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Magnetoresistance of Shadow-masked and Micro-structured Magnetic Tunneling Junctions

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Magnetic tunnel junctions (MTJ) are sandwiches of two ferromagnetic (FM) layers separated by a thin insulating layer. The tunneling resistance of the sandwich for current flow perpendicular to the layers depends on the magnetic arrangement of the moments of the two magnetic layers. Typically the resistance is lowest when these moments are aligned parallel to one another and is highest when antiparallel, thereby giving rise to magnetoresistance (MR). Although MTJs have a long history dating back more than 20 years only small MR effects were observed until recently. We have observed large MR at room temperature in MTJs fabricated using magnetron sputtering, and in-situ plasma processing of the tunnel barrier, with substrates at ambient temperature. MR values exceeding 25 percent at room temperature and 40 percent at low temperatures are found for MTJs with areas ranging in size from 80μm x 80μm to as small as 0.1 μm x 0.6 μm. The area of the MTJ is defined either by contact masks, placed in-situ under computer control, or by a simple self-aligned process, involving optical and/or e-beam lithographies. Whilst the resistance of the junctions scales, as expected, with inverse junction area, the MR is independent of the junction size for junctions varying in area by more than 5 orders of magnitude. Two well defined magnetic states of the MTJ are achieved via the magnetic pinning of one of the FM layers by exchange-biasing with an antiferromagnetic layer. This gives rise to large room temperature MR in small fields since the moment of the unpinned layer can readily be rotated so that it is either parallel or anti-parallel to the moment of the pinned layer. The detailed dependence of the MR and the resistance of MTJ elements for various electrode structures and various tunnel barriers will be discussed. The relationship of the magnitude of the MR to the electronic properties of the FM electrodes will be explored for a variety of Fe, Ni and Co alloys. Possible reasons for the observed decrease of MR with bias voltage will be described. Junction geometry dependencies will also be discussed. Potential applications of magnetic tunnel junctions include magnetic memories and field sensors.

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