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Modification of Microstructure of Pure Al using Shot Peening Treatment

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Pure Al and its alloys are widely used in aircraft and automobile industries due to their high strength-to-weight ratio and corrosion resistance. Surface modification by the ultrasonic shot peening (USP) is often used to enhance the mechanical properties in surface layer to take advantage of the ultra-fine nanostructure [1]. The USP technique was applied to induce severe plastic deformation with high strain rate on the work piece surface, which facilitates the desired surface properties and microstructure with increased hardness. Therefore, the effect of shot peening on the microstructural evolution and mechanical properties of pure Al are investigated here.

The chemical composition of commercial pure Al is Si-0.08 Fe-0.30 Cu-0.01 Mn-0.04 Mg-0.01 Ti-0.01 V-0.01 Al>99.55. The pure Al was annealed at 450°C to reduce the influence of residual stress before shot peening. Subsequently, the specimens were subjected to USP treatment at various peening time (5 min, 10 min, 15 min, and 30 min) with couple of ball sizes (1.0 mm, 1.5 mm). The effects of shot peening on microstructural evolution and mechanical properties were investigated by using analytical techniques: Optical microscopy (OM), Vickers microhardness test, electron backscattered diffraction (EBSD), and transmission electron microscopy (TEM).

In this study, pure Al samples with a purity of 99.55% after USP was analyzed using microhardness test and various electron microscopic analyses. Nanocrystalline structures were produced in the surface region of by the ultrasonic shot peening, resulting in hardening and gradient microstructures from surface to matrix.

(1) Hardness of the pure Al increased from 28 HV to 38 HV after 5 min shot peening. Extension of the shot peening duration slightly increased the hardness from 38 HV to 42 HV after shot peening for 30 min. while the change of ball size (from 1.0 mm to 1.5 mm) showed little effect on the hardness of the specimen.

(2) Grain refinement occurred during shot peening treatment. Grain size decreased from ~200 μm to ~ 200 nm at the top surface region of the specimen. While the grains were refined to ~ 2 μm at the depth of ~100 μm from top surface. And the deformation depth increased from ~100 μm to ~150 μm with the extension of shot peening duration.

(3) Extension of the shot peeing time showed little effect on the grain refinement at the top surface region. While at region of ~100 μm in depth, annihilation of the dislocation and the sub-grain boundaries occurred with increase of the duration of treatment.

References:

[1] Mhaede, Mansour, Materials & Design 41 (2012), 61-66.

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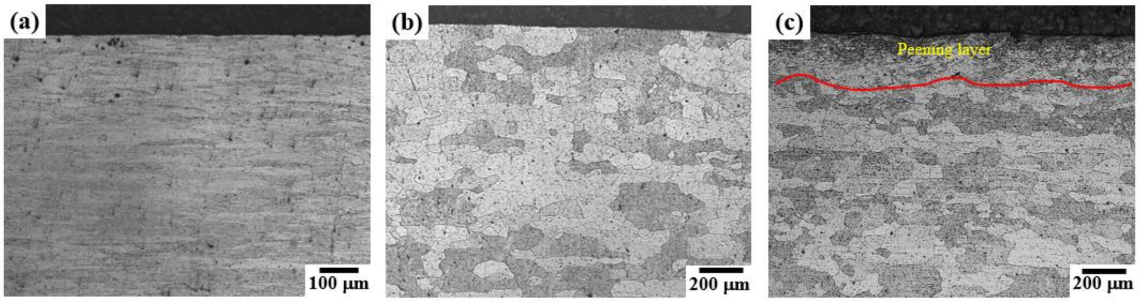

Figure 1. OM images of specimen: (a) as received, (b) annealed, and (c) shot peened.

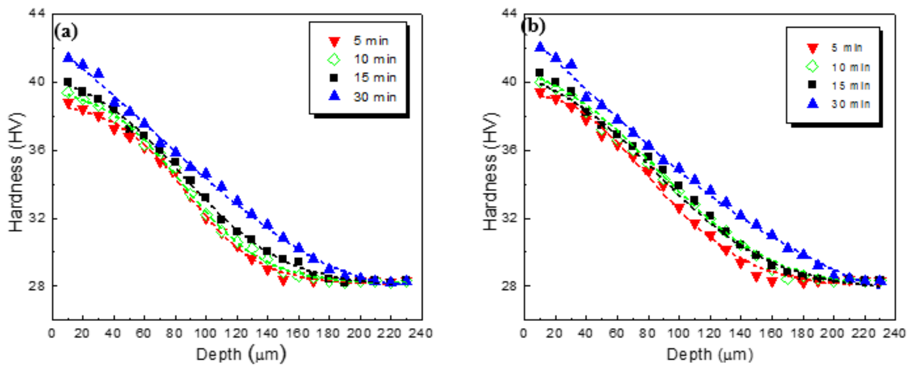

Figure 2. Microhardness change of USP treated pure Al: (a) ball size=1.0 mm, and (b) ball size=1.5 mm.

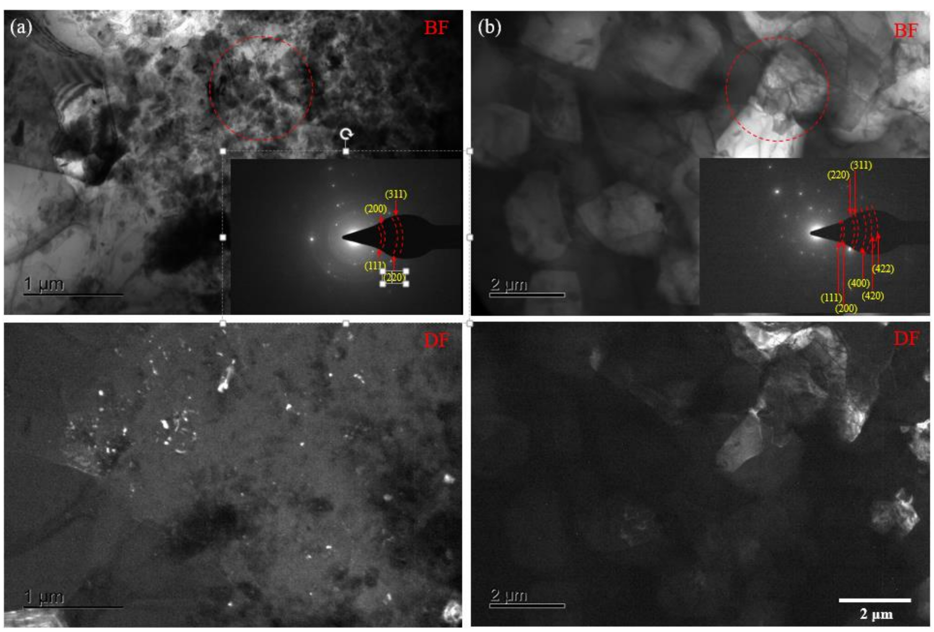

Figure 3. TEM analysis of the USP treated pure Al (ball size 1.0 mm): (a) 15 min-top surface, and (b) 15 min-100µm depth.

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