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Progress in research on nanoprecipitates in high-strength conductive copper alloys: a review

Key words:
Cu alloys; Compound precipitate; Strength; Conductivity

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The Second Largest Nonferrous Metal: Copper

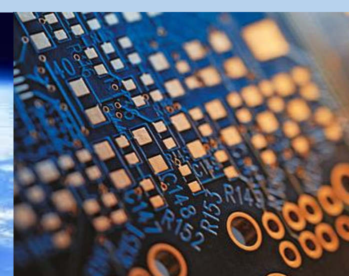
- The wide use of advanced copper alloys

Copper and its alloys have been widely used because of their excellent electrical conductivity. The annual output of copper products in China has reached 18.16 million tons, accounting for more than 2% of the national GDP.

- An important role in high-speed railway

As the source of electricity for the trains, contact wires are the heart of high-speed railways. And the contact wires are commonly made of high-strength conductive Cu alloys.





The Key of Strengthening Mechanism: Precipitates

The second section analyzes the three parameters usually involved in precipitates:

- Shape of precipitates
- Coherence between precipitates and copper matrix
- Orientation relationship between precipitates and the matrix

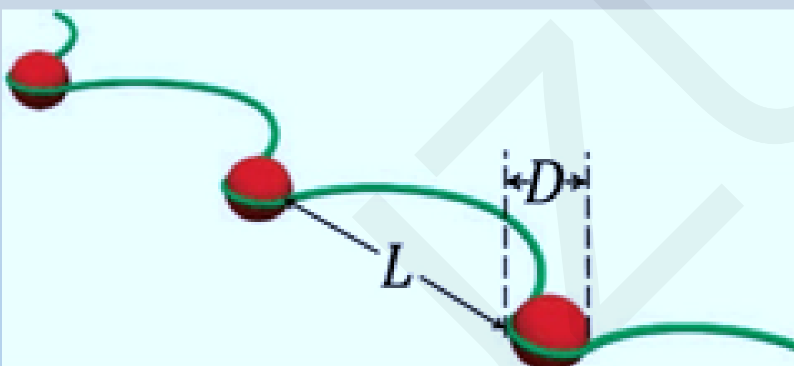


Fig. 1 Schematic diagram of dislocation bending between precipitates with diameter D and distance L. (Szajewski et al., 2021)

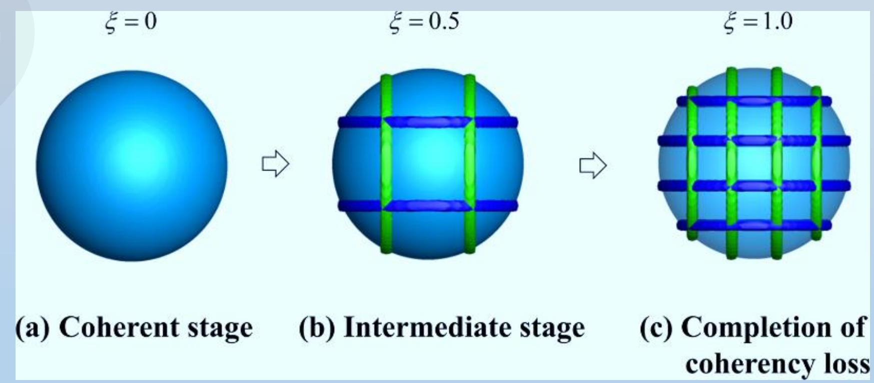


Fig. 2 Schematic diagram of the transition of a precipitate from coherent to incoherent. (Cheng and Wen, 2021)

Some Examples in Precipitation Strengthening Copper Alloys

In the third section, according to four mature systems (Cu-Cr-Zr, Cu-Zr, Cu-Ni-Si, Cu-Fe-P), the existing research on the precipitates was summarized, and the development trend was proposed from the perspective of composition and processing.

