Making Light-weight Mg-Metal Laminated Nanocomposites

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Introduction

Magnesium is the lightest of all the engineering metals [1]. Replacing steel structural materials with Mg-based materials in automotive applications would boost fuel. However, conventional Mg alloys typically suffer from low strength and poor deformability due to very few slip systems and easy twinning [2].

Alloying Mg with other materials and microstructural engineering are promising approaches to increase ductility and strength of Mg. According to Wang et al. [1.3], interfaces with low energy and high coherency may effectively constrict the nucleation of twins in Mg.

In this work, Mg-metal multilayered nanocomposites will be produced by melt spinning procedure and the layers' mechanical properties will be examined by picoindentation. Meanwhile, plastic co-deformation of the layers can be designed by crystallographic theory and multiscale modelling to achieve fine nanolaminate microstructure in bulk Mg alloys.

Materials and Methods

Ni-Sn alloys with the eutectic composition (34 wt.%) have been made by arc melting followed by melt spinning. SEM and optical microscope were used to examine the cross-sectional microstructure. Mg-34%Al alloy have been made by the same procedure. For this case, boron-nitride crucible was used. The characteristics of interface dislocations of Mg (hcp)/Nb (bcc) laminate composite with Nishiyama-Wassermann (NW) and Kurdjumov-Sachs (KS) orientation relationships are investigated by VASP, MD(Molecular dynamics) and AIFB(atomically informed Frank-Bilby).

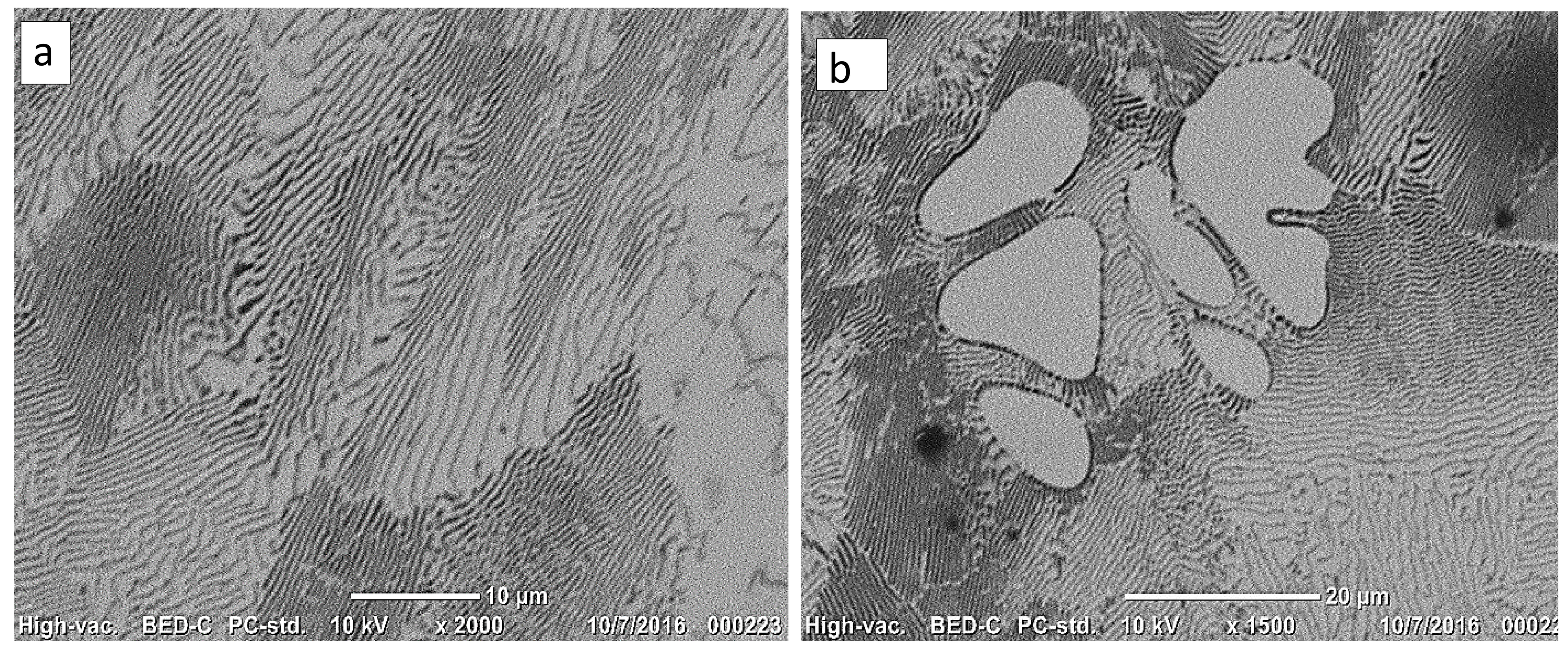

Fig. 1. Microstructure of Ni-Sn arc melted ingot cross section.

