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Unexpected magnetism in thin film dielectric oxides

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High temperature ferromagnetism in thin films of dilute magnetic oxides is a widespread phenomenon, of which there appear to be two distinct sources. One is the contribution of the $3d$ dopant ions themselves, the other is related to crystal defects in the interface region. The latter contributes a magnetic moment of 100 – 400 μ_B per square nanometer of substrate area, which is largely independent of film thickness or dopant concentration. In very dilute films it seems as if there is a giant ionic moment when the film moment is expressed per 3d cation, but this is because the source of the magnetism is misattributed. It is suggested that the magnetic defects are two-electron or two-hole centres which have a spin triplet as ground state or low-lying excited state. In ZnO or SnO_2, examples of the latter, the magnetic dopant stabilizes the spin triplet by exchange. However HfO_2, ZrO_2 and WO_3, examples of the former, are ferromagnetic even when undoped. They are 'd-zero' ferromagnets. A characteristic sign of this exotic magnetism is strong anisotropy of the saturation magnetization. Possible links to other systems such as defective graphite or gold/thiol will be discussed.