Effects of on-site energy difference on the electronic response of $Sr_3(Ir_{1-x}Mn_x)_2O_7$

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We investigated the doping and temperature evolutions of $Sr_3(Ir_{1-x}Mn_x)_2O_7$ single crystal with $0 \leq x \leq 0.36$ by utilizing infrared spectroscopy. As the effective total angular momentum $J_{eff} = 1/2$ Mott insulating state in $Sr_3Ir_2O_7$ is realized by the strong spin-orbit coupling, Mn substitution, which is expected to weaken the spin-orbit coupling, may induce insulator-metal transition. While Mn substitution induced low-energy ingap excitation at about 0.3 eV in optical conductivity, it did not result in insulator-metal transition. Moreover, the resonance energies of the optical transitions between the $J_{\rm eff}$ bands were barely changed with Mn substitution, indicating the robustness of the spin-orbit coupling. We attribute these two phenomena to a large difference between the on-site energies of the impurity Mn states and the host Ir states. This conjecture is supported by the emergence of a high-energy optical excitation at about 1.2 eV, which is larger than those of the optical transitions between the $J_{\rm eff}$ bands, in the Mn-doped compounds. The temperature evolution of the optical response was also affected by Mn substitution. The anomaly in the optical response of the $Sr_3Ir_2O_7$ at the antiferromagnetic transition temperature was suppressed in the Mn-doped compounds despite the persistence of the long-range antiferromagnetic ordering. The absence of the spin-charge coupling was ascribed to charge disproportionation of the Ir ions.