The Journal of Immaterial Science
MISCOMMUNICATION

MATERIALS SCIENCE
Received: 30th July 2023
Accepted: 30th July 2023
Retracted: ~10th August 2023
DOIOU: 10.K431.U02

Synthesis and Characterisation of a Slightly-Above-Room-Temperature Superconductor

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Abstract: The search for a material capable of conducting electricity without resistance at room temperature and atmospheric pressure has preoccupied scientists for more than a century. Such a material has as unrivalled capacity to produce platitudes and hyperbole from science communicators and journalists, as well as some minor implications for the electronics and power industries. Herein, we report the synthesis and characterisation of such a material: a cobalt-doped uranic corium called SK-431.

Room temperature superconductors are frequently referred to as a holy grail of physics and materials science. Many have tried to make them, some have even published on them, but none have passed the most crucial test: trial-by-twitter. This cycle appears to be playing out again, as a group of researchers from Korea have published pre-prints in which a Cu-doped Pb-apatite material called LK-99 appears to exhibit superconductivity up to +127 °C.[1,2] Most impressively, the material exhibits the Meissner effect: partially levitating above a magnet.[3]

Researchers from around the globe are lining up to rubbish these findings, (as if it were a "metal-free" Suzuki reaction), and unfortunately it seems likely that this discovery will soon be consigned to the midden-heap of materials science.

We find it notable that seekers of room-temperature superconductors spend all their time optimising the operating temperature (T_C) of their materials, and ignore the temperature of the room that they put them in. For example, our laboratories in eastern Siberia rarely reach temperatures above -60 °C, and as such a room-temperature superconductor is more viable here than anywhere else in the world.

Our institute[A] began studying the condensed-matter physics of the actinides in 1985, when we obtained some interesting ferro-uranic caesium-iodide composites from our colleagues in Vladivostok.[B] After 37 years of intrepid work, we are pleased to report a novel cobalt-doped uranic-corium, "SK-431", which we tentatively posit is a superconductor with T_C = +27 °C.

