The exciton Mott transition in coupled quantum wells

M. Stern, V. Garmider, V. Umansky, I. Bar-Joseph

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The Mott transition

Insulator to metal transition

Dilute exciton gas
Dense excitons
density

e-h plasma

The Mott criterion: $N \sigma^3 \sim 0.2$
The Mott transition of excitons

- Google scholar: 2780 entries
- Mostly optical studies
- No thermodynamic phase transition is observed
Non equilibrium Phase diagram?

A gradual transition $1 \times 10^{10} - 1 \times 10^{11}$ cm$^{-2}$
The Coupled Quantum wells system

- Long relaxation time
  \[ \Rightarrow \text{Thermodynamic equilibrium} \]
- Low binding energy
  \[ \Rightarrow \text{Low critical density} \]
- Control parameters
  \[ \Rightarrow \text{E field Structure design} \]
$E_B = 2.5 \text{ meV}$
Measuring the Exciton Conductance

Forming ohmic contacts to intrinsic sample
Side contacting

Top n+ layer

Quantum Well

Self aligned lithography

Selective n and p contacts
Conductance measurements
Temperature dependence

An insulator to metal transition?
Exciton Diamagnetism: a measure for exciton size

\[ \Delta E = E(1\text{T}) - E(0) \]

\[ \Delta E(B) = \alpha B^2 \langle r^2 \rangle \]

\[ \alpha = \frac{e^2}{8\mu c^2} \]
How does the diameter change with power?

Abrupt transition in exciton size
The effect of the electric field

Abrupt transition with gate voltage
Conjugate parameters
The PL properties

Line width

Peak energy
The exciton density

The transition occurs at $\sim 2 \times 10^9 \text{ cm}^{-2}$

Lower than BEC critical density at 1.5 K!!!
P-V Phase Diagram
What about the temperature?

Re-enterance behavior!
P-T Phase Diagram

- Indirect Exciton
- e-h plasma

$P \text{ [W/cm}^2\text{]}$

$T \text{[K]}$

- $F=25.75 \text{ kV/cm}$
Has it been observed before?
Phase Transition of an Exciton System in GaAs Coupled Quantum Wells

T. Fukuzawa
IBM Research Division, Tokyo Research Laboratory, Sanban-cho, Tokyo 102, Japan

E. E. Mendez and J. M. Hong
IBM Research Division, T. J. Watson Research Center, Yorktown Heights, New York 10598
(Received 2 April 1990)
Fermi-Dirac Distribution of Excitons in Coupled Quantum Wells

J. A. Kash, M. Zachau, E. E. Mendez, and J. M. Hong
IBM Research Division, T. J. Watson Research Center, Yorktown Heights, New York 10598

T. Fukuzawa
IBM Research Division, Tokyo Research Laboratory, Sanban-Cho, Tokyo 102, Japan
(Received 4 January 1991)

Narrow QWs
Highly disordered
Phase diagram of a two-dimensional liquid in GaAs/Al_{x}Ga_{1-x}As biased double quantum wells

V. B. Timofeev and A. V. Larionov

Institute of Solid State Physics, Russian Academy of Science, 142432 Chernogolovka, Russia
Conclusions

• Mott transition of indirect excitons
• An insulator to metal transition
• A change in exciton diameter
• Re-entrant temperature dependence
• P-V phase diagram