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Study of layer-dependent dynamics of Dirac Fermions in quasi-crystalline bilayer graphene by *concerting* usages of positron diffraction and time-resolved photoemission spectroscopy

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Dynamical behavior of carriers in graphene has attracted academic interests to investigate temporal evolutions of the massless Dirac Fermions and also technical needs to develop the next-generation optoelectronic devices. The comprehensive understanding has been conducted by direct observations of the electronic states by time- and angle-resolved photoemission spectroscopy (TARPES) [1-3]. Using optical pulses, photo-excited carriers in graphene layers were traced in real time and the dynamics was described by various elementary processes. Recently, twisted bilayer graphene was synthesized and showed intriguing properties, such as quasi-crystallinity at twisted angle of 30° [4]. The novel material has further opened a research filed of ”Twistronics”. TARPES measurements on the epitaxial quasi-crystalline bilayer graphene (QCBG) observed the transient voltage between the two layers that were not expected theoretically. The experimental reasoning has required contributions from the substrate or the interface but the detailed scenario has remained unknown. Compared to a free-standing layer of graphene, the epitaxial graphene layer is complicated with various external factors, *i.e.* interface, substrate, and doping. Thus, it is required to investigate the environmental effect to reveal dynamics of the Dirac Fermions in reality.

In the present research, we performed TARPES measurements on various systems of single and bilayer graphene on the Si-face SiC substrates to extensively study the carrier dynamics. In QCBG, we confirmed temporal evolutions of photo-excited carriers in Dirac cones that were asymmetric between the upper and lower layers, which should be described by the transient doping from the interface. The quantitative discussion was made with the structural parameters, interlayer distance, determined by positron diffraction (PD) experiments [5]. The concerting usages of TARPES and PD quantitatively revealed the transport mechanism that was induced by the optical pumping. Furthermore, our systematic results of graphene layers on various types of the SiC substrate [1-3] have led to assign a reasonable source of the doping carrier. The details will be described in the presentation.

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