Direct Observation of the Magnetic Polaron

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Although extensive research in semiconducor electronics has a long history of using quantum mechanics both in design and function of electronic devices, so far it has been focused mainly on its traditional aspects dealing with the transport of the electron charge. Only recently has the spin of the electron become the focus of a new direction in electronics (known as spintronics [1]) which utilizes quantum mechanical concepts in creating devices based on strong mutual influence of magnetic and electrical properties in magnetic semiconductors - semiconducting materials containing magnetic ions. Strong exchange interactions between carriers and these ions give rise to many spin-related phenomena - enormous red shift of the semiconducting gap, giant Faraday rotation, resistivity maximum in the vicinity of the ferromagnetic transition, magnetic phase separation and metal-insulator transition, and, especially, colossal magnetoresistance - which may be used in prospective devices [1,2]. The mechanisms of these phenomena are still a matter of considerable debate, however, all of them involve a concept of magnetic polaron - a microscopic cloud of magnetization made of several neighboring magnetic ions and a carrier(s) - which determines most of the electrical, magnetic and optical properties of the material. Although a great number of experiments indicate the existence of magnetic polaron in magnetic semiconductors and related materials it has eluded direct observation until now.

Here we report the first direct observation of an individual magnetic polaron. Employing muon spin resonance techniques we are able to generate and detect a magnetic polaron bound to the muon in the prototypical magnetic semiconductor, EuS, and determine its size and magnetic moment.

[1] S.A. Wolf et al., Science 294 (2001) 1488.
[2] G.A. Prinz, Science 282 (1998) 1660.