Scientists detect exponential relaxation spectrum in glasses

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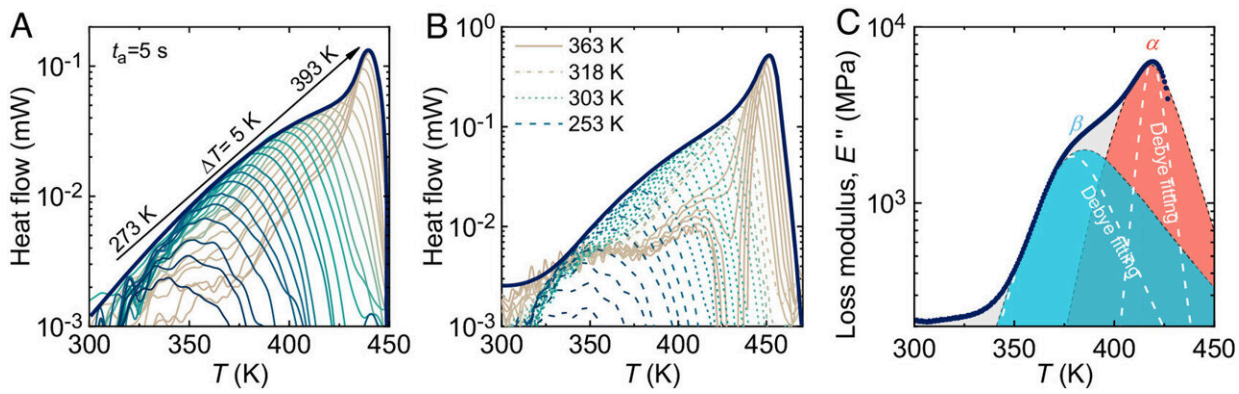

The spectrum of the exponential relaxation peaks. Credit: NIMTE

Prof. Wang Junqiang's team at the Ningbo Institute of Materials Technology and Engineering (NIMTE) of the Chinese Academy of Sciences has revealed the exponential relaxation events during the recovery process of glasses, providing solid evidence that non-exponential relaxation peaks in glasses are composed of a series of exponential relaxation units. The study was published in *Proceedings of the National Academy of Sciences*.

Nonexponential relaxation reflects the nature of glasses, which are among the research hotspots in condensed matter physics. The hypothesis that nonexponential relaxation peaks contain a series of

exponential events is well known, but has not been verified. This is due to the lack of critical experimental evidence, in particular a systematic exponential relaxation spectrum in glasses.

To address this issue, the researchers have studied the exponential relaxation spectrum in glasses during the recovery process.

The enthalpy relaxation peaks after annealing treatment were measured using a high-precision nanocalorimetry technique that is universal for metallic glasses and organic glasses. To compare the enthalpy relaxation spectrum, the dynamic mechanical spectra were measured under sinusoidal tensile stress using a dynamic mechanical analyzer (DMA).

The relaxation peaks exhibited exponential characteristics that can be fitted by the Debye function. The exponential relaxation events are the units of relaxation in glasses. It is referred to as Relaxun, as the abbreviation of relaxation unit. Additionally, the activation energy of the relaxation spectrum under different annealing temperature and annealing time was determined.

A complete spectrum of the exponential relaxation peaks was obtained over a wide temperature range from 0.63 T_g to 1.03 T_g, which was similar to the DMA loss modulus curve, thus reflecting that the non-exponential relaxation peaks can be divided into exponential relaxation units. In other words, the spectrum can be precisely controlled by multi-step annealing treatment.

The activation energy covers a wide range from α relaxation to β relaxation and even the fast γ/β′ relaxation. Furthermore, the quantitative contributions of different relaxation modes to the non-equilibrium enthalpy evolution during aging were measured.

This work sheds light on the research of non-equilibrium

thermodynamics as well as the precise modulation of glass properties by relaxation mode control.

More information: Lijian Song et al, Detecting the exponential relaxation spectrum in glasses by high-precision nanocalorimetry, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2302776120

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