Persistent Current in Two-dimensional Mesoscopic Ring Systems

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Coherent motion of electrons in mesoscopic systems under magnetic fields leads to mesoscopic fluctuations, Aharonov-Bohm (AB) oscillation and de Haas-van Alphen (dHvA) oscillation in physical quantities. Coherence of electrons is reduced at finite temperature. Therefore it will be interesting to investigate effects of temperature in various mesoscopic systems. Two-dimensional mesoscopic disc systems have been studied in wide range of temperature by Ishikawa and Fukuyama [1]. They studied spatial distribution of persistent current and resultant magnetization and presented a phase diagram in the plane of temperature and magnetic fields. The phase diagram indicates three phases, mesoscopic fluctuations at low temperature, dHvA oscillation in intermediate temperature and Landau diamagnetism at high temperature. Spatial distribution of persistent current and magnetization show characteristic features in each region.

In the present paper, we investigate two-dimensional ring systems based on the same exactly solvable model [2] as Tan and Inkson [3]. We study the orbital magnetism of several ring systems with different width [4]. Following the study of Ishikawa and Fukuyama [1], we calculate spatial distribution of persistent current and resultant magnetization in wide range of temperature and aim at giving a systematic understanding of the orbital magnetism of the two-dimensional ring systems. Two-dimensional ring system shows AB oscillation due to interference effects at low temperature, when the width is very narrow and only one Landau sublevel is occupied. The AB oscillation appears even in strong fields, but its amplitude is seen to be suppressed as the magnetic field increases because of the finite width. When the width is not very narrow and several Landau sublevels are occupied, AB oscillation transformed into mesoscopic fluctuations as seen in disc systems. There appears also DHvA oscillation in intermediate temperature. At high temperature where interference effects are reduced, Landau diamagnetism whose magnitude is proportional to the effective area of the ring appears irrespective of the width of the ring. Phase diagrams for both narrow and wide rings in the plane of temperature and magnetic fields are systematically presented.

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