Multiple Channels of Relaxation in Glasses

The knowledge of how atoms (or molecules) move is crucial for understanding the state of a material, and the existence of a decoupling of relaxation modes on cooling supercooled liquids has for instance dramatically improved our knowledge on the ongoing processes responsible for the vitrification and deformation. However, the movement of atoms in glasses – very thick liquids that move extremely slowly, are extremely to model, just as the process of geological evolution in nature, as their relaxation time is incredibly long.

Recently, LUO Peng *et al*. in Prof. WANG Weihua's group from the Institute of Physics, Chinese Academy of Sciences investigated the relaxation dynamics of various metallic glasses (MGs) by following the stress decay under constant strain and temperature on a dynamic mechanical analyzer (DMA).

The temperatures investigated rang from the glass transition temperature T_g, down to the deep glassy state; and the time window spans more than five decades. They find the surprising emergence of two diverging relaxation processes as the temperature decreases. One of them rises faster, exhibiting compressed anomalous exponential decay (*exponent*>1) and negligible temperature dependence; while the other, rises slowly, showing normal stretched exponential decay (*exponent*<1) and an activation energy of $52k_BT_g$, corresponding to the structural α relaxation. The faster one differs in both time scales and activation energy from the known β relaxation, implying the occurrence of a new process of the glassy state that shares many similarities with the microscopic anomalous dynamics of MGs.

These results suggest the existence of additional active processes in the glassy state, which are not taken into account in previous experimental and theoretical works. The current work shows that during this sluggish process, the material relaxes external stresses through

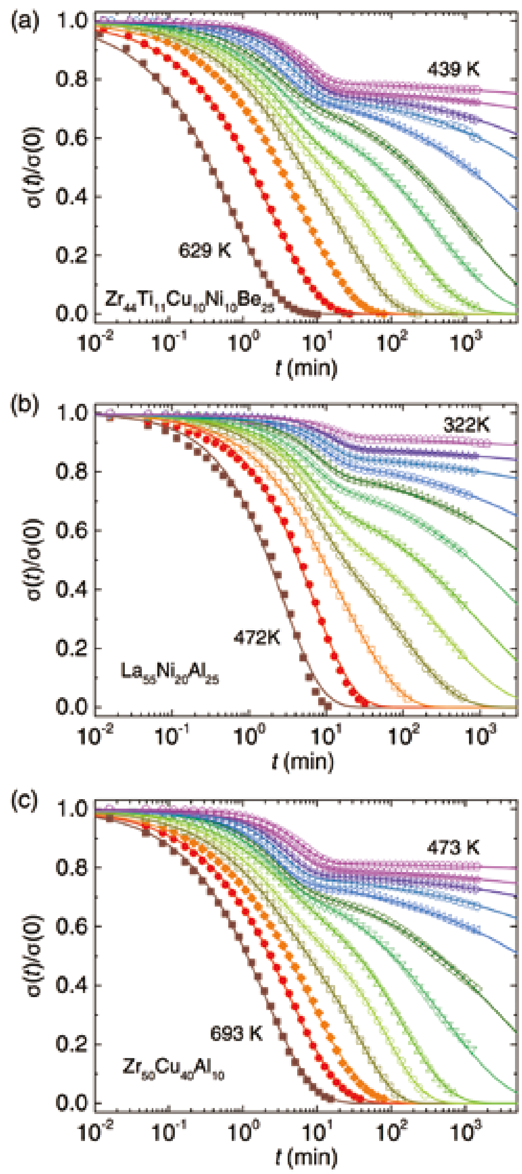

Fig.1 Stress relaxation profiles of three metallic glass systems. The applied tensile strain is 0.3%, and solid lines are theoretical fits to the data. The obtained fitting parameters are plotted in Fig. 2. (Image by Institute of Physics)

two main channels, resulting in a novel fast microscopic reorganization, accompanying a slow heterogeneous relaxation of the whole amorphous matrix.

