



**Figure 1 | Ion movement in a complex metal oxide.** Tsujimoto *et al.*<sup>1</sup> report the preparation of SrFeO<sub>2</sub> (Sr is strontium, Fe is iron), a complex metal oxide with an unusual arrangement of ions. **a**, The starting material (SrFeO<sub>3-x</sub>, where *x* is about 0.125) contains FeO<sub>6</sub> octahedra. On heating with calcium hydride, some of the oxygen ions (known as oxide ions) are lost, so that intermediate FeO<sub>4</sub> tetrahedra form. One of the remaining oxygen ions then moves to a vacant site left behind by an ion (indicated by the arrow), forming an FeO<sub>4</sub> square. **b**, The crystal lattice of the starting material is an array of FeO<sub>6</sub> octahedra, in which each oxygen is shared between two iron atoms. Strontium ions (Sr<sup>2+</sup>) fit in between the rows of octahedra. In the first step of the reaction, loss of some of the oxide ions leads to an intermediate compound, Sr<sub>2</sub>Fe<sub>2</sub>O<sub>5</sub>, consisting of alternating rows of FeO<sub>6</sub> octahedra and FeO<sub>4</sub> tetrahedra. In the second step, more oxide ions are lost and some of the remaining oxide ions change position. The SrFeO<sub>2</sub> product thus forms as sheets of FeO<sub>4</sub> squares, interleaved with strontium ions. The iron and strontium ions retain their positions throughout the process.

consider the differences between solid-state reactions and those that occur in solution. Reactions in solution can be performed at low temperatures, because molecular diffusion occurs easily and the reacting molecules don't require much energy to mix together. Under these conditions, if a molecule can take part in several reactions, only the one with the lowest energy barrier to activation tends to occur. The product of such a 'kinetically controlled' reaction is the one that forms fastest, and is not necessarily the one that is most stable. It is therefore possible to control reactions in solution so that they occur only at specific parts of a molecule. By performing stepwise transformations on individual chemical groups, a product can be prepared that has a controlled composition and structure that are clearly related to those of the starting compound.

But nearly all complex metal oxides are prepared at high temperatures (typically greater than 1,000 °C). This is because no solvent is used to aid diffusion, yet the reacting ions must travel large distances (of the order of micrometres) to form the products. At these temperatures, enough energy is available to allow the occurrence of reactions that have high energy barriers. Given a choice of reaction pathways, the most favourable one is that which yields the most thermodynamically stable configuration of atoms. In such

thermodynamically controlled systems, the product generally does not conserve any of the structural features of the reactants (unlike reactions in solution), and it is therefore much more difficult to direct the course of the reaction<sup>5</sup>.

Tsujimoto *et al.*<sup>1</sup> overcome these limitations in their preparation of SrFeO<sub>2</sub>. Their starting material is a complex metal oxide that contains Fe<sup>4+</sup> ions (SrFeO<sub>3-x</sub>, where *x* is about 0.125). The authors form their unusual product by removing an oxide ion from the starting material, a process that is coupled to a redox reaction in which Fe<sup>4+</sup> ions are converted into Fe<sup>2+</sup> ions.

The overall process uses a recently discovered reagent (calcium hydride) for the kinetically controlled removal of oxygen from oxides<sup>6</sup>, and it occurs at the remarkably low temperature of 280 °C. These conditions provide insufficient thermal energy to rearrange the structure of the starting material completely — only the relatively mobile oxide ions can change position (Fig. 1). The strontium and iron ions in the product retain the positions they held in the starting material. The most thermodynamically stable products — iron metal and strontium(II) oxide — do not form, because the required long-range diffusion for the process is too slow at this temperature. The less stable SrFeO<sub>2</sub> forms instead, because this is a faster reaction.

Nevertheless, the reaction pathway that

leads to SrFeO<sub>2</sub> (Fig. 1) is unexpected. An intermediate (Sr<sub>2</sub>Fe<sub>2</sub>O<sub>5</sub>) is formed first, as oxide ions are removed from the starting material. This intermediate consists of alternating sheets of FeO<sub>4</sub> tetrahedra and FeO<sub>6</sub> octahedra. Conversion of the tetrahedra into the square planes of the final product requires that the oxide sites vacated in the formation of the intermediate be refilled with other oxide ligands. This is a crucial observation, because it demonstrates that all the oxide ions are mobile, not just those being removed from the system.

The discovery that oxide ions can be mobile at relatively low temperatures, albeit in the presence of a strong chemical driving force, opens up a host of synthetic possibilities — for example, the strong magnetic interactions seen in SrFeO<sub>2</sub> could be modified in a controlled way by making complex oxides of different transition metals. But the practical applications are just as exciting — high oxide-ion mobility is required for several emerging technologies, most notably solid-oxide fuel cells<sup>7</sup>. So although Tsujimoto and colleagues' discovery<sup>1</sup> may occur only at an atomic level, its ramifications could extend far more widely.

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#### Corrections

■ The News & Views article "Venus: Express dispatches" by Andrew P. Ingersoll (*Nature* **450**, 617–618; 2007) contained the erroneous statement that Venus's equator is warmer than the poles at altitudes above 65 km. It is colder.

■ There was an incorrect reference citation in the article "Microscopy: Elementary resolution" by Christian Colliex (*Nature* **450**, 622–623; 2007). In the statement "The first experimental maps are now demonstrating the importance of refining descriptions of electron-matter interactions<sup>2</sup>," the correct citation is not reference 2 but reference 12 (M. Bosman *et al.* *Phys. Rev. Lett.* **99**, 086102; 2007).

■ In the article "Astronomy: Sloan at five" by Robert C. Kennicutt Jr (*Nature* **450**, 488–489; 2007), we should clarify that the Sloan Digital Sky Survey was used only to select candidate stars for the spectroscopic observations that led to the discovery cited in reference 9 (W. R. Brown *et al.* *Astrophys. J.* **622**, L33–L36; 2005).