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Why physics needs materials science and why materials science needs physics

It is the beauty and strength of solid state physics to comprehensively describe matter with the help of both, experimentally accessible model systems and theory. Regrettably, the number of materials in which the pure models accurately describe the experimental findings is usually small, and very often these model systems have exotic compositions and no or only limited practical application. The strength of materials science lies in its pragmatic way of optimizing complex materials and alloys for applications, often – because of the application – with high significance and impact. But regrettably, too, this materials' optimization has only limited guidance from a theoretical point of view. I will discuss this discrepancy between experimentally and/or theoretically accessible model systems in solid state physics and engineered materials for broad applications on the example of charge density wave (CDW) phases. Conceptually CDW phases are well understood. Their signatures have theoretically been proposed and experimentally been evidenced in a handful of materials, all of them exotic, and rarely relevant for application, but fascinating enough to give work to a large community of physicist. The most important features that give an experimental hint on the occurrence of such CDW phases are fermi surface nesting, phonon softening and with it the softening of the elastic constants, Kohn anomalies, transport anomalies, and most importantly, a non-diffusive structural phase transition. Non-diffusive structural phase transitions are well known in materials science. The most important one is the martensitic phase transition that occurs in steel or shape memory alloys and students of materials science learn it in their first semester. These non-diffusive structural phase transitions are important enough to give work to a large community of material scientists. Looking in more detail at them, it is found that they show fermi surface nesting, phonon softening and with it the softening of the elastic constants, Kohn anomalies and transport anomalies, all strong indications for CDW phases to occur. Nonetheless has theory never made an attempt to describe such applied engineering materials, neither has the engineering community ever tried to let their materials' development be guided by theory. Maybe it is time that the theoretical concepts of charge ordering in matter meet the engineering of steel!

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