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InAs quantum well Hall devices for room-temperature detection of magnetic biomolecular labels[1]

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The integration of micro- and nanoscale magnetics with molecular biology promises novel applications in fundamental studies of molecular interactions as well as in bioanalysis and biomedical functions. The implementation of this concept requires detection of biomolecular labels in the form of superparamagnetic micro/nano beads, ideally with single bead sensitivity. In this talk we will present our work on the development of miniaturized Hall sensors for detection of such beads. The devices, with Hall cross widths of $\sim$1 μm and $\sim$250 nm, were fabricated from InAs/AlSb quantum well semiconductor heterostructures. Their room-temperature characteristics were examined by Hall effect and electronic noise measurements. In the low frequency range, from 20 Hz to 1.6 kHz, devices have the noise-equivalent magnetic moment sensitivities of order $10^6\mu_B/\sqrt{\text{Hz}}$ and $10^5\mu_B/\sqrt{\text{Hz}}$ respectively. The sensitivity of the latter reaches the $10^4\mu_B/\sqrt{\text{Hz}}$ range above $\sim$ 1 kHz. By using a phase-sensitive measurement technique and micron-sized Hall crosses we achieved detection of a single 1.2 μm diameter bead with a signal to noise ratio (S/N) of $\sim$ 33.3 dB, as well as detection of six 250 nm beads with S/N of $\sim$ 2.3 dB per bead. Our results from the micro-Hall susceptibility measurement on a single microbead can be explained quantitatively as due to the magnetic response of an ensemble of non-interacting magnetic nanoparticles with broad distribution of magnetic moments. The work demonstrates the efficacy of InAs quantum well Hall devices for applications in high sensitivity magnetic biomolecular detection.

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