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Distinctive slow β relaxation and structural heterogeneity in (LaCe)-based metallic glass

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Abstract

The $(LaCe)_{32.5}Co_{20}Al_{15}$ bulk metallic glass was found to display a pronounced slow β-relaxation at low temperature, which was well separated by α-relaxation based on the mechanical spectroscopy. The activation energy for α-relaxation E_α is 335 kJ/mol, and this process revealed in the master curve can be well fitted by a Kohlrausch-Williams-Watts (KWW) function with γ_{KWW} value of 0.463. The activation energy for the slow β-relaxation E_β is determined to be 76 kJ/mol, which obeys an empirical rule that E_β equals $22RT_g$. The dynamic mechanical behavior of this metallic glass can be well explained by quasi-point defects (QPDs) theory. The correlation factor χ is deduced to be 0.44 from the experimental results, which suggests remarkable heterogeneity in this (LaCe)-based metallic glass. This closely relates to the origin of the prominent β-relaxation.

Keywords: α relaxation, β relaxation, dynamic mechanical property, metallic glass.

1. Introduction

Mechanical relaxation of metallic glasses is one of key issues which arouses great scientific interests in the field of condensed matter physics [1,2]. There are at least two kinds of relaxation processes in metallic glasses [3]: (i) a main relaxation process named α-relaxation, which is an irreversible process around the glass transition temperature T_g and corresponds to the cooperative movement and rearrangement of atoms in a large scale. (ii) a secondary relaxation, also called β-relaxation or Johari-Goldstein (JG) relaxation [4], which is related to a reversible process that is limited in local non-cooperative atomic movements. In contrast to α-relaxation, the slow β-relaxation always observed at low temperature or high frequency domain, and the temperature dependence of its peak frequency below T_g obeys an Arrhenius law [5].

Previous studies [6,7,8] show that the property of α- and β- relaxations is sensitive to the alloy composition and mainly determined by the fluctuations of chemical interactions among the constituting atoms in metallic glasses. The slow β-relaxation is reported to be closely linked to