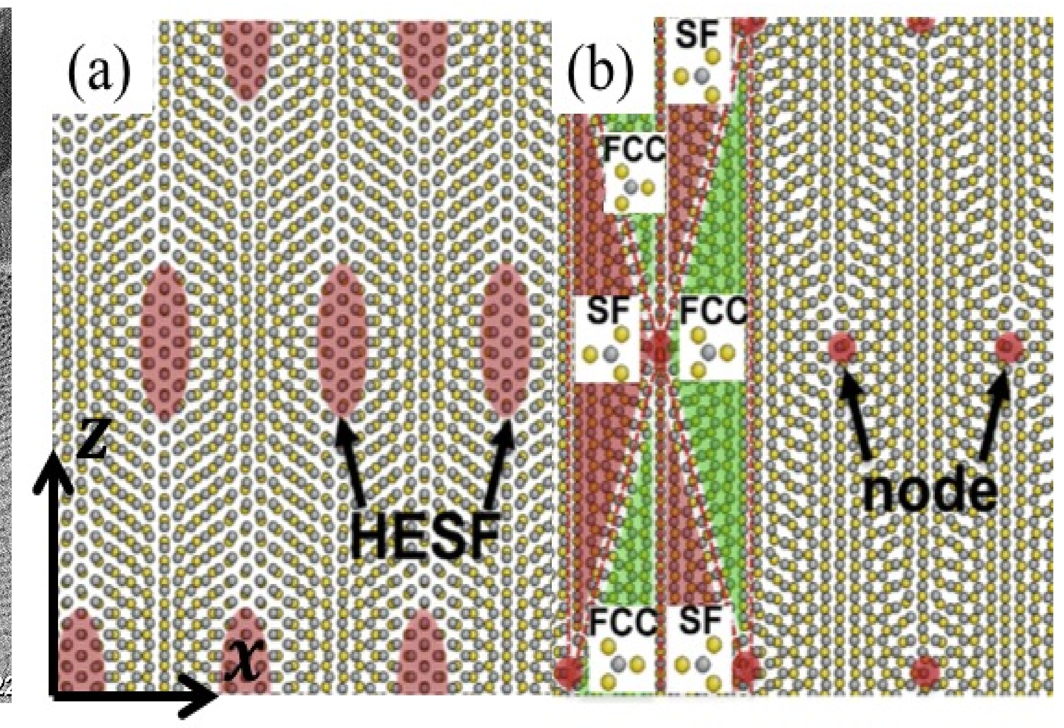

Fig.4. Atomic structures of before (a) and after (b) relaxation of the NW interface.

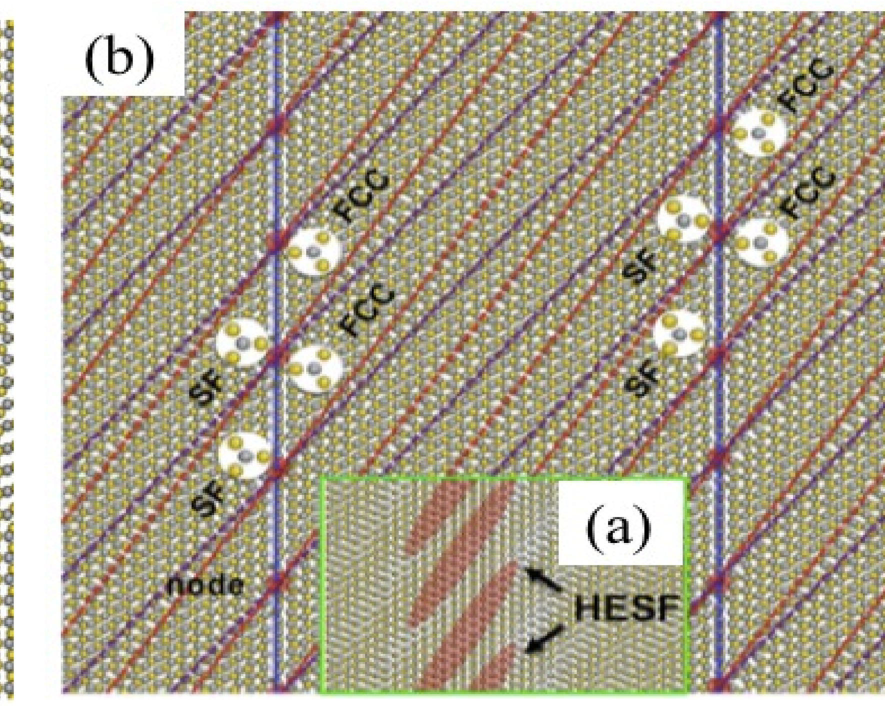

Fig.5. Atomic structures of before (a) and after (b) relaxation of the KS interface.