- Cu-Cr-Zr

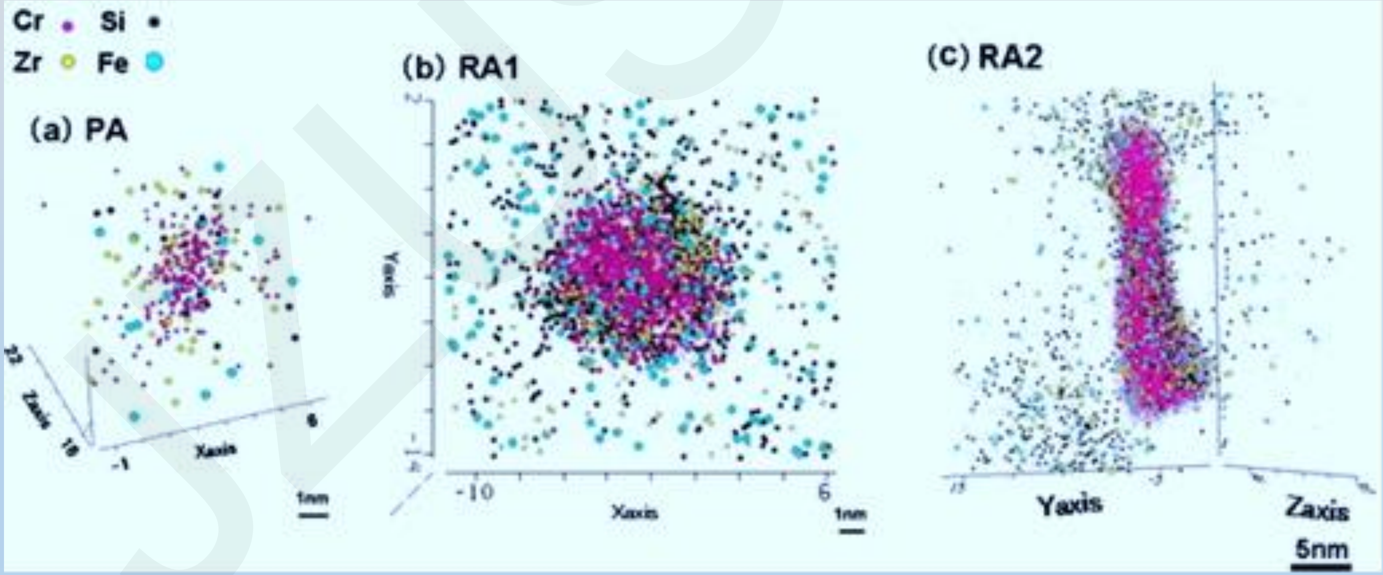


Fig. 3 Exploring the mechanism of Zr hindering the coarsening of Cr phase in Cu-Cr-Zr by 3D atomic probe. (Hatakeyama et al., 2009)

Some Examples in Precipitation Strengthening Copper Alloys

- Cu-Zr

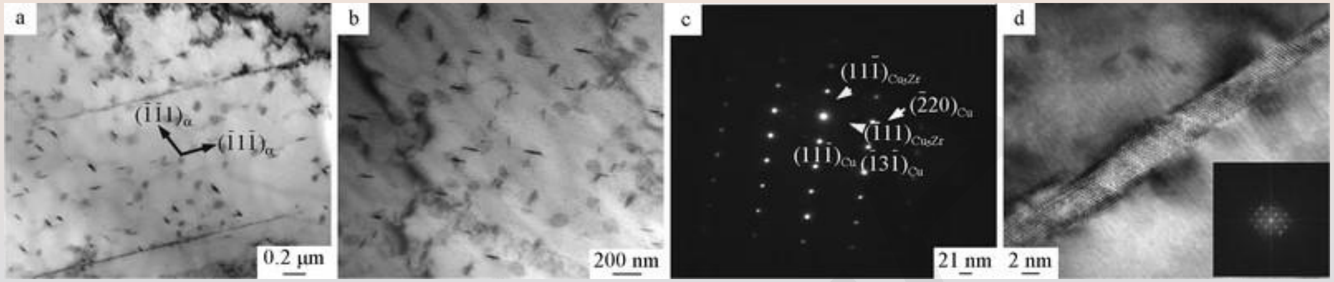
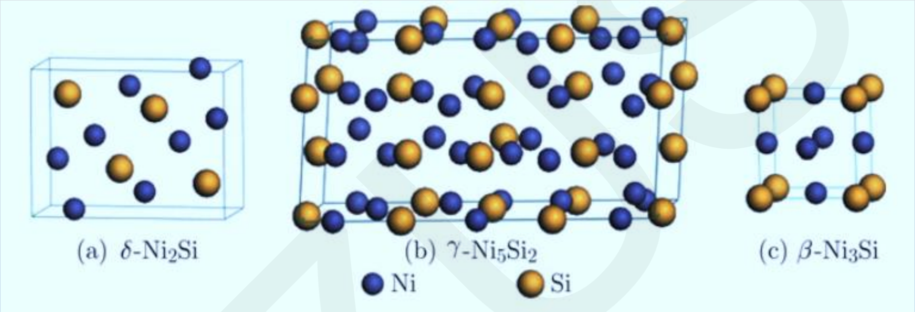


