MATERIAL WITNESS

Masters of disguise

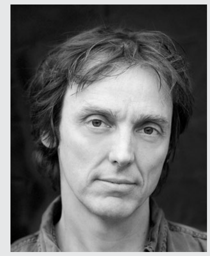
The transmutation of metals — popularly, turning lead into gold — is usually regarded as the futile dream of alchemists, but it's rarely acknowledged that some of them succeeded, by the standards of their day. There are many old recipes for treating a base metal to give it the appearance of gold, some of which can be retrospectively interpreted as chemical modifications of the surface that would produce the desired effect. That might be regarded as cheating. But although sometimes outright trickery was indeed the intent, appearances were one of the only things early chemists had to go on — and so it was probably far from clear even to some of the practitioners that they weren't truly making a substance like gold.

There's something of this ambiguous spirit in a new technique that could potentially achieve the same end by very different means. McCaul and colleagues have described how coherent quantum control of the electronic properties of a material, for example using tailored laser pulses, might give it the characteristics of another material while the control field is applied[1]. It seems perfectly within the scope of such a method — in principle, at least — to modify the band structure of, say, tin or lead so that it takes on the alluring sheen of gold.

The basic idea of 'sculpting' electronic structures and their optical responses using photons has been around for some time. Recently Campos et al. described how it might be used for the distinctly alchemical goal of making one type of atom appear spectrally identical to another[2]. The idea is that a laser photon field interacts with the many-electron system so as to generate a predefined time-dependent polarizability. There is no obvious reason, the researchers said, why any atomic or molecular system could not by this means be made to resemble any other, if the laser field can be controlled with enough precision.

That work, however, was forced to resort to a single-electron approximation for the atoms in question. What about extended many-electron materials? McCaul et al. explore that issue for the theoretical case of a relatively simple and well-studied crystalline solid called a Fermi–Hubbard model: a set of fermions (such as electrons) interacting in a one-dimensional chain. This system can exist either as a conducting or an insulating phase, and the researchers deduce what kind of laser driving field is needed to make their emission spectra identical — so that the insulator looks like the conductor, say. To do this, they use a method of coherent control called tracking control[3] to deduce what the driving field must look like to create a particular target response — namely, an observable that is following a desired path over the duration of the driving laser pulse.

A challenge here is to induce this kind of mimicry without actually driving a change in the nature of the underlying system — in this case, the laser field is predicted to flip the insulator into the conductor, so mimicry becomes something more akin to transmutation, so to speak. Another potential problem is how to sustain the mimicry over long periods, since any small errors in the initial setup will accumulate over time.



Philip Ball

One of the enticing prospects from this technique is to make well-understood materials mimic exotic ones: for example, to replicate unusual and otherwise hard-to-observe forms of superconductivity or topological electronic properties. That would not realistically be a way to make such materials for applications — unless, perhaps, the property in question were needed only transiently — since the effect persists only so long as the control fields are applied. But it could offer a way to study them in the laboratory. Better still, the method could create electronic states that are known only in theory and not in any real materials systems. In such ways, it could probe the space of the possible. ❐

Published online: 24 June 2020
https://doi.org/10.1038/s41563-020-0714-8

References

1. McCaul, G., Orthodoxou, C., Jacobs, K., Booth, G. H. & Bondar, D. I. *Phys. Rev. Lett.* **124**, 183201 (2020).
2. Campos, A. G., Bondar, D. I., Cabrera, R. & Rabitz, H. A. *Phys. Rev. Lett.* **118**, 083201 (2017).
3. Rothman, A., Ho, T.-S. & Rabitz, H. *Phys. Rev. A* **72**, 023416 (2005).