Different from previous works, here the researchers probe the mechanical response in the deep glassy state. Their findings of a two-step response function under stress unveil a complex dynamical pattern even at macroscopic scales, and suggest the existence of a far richer-than-expected scenario in glasses with the potential occurrence of unexplored phenomena likely hidden by their long-time nature.

The study titled "Relaxation Decoupling in Metallic Glasses at Low Temperatures" was published in *Physical Review Letters*, and was selected as a "Viewpoint" in *Physics* (please see https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.118.225901 and https://physics.aps.org/articles/v10/58)

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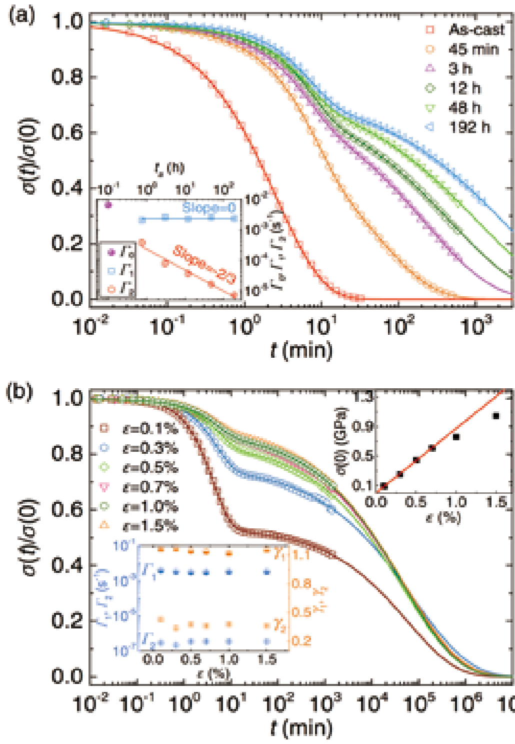

Fig.3 Stress relaxation profiles for samples of different ages (a) and at different strains (b). (Image by Institute of Physics)

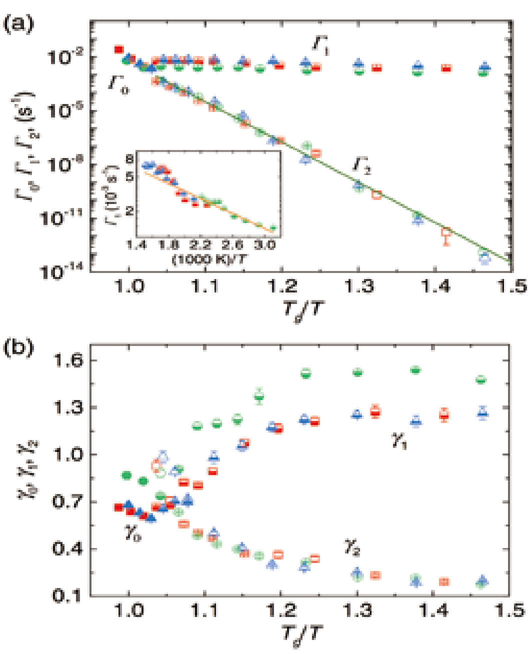

Fig.2 The fitted relaxation rate (a) and exponent (b) as a function of *Tg/T*. (Image by Institute of Physics)

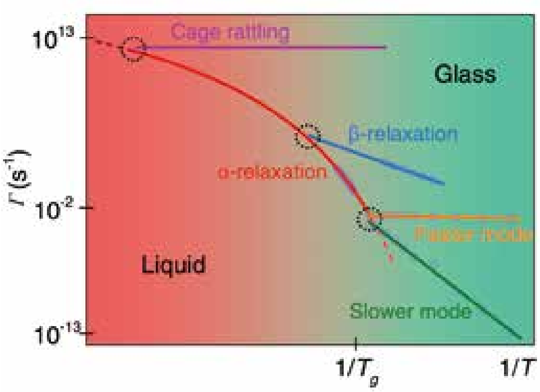

Fig.4 Schematic Arrhenius diagram concerning dynamical behaviors of MG and its high temperature precursors. (Image by Institute of Physics)

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