Fig. 4 Observation of the shape, size, distribution and orientation relationship of precipitates in Cu-Zr alloy by TEM. (Peng et al., 2015b)



- Cu-Ni-Si

Fig. 5 Models of three possible precipitates in Cu-Ni-Si alloy. (Long et al., 2011)

- Cu-Fe-P

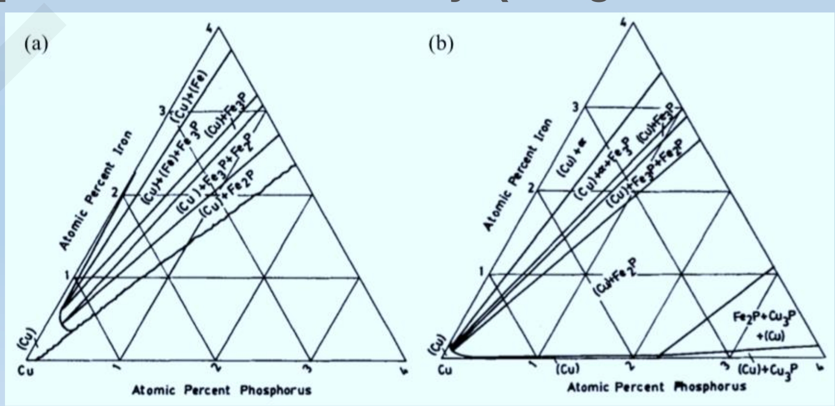


Fig. 6 Calculated phase diagrams of Cu-Fe-P at 1000 °C (a) and 700 °C (b). (Raghavan, 1998)

Some Work by Our Research Group

Below is a list of alloy systems with development potential that our research group has developed and confirmed in recent years.

Table 1 Properties of some potential alloys and their compositions and processes

Alloy composition	Processing	Hardness (HV)	Electrical conductivity	Reference
Cu-1.06Co-0.45Si (%, mass fraction)	1050 °C solution treatment and 450 °C aging treatment	190	34.4% IACS	(Lei et al., 2021)
Cu-0.61Co-0.43Ti (%, mass fraction)	1050 °C solution treatment, cold deformation, and 450 °C aging treatment	170	81% IACS	(Yang et al., 2021a)
Cu-0.44Fe-0.23Ti (%, mass fraction)	1050 °C solution treatment and 500 °C aging treatment	183	78% IACS	(Zhao et al., 2021)
Cu-0.74Fe-0.33Ti (%, mass fraction)	1050 °C solution treatment, cold deformation, and 500 °C aging treatment	196	69% IACS	(Yang et al., 2021b)

Conclusions and prospect

Precipitation-strengthened Cu alloys represent an essential segment of fields with high performance requirements. An important aspect of this research is finding ways to control the properties of each system. One can regulate properties by adding alloying elements or changing the preparation process, and use characterization technology and simulation methods to provide an understanding of the mechanisms involved. By summarizing the contents of this review, the current prospects of high-strength conductive Cu alloy with nanoprecipitates become clear.