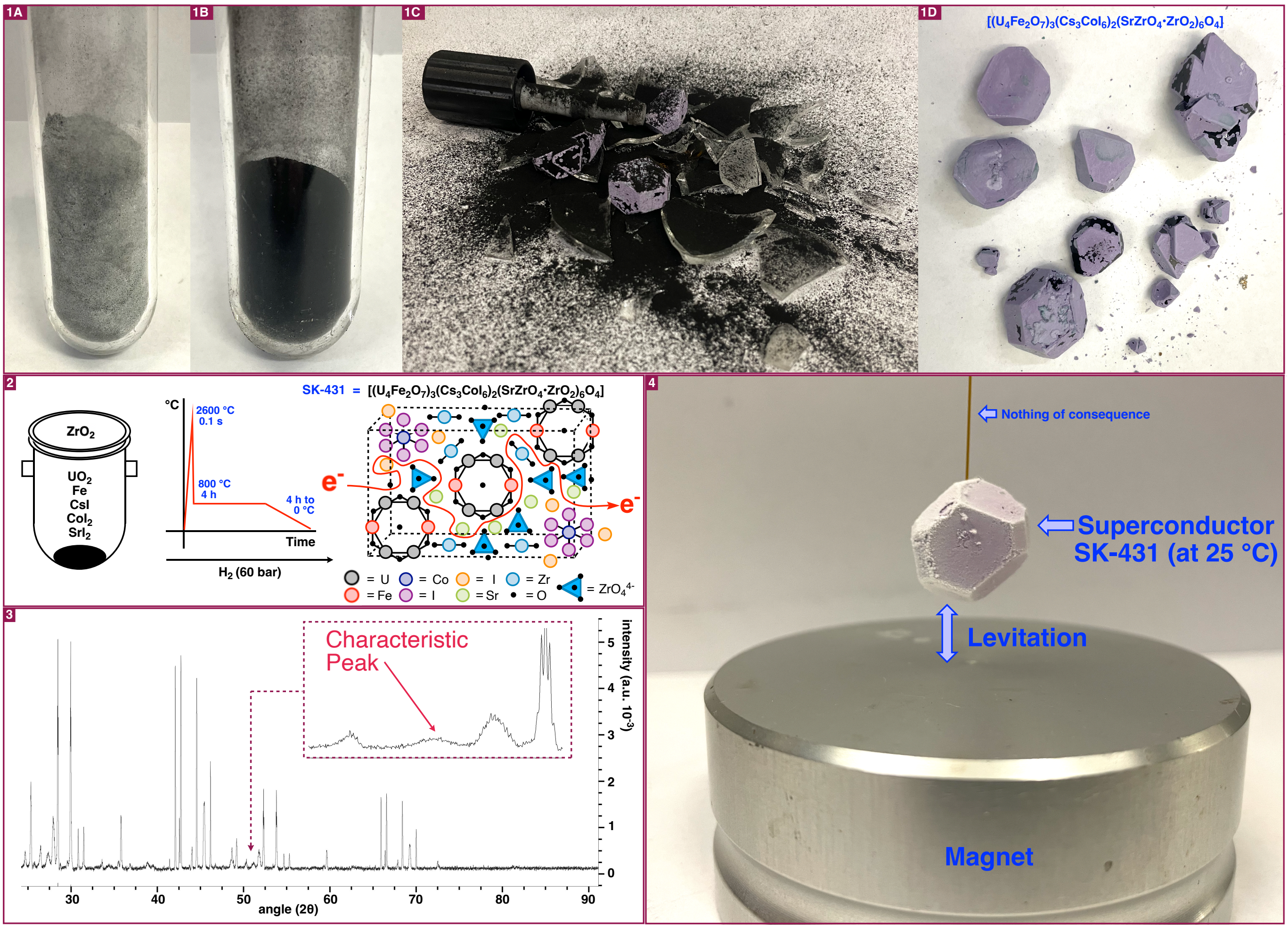

Figure 1A: Zirconia Schlenk containing Fe, UO_2, CsI, CoI_2, SrI_2, and ZrO_2, prior to heating. **1B:** Reaction post heating. **1C:** Isolation of SK-431 by percussive scission and mechanical separation. **1D:** Pure crystals of SK-431. **2:** Reaction scheme with heating profile and diagrammatic unit cell for SK-431 Also shown is the barrierless path taken by conductive electrons. **3:** XRD data used to determine the structure of SK-431. **4:** A crystal of SK-431 exhibiting the Meissner effect by levitating above a magnet, at room temperature and pressure.

Synthesis and Structure

We first obtained promising conductivity results with a zirconia-corium composite in 1985. However, repeating our initial results proved to be exceedingly challenging, and has consumed much of the intervening decades. The discovery of SK-431 was serendipitous, and the conditions under which the compound was first synthesised could not readily be repeated. 430 unsuccessful attempts were made to remake our initial material, the details of which are contained in pages 7–12,056 of the electronic supporting information. To our delight, the 431st experiment yielded a material with desired properties, the synthesis of which is described below.

To prepare corium SK-431, powdered iron, UO_2, CsI, CoI_2, SrI_2 and ZrO_2 were combined in a thick-walled zirconia Schlenk flask and pressurised with 60 atmospheres of wet H_2 (Fig. 1A). The reaction vessel was then placed in a pre-heated arc-furnace at 2600 °C for 0.1 seconds, then transferred to a conventional furnace at 800 °C for 4 hours, during which time the reaction mixture partially liquefied (Fig. 1B). Subsequent cooling to room temperature over a further 4 hours prompted the product to crystalise, after which time the reaction flask was smashed with a hammer. Pure product was obtained by mechanical separation of crystalline material from the broken glass and slag (Fig. 1C). The material takes the appearance of deep purple crystals with pink frosting.

The composition of the product was determined by X-ray powder diffraction (XRD) and X-ray crystallomancy (XRC).[4] The XRD data was definitive in this endeavour, as the minor peak at 51.2° incontrovertibly confirmed a unit cell with the formula $[(U_4Fe_2O_7)_3(Cs_3CoI_6)_2(SrZrO_4\bullet ZrO_2)_6O_4]$ (Fig. 2). Data obtained by X-ray crystallomancy was less informative, but did indicate that the vibes of the material were definitely sus. Strong alignment of the $C_{sp}{}^2$ shakras was detected, as was some hefty BDE.

With the structure of our material comprehensively characterised, we moved on to assessing its conductive properties. Exhaustive density dysfunctional theory (DDT) calculations were performed at the *ad infinito* level of theory to probe the electronic nature of the material. These calculations implied that an electron originating in a uranium *5f* orbital could undergo a barrierless transition between unit cells following a specific pathway. Initially swinging by O*2*, the electron doubles back around Cs*7* and skirts a zirconate to reach Sr*4*. Hooking around the central ferro-uranate cluster allows the electron to dodge the congested lower-right sector, after which it U-turns off at SiO_2 *1*. Thereafter, it's a straight run to cobaltate *3*, and a left turn at iodine brings the election into the next unit cell. The particle-economy of an electron traversing this route was calculated at less than 0.3 nCal/Åmol.

In the interest of time, extensive conductivity and resistivity measurements were not collected, and instead we progressed directly to observations of the Meissner effect. A crystal of SK-431 was placed atop a neodymium magnet, at ambient pressure and temperature. Levitation was clearly observed (Fig. 4), at temperature up to 299 K. In lieu of actual measurements, this observation serves to confirm the superconducting nature of SK-431, with a T_c of 27 °C. As such SK-431 is the first superconducting material at slightly-above-room-temperature, or at least it will be when LK-99 gets retracted.

Conclusion

For most of a century, some physicists have openly stated that a room-temperature superconductor is a scientific impossibility. A smaller selection of scientists posit that an ambient condition superconductor is still more achievable than a stable relationship, constructive reviewers' comments, a work-life balance, or tenure. We have finally put this question to rest, by synthesising the former without obtaining any of the latter. We'll be waiting by the phone for our Nobel prizes.

Experimental details, computational parameter and spectra are collected in the electronic unsupported information, available from www.onlyfans.com/schlonkitup, for a modest fee.

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Notes and references

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3 Levitation video: https://sciencecast.org/casts/suc384jly50n

4 "*X-ray Crystallomancy: A Practical Guide*" Rosiland, F.; Crockson, J.; Wick, F.; Schlonk, G. **2022**, *J. Immat. Sci.* **2**, 15–17. DOI: https://tinyurl.com/fk7y9nx9

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