Magnetism and Superconductivity in Iron-based Superconductors as Probed by Nuclear Magnetic Resonance

Franziska Hammerath

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Foreword by Prof. Dr. Bernd Büchner

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Foreword

Since iron and its compounds are often ferromagnets - a notation that originates from the latin word “ferrum” for iron - superconductivity is not the first property to check for in an iron-based compound. It was therefore even more surprising that the superconducting transition temperature could be raised up to 55 K shortly after Kamihara and co-workers reported the discovery of superconductivity in the so-called iron pnictides in 2008. In fact, this is the highest transition temperature ever, seconded only by the cuprates, which were found in 1986.

Similar to these, the observation of another family of high temperature superconductors led to an enormous activity within the research community, resulting in thousands of papers presenting surprising and also promising new results. For example, high critical current densities and high critical fields raise the hope that these materials could be well used for applications. On the other hand, the mechanism of superconductivity is still not clear. While a simple phonon-mediated Cooper pairing seems to be excluded by the high transition temperatures, it is not yet established if antiferromagnetic spin fluctuations can indeed mediate the pairing, or if they are just a remnant of a nearby spin density phase. Also, the symmetry of the order parameter seems to change from compound to compound. While most of the experimental results are in line with the theoretically proposed s_{+-} -symmetry, there is substantial evidence for d -wave symmetry from other experiments. Even the possibility of p -wave superconductivity has been proposed, but with contradictory results on the experimental side.

All these intriguing questions are addressed in the PhD thesis at hand. In this thesis, Franziska Hammerath has used the experimental technique Nuclear Magnetic Resonance (NMR) in order to investigate several different compounds of superconducting iron pnictides. NMR has been invented already 60 years ago, and contributed to the field of superconductivity from the beginning on. To name but a few examples, the peculiar temperature dependence of the spin-lattice relaxation rate observed by Hebel and Slichter in the superconducting state of aluminum supported the theory of superconductivity by Bardeen, Cooper and Schrieffer, and the constant Knight shift in Sr_2RuO_4 in the superconducting state provided evidence for triplet superconductivity in this compound. Furthermore, its local character and the sensitivity to low frequency magnetic excitations render it a perfect tool to investigate also the normal state properties of a new superconducting family, such as the iron pnictides.

This thesis comprises a coherent summary of the basics of NMR as well as a brief description of the fundamental properties of the iron pnictides. With this at hand, the interested reader can immerse into the enlightening results of Nuclear Magnetic Resonance on iron-based superconductors, gaining a deeper insight also into the details of this powerful experimental tool as well as a better understanding of the iron pnictides as a new bearer of hope in the research of high temperature superconductivity.

Prof. Dr. Bernd Büchner
Director of the Institute of Solid State Research
IFW Dresden

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