

It is perhaps too early to make definitive comparisons between the superconducting states in the bulk and at the liquid/solid interface. However, it is intriguing that increased carrier density by electrostatic charge accumulation leads to a monotonically increasing T_c , whereas in bulk Li_xZrNCl , T_c emerges at a maximum through the insulator/metal boundary and decreases continuously as the doping level increases. Whether this implies differences in the physics remains to be explored, but it should be noted that the crystalline structure of the chemically accessible Li_xZrNCl superconductor (YOF-type) is different from that of

the electrostatically doped pristine ZrNCl (SmSI-type)¹⁰.

Whether the electric-field-induced superconductivity could one day compete with that obtained by chemical doping remains an open question, but the results leave room for several new directions. It would be interesting to see if the field effect in its liquid-gated version could be used to induce high- T_c superconductivity without concomitant chemical doping in the layered cuprate perovskites. Even more intriguing is the possibility of unveiling insulator-to-superconductor transitions in materials where conventional chemical routes have failed to do so. □

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STEALING A LEAD ON LEAD

The trouble with lead is that it is so useful. Although the least revered of the classical metals, its physical, chemical and mechanical properties gave it virtues that the ancients appreciated. Malleability, low melting point and relative inertness recommended it for plumbing, stained-glass-window casements, solder and roofing; the strongly coloured compounds provided artists' pigments until the nineteenth century. That was when lead's toxicity became most pressing, not least because of industrial-scale manufacture of lead white paint. The recent scare over lead paints on cheap toys from China shows that this issue is still present, while lead-acid vehicle batteries now leak the poisonous heavy metal into landfills worldwide.

The drive to eliminate lead from commercial materials is also proceeding in more sophisticated applications, notably piezoelectrics. Lead zirconate titanate (PZT) has for several decades been the canonical piezoelectric material, which interconverts electrical and mechanical energy. PZT is the exemplary smart material, used in all manner of sensors, actuators and transducers from vibration dampers to sonar equipment. But the presence of lead is a drawback not only for environmental reasons. It also confers a relatively high density — a hindrance in some applications, for example because it produces a high

acoustic impedance. And PZT does not work at high temperatures.

That's why alternative lead-free piezoelectrics are eagerly sought. The quest has been pursued with particular vigour in Japan, where there is a long tradition of expertise in ceramics — PZT itself was developed there at the Tokyo Institute of Technology in the 1950s. The work has tended to focus on other titanates and zirconates, and related perovskite-type oxides such as niobates¹. Similar to PZT and its precursor barium titanate, these typically have an asymmetric perovskite crystal structure in which a large metal ion is systematically displaced from its symmetric position, creating spontaneous electrical polarization. In the field-induced flipping of this displacement lies the origin of the piezoelectric behaviour.

In complex mixtures of such oxides, small changes in composition may lead to phase changes that induce piezoelectric and ferroelectric behaviour². Six years ago a Japanese team discovered a niobate-based system of this sort that showed a very promising piezoelectric response (quantified by the piezoelectric constant d_{33}), especially when prepared in textured polycrystalline form³. There is no lack of other candidates^{4,5}, but none has yet been able to boast a d_{33} comparable to that of PZT — until now.

Liu and Ren have found that a mixed barium–calcium



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zirconate–titanate shows a piezoelectric constant in the same range as PZT, and they claim that in theory a single-crystal form of their new material could exceed it by more than threefold⁶. One of the key questions has been whether such behaviour can be understood sufficiently to enable further refinement by rational design. Liu and Ren think they can explain how the phase behaviour in such systems generally produces a smaller piezoelectric response in lead-free materials, but also how it might be tuned to circumvent this limitation (by introducing a solid-phase triple point) — thereby helping these smart materials become smarter still. □

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