Results

Microstructure of Ni-Sn arc-melted ingot samples are shown in Fig. 1. The cross section includes mostly the eutectic layers (a) and dendrites in some areas (b) which were made due to the cooling rates higher than equilibrium and probable small variation in the composition during arc melting process.

Figure 2 indicates the microstructure of melt-spun ribbons. The cooling rate is much higher than equilibrium in this process. Hence, roughly half of the cross sectional area is composed of dendrites (Fig. 2a). However, the eutectic layers are obviously present between the dendrites as well as the other half of the cross sectional area (Fig. 2b and c). Due to the high reactivity of magnesium with oxygen, arc melting of Mg-34%Al (eutectic composition) is accompanied by severe oxidation of Mg leading to a highly non-uniform microstructure.

For the NW interface, the atomic structures of the unrelaxed and relaxed Mg/Nb interfaces are shown in Fig.4. For the unrelaxed Mg/Nb interface in Fig.4(a) , the orange ellipses highlighted are HESF regions.

After relaxation, these HESF regions shrinkinto nodes and six coherent interface regions occur around a node taking either FCC structure or SF structure in Fig.4(b). Combined with the further disregistry analysis, it can be concluded that the NW interface is composed of three sets of partial dislocations.

For the KS interface, the atomic structures of the unrelaxed and relaxed Mg/Nb interfaces are shown in Fig.5. In real crystals, overlapped dislocation cores react and form new dislocations.

For instance, the KS interface is composed of four sets of interface dislocations - three sets of partial dislocations and one set of full dislocations that forms from the reaction of two close partial dislocations.

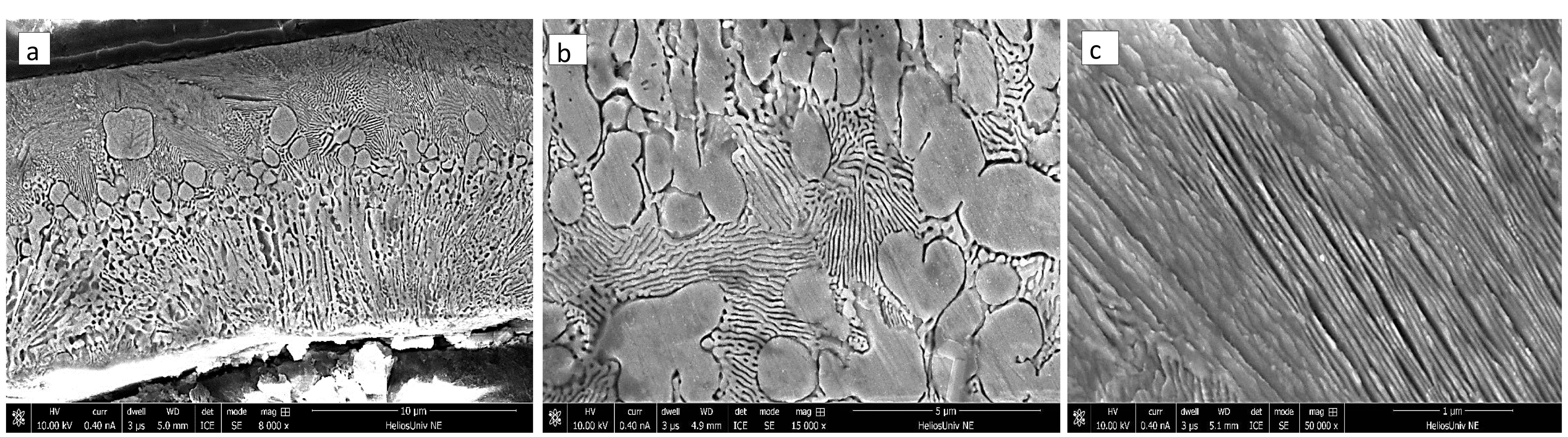

Figure 2. Microstructure of melt-spun ribbons including dendrites and eutectic layers in between.

Fig. 4. Microstructure of Mg-34%Al arc melted ingot.

Conclusions

Studies have shown that magnesium alloys have a great potential to successful use in automotive industry due to the weight reduction which leads to more fuel efficient automobiles and therefore, reduce the greenhouse gases. Accordingly, several Mg-Al laminated composites were produced via arc melting and melt spinning processes and their microstructures were examined. In the future, the experiments will continue in order to achieve a completely layered microstructure and characterization of mechanical properties will be done by picoindentation of micropillars. The further work of simulation will be focused on the understanding thermodynamic properties and mechanical response of Mg/Nb interfaces.

Acknowledgment

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References

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