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This Week's Citation Classic®

Knight W D. Electron paramagnetism and nuclear magnetic resonance in metals.
Solid State Phys. **2**:93-136, 1956.
[University of California, Berkeley, CA]

Nuclear hyperfine interactions with magnetically polarized electrons give rise to nuclear magnetic resonance shifts, which may be used to identify and analyze the electronic structures of metals and other materials. [The *SCI*® indicates that this paper has been cited in over 210 publications since 1956.]

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My graduate studies in physics at Duke University were interrupted in 1944 by World War II, following which I returned to teach physics at Trinity College in Hartford, Connecticut. I completed my PhD research during summers and weekends in 1948 and 1949 at the Brookhaven National Laboratory. Molecular beam experiments were then emphasizing nuclear moments in connection with models of the nucleus. However, the number of stable nuclei remaining to be studied was small. Also, the nuclear magnetic resonance (NMR) methods of E.M. Purcell[1] were promising alternatives.

With advice from R.V. Pound,[2] I developed an NMR spectrometer to search for nuclear resonances. During the first search, I found a strong signal; however, it turned out to originate in the sample test tube. A more careful search, with test tube and sample removed, revealed another signal that proved to arise from the metallic copper in the rf coil of the spectrometer. Most exciting was the observation that the resonance frequency was shifted from the known value for diamagnetic salts of copper. Shortly afterward, I observed the first NMR shifts among compounds of phosphorous.[3]

C.H. Townes, who was visiting Brookhaven in the summer of 1949, suggested that the resonance shift in metals (later dubbed "Knight shift" by N. Bloembergen) should result from the nuclear hyperfine interaction with the metallic conduction electrons. I calculated the effect for sodium[3] and found a good agreement with experiment.

The NMR experiments developed a new role for the nuclei, which became convenient noninvasive probes of material structures. I continued working on NMR in metals, alloys, and compounds, along with many other workers who were exploring this rapidly expanding area of research. My article reviewed the status of the field in 1956, when the basic ideas had been tested and the promise for future development seemed to be great. Recent reviews[4] confirm the original promise. NMR shift studies continue to provide fundamental physical and chemical information for the identification and study of material structures.

1. **Bloembergen N, Purcell E M & Pound R V.** Relaxation effects in nuclear magnetic resonance absorption. *Phys. Rev.* **73**:679-712, 1948. [See also: **Bloembergen N.** Citation Classic. *Current Contents* (18):7, 2 May 1977.]
2. **Pound R V & Knight W D.** A radiofrequency spectrograph and simple magnetic-field meter. *Rev. Sci. Instr.* **21**:219-25, 1950. (Cited 200 times since 1955.)
3. **Knight W D.** Nuclear magnetic resonance shift in metals. *Phys. Rev.* **76**:1259-60, 1949. (Cited 115 times since 1955.)
4. **Carter G C, Bennett L H & Kahan D J.** Metallic shifts in NMR: a review of the theory and comprehensive critical data compilation of metallic materials. Parts I-IV. *Prog. Mater. Sci.* **20**:1-378; 379-1126; 1127-2032; 2033-341, 1977.

