surface and centre region show an increase in the fraction of HAGBs at high ARB cycle (Fig. 4). At the centre region, a slightly higher fraction of HAGBs is generated compare with the surface region. In contrast, the fraction of LAGBs decreases with increasing ARB cycles. However, the decline rate of the fraction of LAGBs is lower than the increment of the fraction of HAGBs.

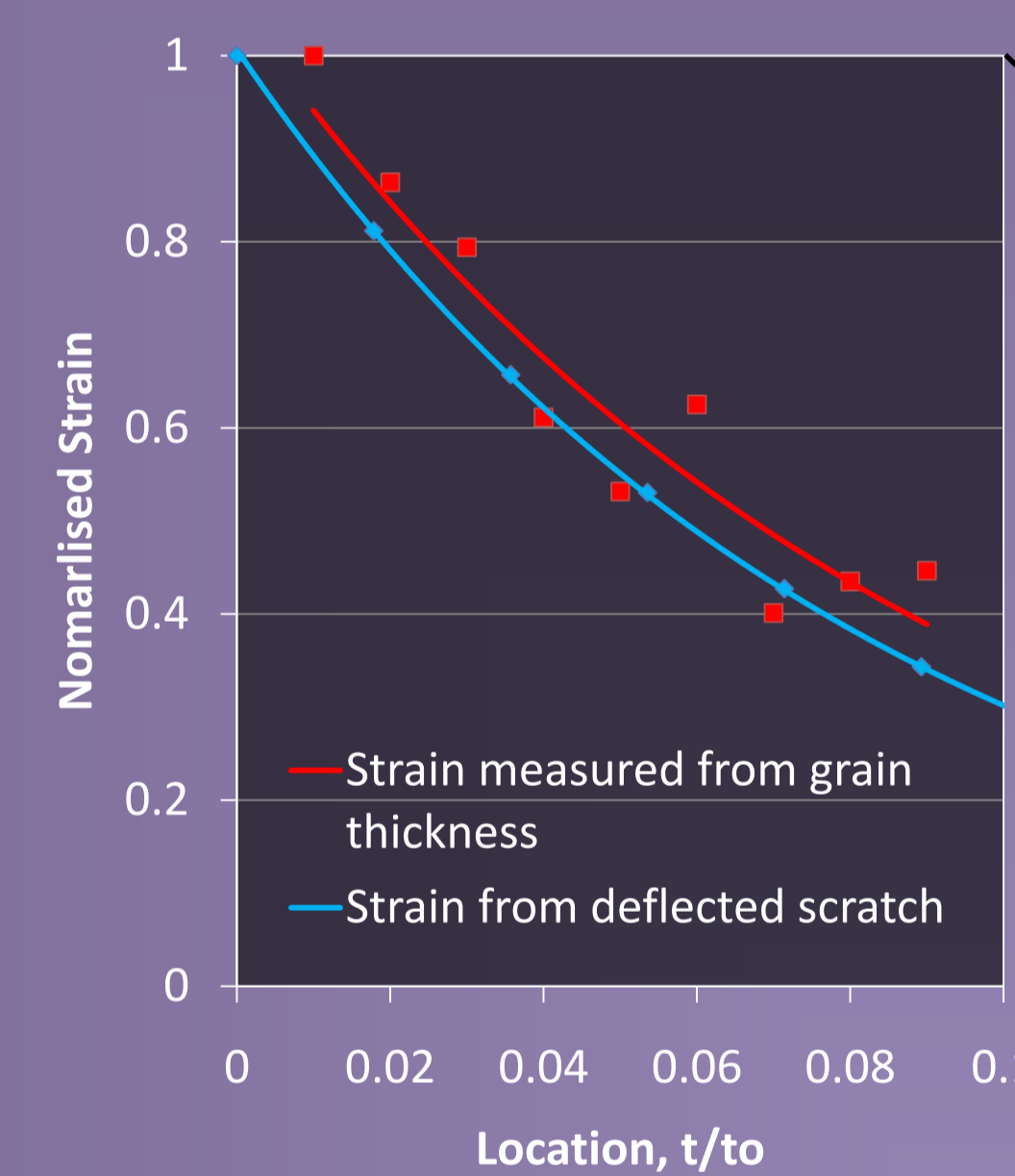


Figure 5) Partial normalised strain distribution after 1 ARB cycles.



Figure 6) The deflected scratch after 1 ARB cycle.

The strain accommodated in deformed grains near the surface region is shown as a function of thickness (fraction) in Fig.5. In a complementary study, Fig.6, the shear strain is also measured by the amount of deflection of an embedded scratch. The result in Fig.5 show a close correlation between techniques.

## Conclusion

The formation of HAGBs and LAGBs do not have a strong correlation with the amount of strain distribution, as demonstrated by the comparison of Fig. 3 and Fig. 5

## References

- [1] Y. Saito, H. Utsunomiya, N. Tsuji, T. Sakai, Acta Materialia 47 (1999) 579-583.
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- [3] M. Z. Quadir, O. Al-Buhamad, L. Bassman, M. Ferry, Acta Materialia 55 (2007) 5438-5448.

