Advanced Characterization of New High Entropy Alloys That Show Stress-Induced Martensitic Transformation

The low-cost high entropy alloys based on the Fe-Ni-Mn-Cr-Al system showed enhanced mechanical properties through controlling the phases-constitution by alloying. The alloys were characterized using TEM, EBSD, XRD, EPMA and ThermecMaster-Z techniques to understand the internal structure and strengthening mechanisms in them.

The low-cost high-entropy $Al_{(5+X)}Cr_{12}Fe_{35}Mn_{(28-X)}Ni_{20}$ alloys (X= 5 & 10) are designed based on the thermodynamic principles to be along the fcc/(fcc+bcc)/bcc phase boundary [1]. The alloy at the (fcc+bcc)/bcc phase boundary showed apparent high spring back during compression test where stress induced martensitic transformation is expected [2]. The microstructure and mechanical properties of the alloys are investigated using advanced characterization techniques available at IMR, Tohoku University. The alloys were produced using arc melting and tested in the as-cast and cold deformed condition. Elemental mapping of the as-cast and deformed structures was conducted using electron microprobe analysis (EPMA). It was confirmed that the segregation (i.e. dendritic structure) in the as-cast alloys is increasing with increasing the Al-content in the alloy. So, the alloys at the (fcc+bcc)/bcc phase boundary seems show multi-deformation mechanism.

The high magnification EMPA analysis shown in fig. 1.a declares the formation of submicron precipitates rich with Al, Cr and Ni elements. This precipitates is confirmed to be B2 phase impeded in bcc matrix phase through TEM investigations, as show in the diffraction pattern and dark field images in fig. 1.b.

Also, it was confirmed that the alloy produced using low-C Fe-Mn as source of Mn contains C of around 0.54 mass%. Both alloys (with C and C-free) have comparable mechanical performance, as shown in figure 2.a. The microstructure of the alloys was studied using X-ray diffraction and electron backscatter diffraction. No evidence for the stress induced transformation in both alloys (with C and C-free). In situ microstructure change with deformation is needed to confirm or deny the occurrence of stress induced transformation in the alloys. In situ SEM and TEM bending test for micro-cantilever made of the alloy is planned to be done in cooperation with Prof. Takayuki Kitamura at Kyoto University.

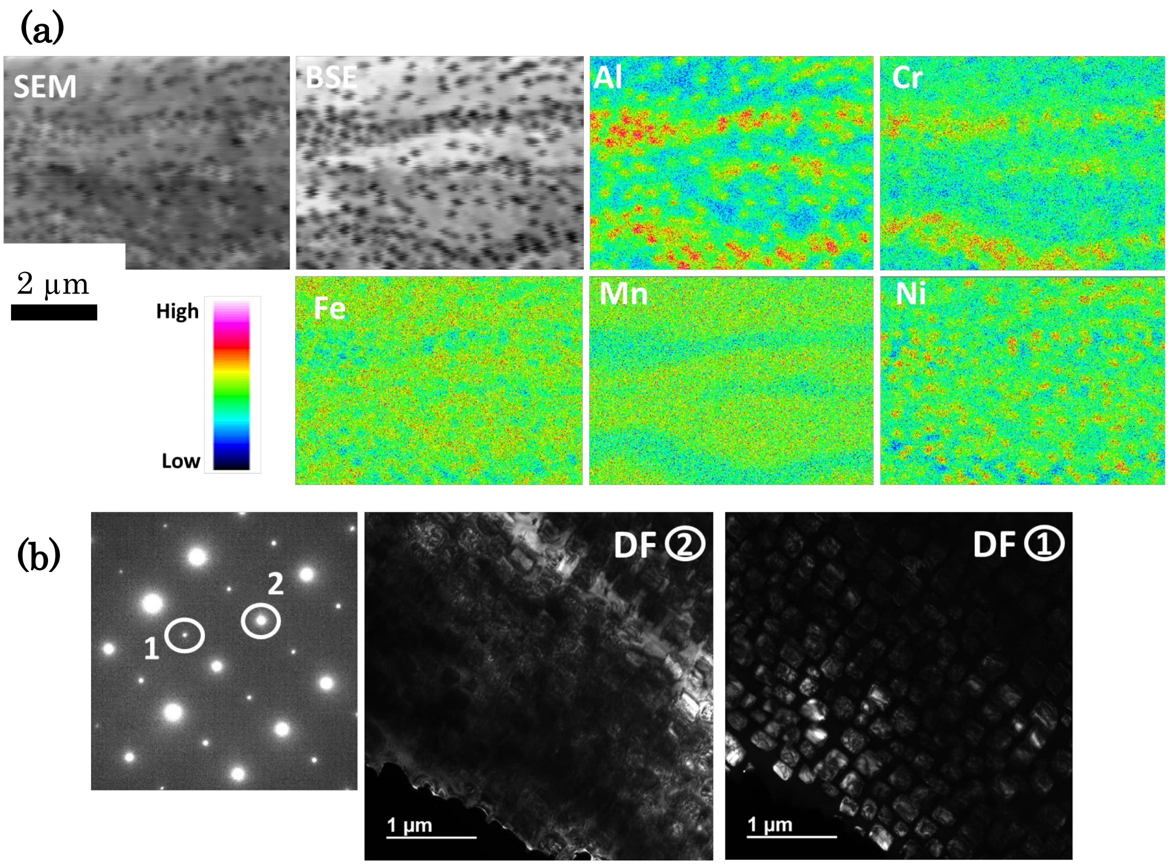

Fig.1 (a) EPMA analysis of $\mathbf{Al_{(15)}Cr_{12}Fe_{35}Mn_{(18)}Ni_{20}}$ alloy in the as cast condition conducted at a spot size of 20 nm, and (b) TEM images (diffraction pattern, left and dark filed, DF images) of $\mathbf{Al_{(15)}Cr_{12}Fe_{35}Mn_{(18)}Ni_{20}}$ alloy in the as-cast condition showing B2 phase (spot 1)impeded in the bcc matrix (spot 2).

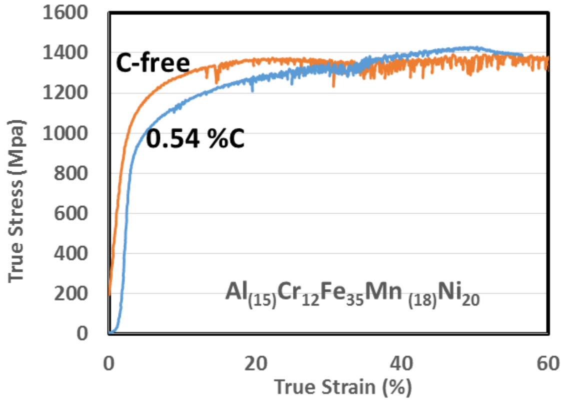

Fig.2 True stress-true strain compressive curves of the $\mathbf{Al_{(15)}Cr_{12}Fe_{35}Mn_{(18)}Ni_{20}}$ alloys with and without 0.54 mass% C-content measured using ThermecMaster-Z technique at initial strain rate of 10^{-3} S^{-1}.

After substituting Mn with Al in $Al_5Cr_{12}Fe_{35}Mn_{28}Ni_{20}$, the yield stress of $Al_{10}Cr_{12}Fe_{35}Mn_{23}Ni_{20}$ increased by ~14%. Moreover, the alloy maintained good cold workability and its tensile ductility exceeded 40%. Cold rolling the alloy to 90% increased its yield stress more than four times. Despite the heavy deformation caused by cold rolling (2.3 true strain), deformation twinning was induced in these alloys [3].

References

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