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NMR Observation of Dynamics in Metallic Supercooled Liquids and Glasses¹

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Dynamic crossover at temperature $T_c > T_g$ in the supercooled liquid is an important issue for understanding the nature of glass transition. In a liquid of densely packed atoms, any given atom is temporarily trapped by the transient cage formed by neighboring atoms. Mode-coupling theory (MCT) predicts that such cage trapping of atoms undergoes a dynamic arrest below T_c leading to a liquid to solid transition in the absence of hopping. Here we show that NMR could detect selectively different types of atomic motions based on their different spatial characteristics and timescales. The discussion will focus mostly on results obtained from the bulk metallic glass $Pd_{43}Ni_{10}Cu_{27}P_{20}$, one of the best glass formers with extremely high accessibility to the supercooled liquid region. We will show that the Knight shift of ³¹P is an NMR parameter sensitive to the Debye-Waller factor caused by local vibrations and cage rathing. Experiment shows that the mean-squared amplitude of such local motions depends linearly on $k_B T$ above a certain crossover temperature T_c as well as below T_g as expected by the equipartition theorem for harmonic vibrations. From T_c down to T_g , the mean-squared amplitude decreases much more rapidly. Such crossover behavior is shown to be in good agreement with the prediction of the MCT with regard to motions of cage rathing. We will also show that NMR of quadrupolar nuclei ⁶⁵Cu and ⁶³Cu can probe the time correlation function of the local electric-field gradient (EFG) in the supercooled liquid. We measured the temperature dependence of the EFG correlation time which is closely related to atomic diffusion. Once again, the result is shown to be consistent with the prediction of the MCT.

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