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Anomalous net magnetization in collinear antiferromagnets with uncompensated surfaces[1]

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Like ferromagnets (FM), antiferromagnets (AFM) exhibit spontaneous long-range spin order below a transition temperature. The traditional FM order parameter is the spontaneous magnetization, while that of a simple AFM is the staggered magnetization, sometimes called the Neel vector N. The net magnetization M of a perfect AFM is (seemingly) zero at all temperatures T; however, defects such as vacancies, grain boundaries, and even surfaces create an M(T) which has a non-trivial relationship to the staggered magnetization N(T), even in ideal systems. As a specific example, we consider AFM CoO, which consists of AFM-coupled FM (111) planes; (111)-oriented epitaxial films with an odd number of planes will exhibit non-zero M due to uncompensated surfaces. These uncompensated surfaces were used to produce an artificially-structured FM semiconductor using epitaxial layers of AFM CoO with a doped semiconductor Al:ZnO (AZO). Both M(T) and the anomalous Hall effect show oscillatory behavior with thickness of either CoO (odd vs even numbers of planes) or AZO ($\sim$1 nm RKKY-like oscillations related to the AZO Fermi wavevector due to electron-induced coupling between Co moments at its two CoO surfaces). Mean field theory and Monte Carlo simulations show that M(T) of collinear AFM such as CoO with uncompensated surfaces exhibits T-dependence unlike that of N(T), of the absolute value of its individual layers, or m(T) of any single atomic plane including the uncompensated surface, due to incomplete cancellations of different planes. This phenomenon is valid even in the limit of semi-infinite systems; it is a topological state due to the presence of a free surface. Modifications of surface exchange coupling (leading to ordinary or extraordinary transitions), due to electron correlations in these Mott insulators, changes in crystal fields, spin-orbit coupling, or an incomplete (rough) surface, result in compensation points and highly non-Brillouin-like M(T).

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