Class 7: Perovskite manganese oxides and magnetoresistance

Structure of perovskites, typical charges, notion of the tolerance factor:
Please see the handout, or read a book (Megaw, Galasso etc.)

The notion of aliovalent substitution:

In $La_{1-x}Sr_xBO_3$, the B atom (a transition metal) has the formal charge 3+x. This makes a huge difference to property.

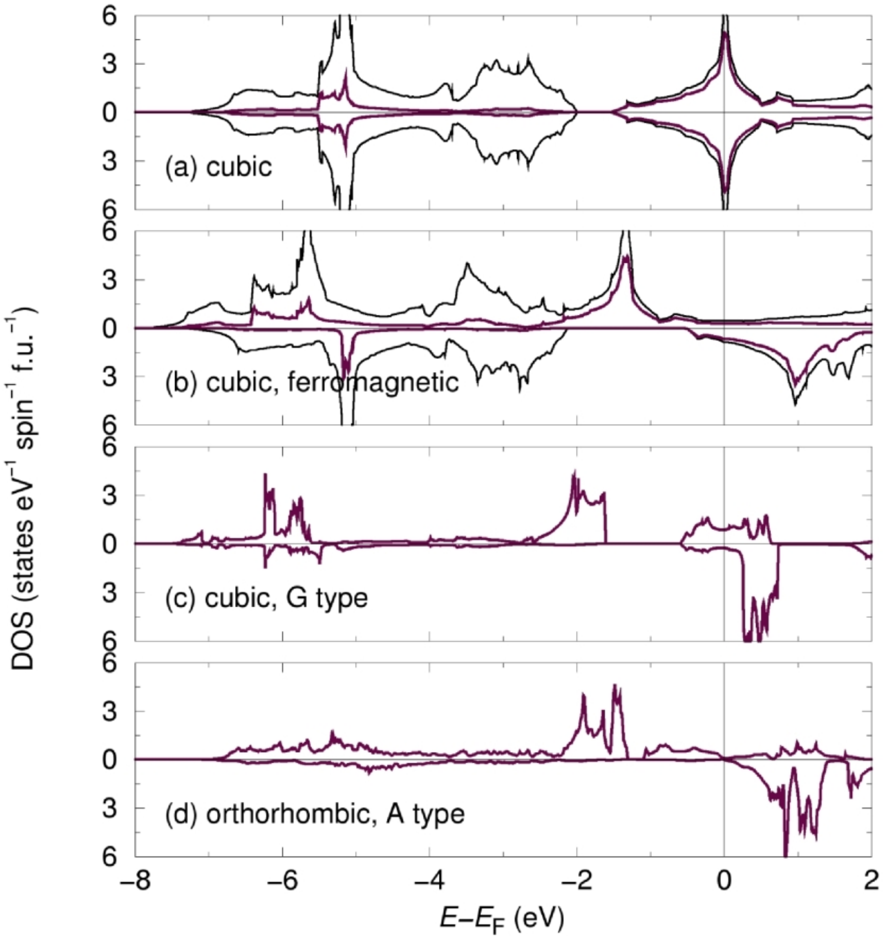
Most 1st transition metal series $LaBO_3$ perovskites are insulating antiferromagnets. $LaNiO_3$ and $LaCuO_3$ are paramagnetic metals.

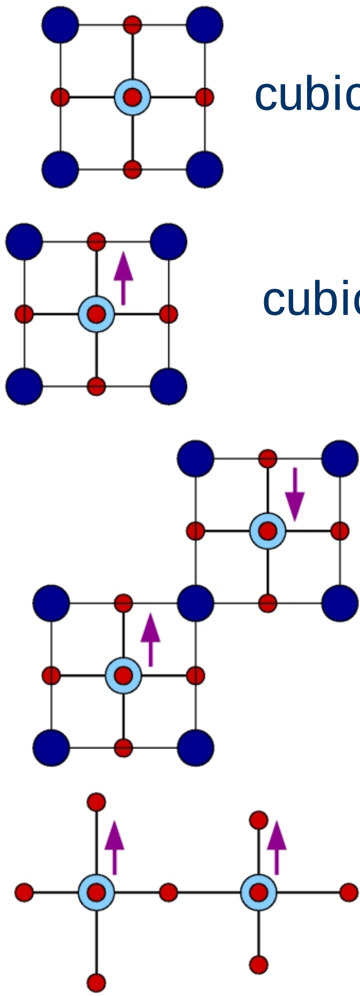
The nature of the insulating ground states has mostly to do with electron correlation. The precise nature of the gap in the insulators changes as a function of the B atom. See Arima et al. Phys. Rev. B. 48 (1993) 17006; Zaanen et al. Phys. Rev. Lett. 55 (1985) 418.

Ram Seshadri, UCSB MRL, Room 3008, x6129 seshadri@mrl

In 1950, Jonker and van Santen studied the electrical and magnetic properties of the series of $La_{1-x}A_xMnO_3$ compounds, with A a divalent (alkaline earth) cation. They found that the mixed systems display a transition from indulating behavior to metallic behavior (seen as a change in the sign of slope of the resistivity as a function of temperature) as the same temperature that the systems became feromagnetic. [Physica 16 (1950) 337 and 16 (1950) 599, obtainable through the ScienceDirect website]. The behavior was explained by C. Zener in 1951 [Phys. Rev. 82 (1951) 403] using the idea of **double exchange.**

We first attempt to understand the electronic structure of $LaMnO_3$:





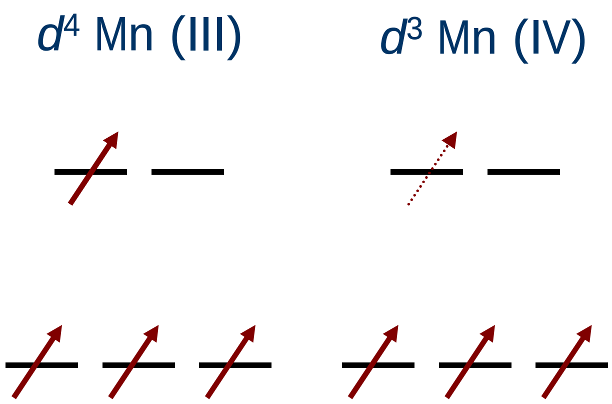
cubic, non-magnetic

cubic, ferromagnetic

cubic, G-type antiferromagnetic

orthorhombic, A-type antiferromagnetic

Zener double-exchange. When an electron hops from Mn(III) to Mn(IV), it tends to align spins on both atoms:



Such hopping requires there to be adequate *bandwidth*.

One of the consequences of Zener DEX is that the application of a high magnetic field tends to align spins on neighboring Mn and thereby results in a strong decrease in the electrical resistivity → Colossal Magnetoresistance or CMR, as opposed to Giant Magnetoresistance observed in metallic/ferromagnetic multilayers: Baibich et al. Phys. Rev. Lett. 61 (1988) 2472. The paper that made CMR well known is Jin et al. Science 264 (1994) 414.

Soon after CMR was discovered, the unusual physics of these materials started becoming evident. For example, the tolerance factor strongly controls properties [Phys. Rev. Lett. 75 A(1995) 914], and does disorder [Phys. Rev. B. 58 (1998) 2426], and phase coexistence [Nature 399 (1999) 560]. Issues of CMR are reviewed by Millis, Nature 392 (1998) 147. Mazumdar and Littlewood have looked at the general phenomena across a number of different materials: Nature 395 (1998) 479.