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**Effects of co-addition of Ni and Al on precipitation evolution and mechanical properties of Fe-Cu alloy**

**Qin Shen<sup>a</sup>, Xiangyuan Xiong<sup>b</sup>, Tong Li<sup>a</sup>, Hao Chen<sup>a</sup>, Yangming Cheng<sup>a</sup>, Wenqing Liu<sup>a\*</sup>**

<sup>a</sup> Institute of Materials, School of Materials Science and Engineering, Shanghai University,  
Shanghai 200444, China.

<sup>b</sup> College of Materials Science and Engineering, Beijing University of Technology, Beijing  
100124, China.

**ABSTRACT** Fe-Cu and Fe-Cu-Ni-Al alloys were aged at 500 °C for different time after solution treatment at 900 °C for 2 h. The influence of co-addition of Ni and Al on the microstructure evolution of Cu-rich phase was studied using atom probe tomography (APT). APT results showed that the addition of Ni and Al effectively increased the number density of Cu-rich particles and reduced their sizes with a narrow size distribution. In the peak hardness condition, the precipitates in the Fe-Cu-Ni-Al alloy exhibited a core-shell structure with the Cu-rich phase in the core and NiAl phase in the outer shell, leading to a dramatic improvement of peak hardness and strength. The NiAl shell of the precipitates impeded the growth and coarsening of the Cu-rich phase by decreasing the interfacial energy and the diffusion rate of Cu, Ni and Al atoms in the shell. After further ageing, the core-shell structure of the precipitates decomposed, forming separate Cu-rich phase and NiAl phase.

**KEY WORDS** Cu-rich phase, Precipitation hardening, Atom probe tomography Fe-Cu-Ni-Al alloy, Ageing

\*Corresponding author: Wenqing Liu

Address: No. 99 Shangda Road, Shanghai 200444, China.

Tel.: +86 21 66135027.

E-mail addresses: wqingliu@163.com.

## **1. Introduction**

Cu precipitation strengthening in steels has been studied extensively and has

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