

## 用三维原子探针研究压力容器模拟钢中富铜原子团簇的析出

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## 3D Atom Probe Characterization of Precipitation of Cu-rich Clusters in Pressure Vessel Model Steel

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摘要 用三维原子探针(3DAP)和热时效处理方法研究压力容器模拟钢中富铜原子团簇的析出过程.提高了Cu含量的压力容器模拟钢样品经过880 °C加热淬火后,在400和500 °C进行了不同时间的时效处理,显微硬度测试结果表明,在400和500 °C时效的过程中硬度峰值分别出现在100和5 h.3DAP分析结果显示,样品在400 °C分别时效100, 150和300 h后,富铜原子团簇的数量密度是递增的,从 $1.5 \times 10^{23} \text{ m}^{-3}$ 增加到 $6.2 \times 10^{23} \text{ m}^{-3}$ ,但富铜原子团簇的长大非常缓慢,团簇的最大等效直径只从2 nm增大到了3.5 nm,团簇中的Cu原子数分数 $x$ 为20%,还含有Mn和Ni,并且观察到Mn和Ni在团簇和基体金属的界面处发生明显的富集.

关键词: 压力容器钢 富铜原子团簇 三维原子探针(3DAP) 热处理

Abstract: Three-dimensional atom probe (3DAP) and thermal aged method were used to characterize precipitation of Cu-rich clusters in pressure vessel model steel. Pressure vessel model steel specimens were quenched at 880 °C, then aged at 400 °C and 500 °C for different time. The results of hardness test show that peak hardness reached for 100 h aged at 400 °C and 5 h aged at 500 °C, respectively. Analysis results of 3DAP indicate that the number density of Cu-rich clusters increases from  $1.5 \times 10^{23} \text{ m}^{-3}$  to  $6.2 \times 10^{23} \text{ m}^{-3}$ , and equivalent diameter of the biggest clusters increases from 2 nm to 3.5 nm after aging 100 h and 300 h at 400 °C. It shows that the growth of Cu-rich clusters is very slow. The content of Cu in Cu-rich clusters is about 20%. Both Mn and Ni atoms are also segregated in Cu-rich clusters and distribution riched at the  $\alpha$ -Fe matrix/clusters interfaces.

Keywords: pressure vessel steel, Cu-rich cluster, 3-dimensional atom probe, thermal aging

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