

Exciton Mott transition and quantum pair condensation in electron-hole systems: Dynamical mean-field theory

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Quantum cooperative phenomena in electron-hole (e-h) systems are reviewed from a theoretical viewpoint, stressing the exciton Mott transition, the exciton Bose-Einstein condensation (BEC), the e-h BCS-type condensed state, and their crossover. To clarify these phenomena, modern theoretical tools are necessary which can cover not only low and high particle density regions but also intermediate density region.

Here, we confine ourselves to high-dimensional e-h systems, which are described simply by the e-h Hubbard model with both repulsive (e-e and h-h) U and attractive (e-h) U' *on-site* interactions. We study the metal-insulator transition called the “exciton Mott transition (EMT)” at zero and finite T temperatures, investigated with the dynamical mean-field theory (DMFT) [1] and with the slave-boson mean-field theory [2]. Away from half-filling we find two types of insulating phases: exciton-like and biexciton-like insulators in the (U, U') plane. Coexistence region between metallic and insulating phases is also found reflecting the first-order transition of the EMT. At the Mott-critical temperature such EMT disappears, and the crossover is observed above the critical temperature.

Effects of inter-site interaction on the EMT are investigated by the extended DMFT applied to the extended e-h Hubbard model, which incorporates both repulsive v and attractive v' *inter-site* interactions in addition to U and U' . The inter-site interactions do not change the nature of the EMT in high dimensions but tend to stabilize the metallic e-h plasma state when v and v' have the same strength. By contrast, small difference between v and v' drives the system to the insulator with the strong fluctuations of the mass density wave [3].

We discuss also the crossover between the exciton BEC and the e-h BCS states using the self-consistent t -matrix and local approximations [4] in the framework of the DMFT for the e-h Hubbard model. The transition temperature is calculated in the crossover regime. Then, we will discuss the whole phase diagram of the e-h system in the $(U=U', T)$ plane. Optical absorption spectra are also introduced. We will mention comparison with the one-dimensional e-h systems [5].

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References

1. Y. Tomio and T. Ogawa, *J. Lumin.* **112**, 220 (2005); T. Ogawa, Y. Tomio, and K. Asano, *J. Phys.: Cond. Mat.* **19**, 295205 (2007); T. Ogawa and Y. Tomio, *J. Lumin.* **128**, 1022 (2008).
2. K. Asano and T. Ogawa, *Physica E* **40**, 1249 (2008).
3. T. Ohashi, Y. Tomio, and T. Ogawa, *phys. stat. sol. C* (in print).
4. Y. Tomio, K. Honda, and T. Ogawa, *Phys. Rev. B* **73**, 235108 (2006); *J. Lumin.* **128**, 1032 (2008).
5. K. Asano and T. Ogawa, *J. Lumin.* **112**, 200 (2005); T. Hanamiya, K. Asano, and T. Ogawa, *Physica E* **40**, 1401 (2008); T. Ogawa, *phys. stat. sol. B* **118**, 83 (1995).