arXiv:submit/3979492 [cond-mat.supr-con] 15 Oct 2021

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Hole Superconductivity xOr Hot Hydride Superconductivity

J. E. Hirsch *
Department of Physics, University of California, San Diego, La Jolla, CA 92093-0319

Under the spell of BCS-electron-phonon theory [1], during the last 6 years experimentalists have purportedly discovered a plethora of high temperature conventional superconductors among pressurized hydrides [2, 3], and theorists have been busy predicting and explaining those findings [4–6]. The alternative theory of hole superconductivity [7] predicts instead that *no superconductivity* can exist in these materials. In this Tutorial I will first argue that, unclouded by the prejudice of BCS's validity, the existing experimental evidence for superconductivity in pressurized hydrides does not withstand scrutiny. Once it is established that superconductivity in pressurized hydrides is a myth and not a reality, the claim to validity of BCS-electron-phonon theory as a descriptor of superconductivity of real materials will be forever shattered, and an alternative theory will become imperative. I will explain the fundamentals of the theory of hole superconductivity, developed over the past 32 years [7, 8], and why it is compelling. Crucially, it explains the Meissner effect, that I argue the conventional theory does not. It applies to all superconducting materials and provides guidelines in the search for high temperature superconductors that are very different from those provided by BCS-electron-phonon theory. Light elements are predicted to be irrelevant to warm superconductivity, because according to this theory the electron-phonon interaction plays no role in superconductivity.

PACS numbers:

I. INTRODUCTION

Over the past 65 years, BCS-electron-phonon theory has been generally accepted as the correct explanation of superconductivity in conventional materials [1]. Yet before the hydride era, BCS was notoriousy *unable* to predict new superconducting materials before they were experimentally discovered [9, 10]. A tectonic shift took place in 2015 when Mikhail Eremets, guided by a theoretical prediction [11], discovered "Conventional superconductivity at 203 kelvin" in sulfur hydride under pressure [12]. Since then, BCS theory has been the driving force and guiding light in the search and discovery of high temperature superconducting hydrides under pressure [4–6]. The hydrides have been BCS's greatest triumph. As the other side of the same coin, if it is eventually established that there never was superconductivity in the hydrides, this will become BCS's greatest and final defeat. The credibility of BCS as a predictor of superconductivity in real materials will be forever shattered.

How do we *know* that conventional superconductivity exists in pressurized hydrides? The reality is, we don't. The scientific community currently believes it does, largely because (i) the conventional BCS-electron-phonon theory of superconductivity [1] predicts that high temperature superconductivity should occur in these materials [13, 14], *and* (ii) the conventional theory is believed to be correct and to describe many materials in nature. Propelled by this belief, high temperature conventional superconductivity in pressurized hydrides has been intensively searched for in recent years [15, 16], and phenomena that have been observed suggestive of superconductivity in these materials [12, 17–34] have been interpreted as proof that they are superconductors.

I share the general belief that (i) is true, as most physicists do. However, if (ii) is not true, i.e. if the conventional theory of superconductivity is not correct and does not describe real materials [36], the case for high temperature superconductivity in pressurized hydrides falls apart. If so, the detailed theoretical calculations that predict it and explain it [2, 5, 37–57] are a myth unrelated to physical reality, and the experimental observations suggesting the existence of high temperature superconductivity in pressurized hydrides [12, 17–34] have a different explanation that is *not* superconductivity.

The theory of hole superconductivity [7] predicts that *no high temperature conventional superconductivity exists in pressurized hydrides*. Or any other high temperature superconductivity for that matter. If it does exist, the theory of hole superconductivity will be proven wrong. In this Tutorial I will explain why the theory of hole superconductivity is compelling and therefore no high temperature superconducting hydrides can exist. This implies that the phenomena reported to occur in these hydrides at high pressure interpreted as indicating superconductivity are not associated with superconductivity.

Enormous research efforts and resources are being currently devoted to high temperature superconductivity in hydrides [58, 59]. If the phenomenon does not exist, those efforts and resources are wasted. They should instead be redirected to either the study of other phenomena in hydrides that are real and could lead to important technological applications for the benefit of society, or to the study of real superconductivity in systems where it really exists. For these reasons it is important to settle this question as soon as possible. This Tutorial is a con-

*Corrresponding author *email*: jhirsch@ucsd.edu