

# The possible dynamic polarization of nuclei by using coal surface paramagnetic centers.

G.V.Mamin <sup>a,b,1</sup>, H.Suzuki <sup>a</sup>, M.S.Tagirov <sup>b</sup>, V.N.Efimov <sup>b</sup>, A.N.Yudin <sup>b</sup>

<sup>a</sup> *Physics Department, Kanazawa University, Kanazawa, 920-1192, Japan*

<sup>b</sup> *Physics Department, Kazan State University, Kazan, 420008, Russia*

---

## Abstract

Electron paramagnetic resonance (EPR) spectra of paramagnetic centers on coal surface at 4.2-300 K have been measured when the sample is in contact with <sup>3</sup>He, <sup>4</sup>He or oxygen gases. At low temperature the transferred hyperfine interaction was manifested in the case helium-3 gas. Our experimental data support a possibility of dynamics polarization of nuclei by using coal surface paramagnetic centers.

*Key words:* Dynamic polarization; noble gas; <sup>3</sup>He; EPR;

---

The study of spin polarized quantum fluids has constituted an important field of research in low temperature physics for a number of years. The result of such interest has a twins nature: fundamental low temperature physics as well as high resolution helium NMR tomography of lungs. Among well known methods we are going to mention brute force polarization, polarization of Rapid melting of solid helium-3, polarization by optical pumping by helium vapor, and polarization with a Leiden dilution refrigerator. Recently a new novel method was suggested for dynamic nuclear polarization of liquid <sup>3</sup>He by using dielectric Van-Vleck paramagnets [1]. But in this case the main obstacle for obtaining high polarization of liquid <sup>3</sup>He is defects paramagnetic centers on the surface of crystals of Van-Vleck paramagnets. These centers located on the surface and leads to the polarization leakage [2]. From this point of view dynamic nuclear polarization by using flowing helium three (liquid or gaseous) through the tablet of coal seams to be more attractive because there are only one sort of paramagnetic centers located on the surface of solid substrate.

We choose one of a type of coal as solids substrate. The coal sample was prepared by hydrocarbonate

heated at 800°C in vacuum. Paramagnetic centers are occurred due to the broken chemical bound on coal surface. As it was founded by V.A. Atzarkin and others [3] the EPR line width ( $g=2.00$ ) is extremely narrowed up to 0.125 Oe due to exchange interaction of those paramagnetic centers. In presents work we discuss our results of EPR spectroscopy as a function of different contact gaseous. In (Fig. 1) typical EPR spectra at room temperatures are demonstrated for the coal under the vacuum (narrowest lines), and in contact with <sup>3</sup>He (0.64 Oe), <sup>4</sup>He (0.77 Oe) and oxygen (12.5 Oe; upper scale) gases. The nature of broadening EPR line of paramagnetic centers is obviously coupled with disturbance of electron shell overlapping by absorbed atoms or molecules of contacting gases. At low temperatures (see (Fig. 2)) the nuclear magnetic moments of helium-3 as well as the electron magnetic moment of paramagnetic oxygen start to play a role of additional broadening mechanism. From this experimental data we can conclude that transferred hyperfine interaction between electron spin of paramagnetic centers and nuclear spins of helium-3 is certainly exist. It is very important for realization of suggested novel method for obtaining high polarization of liquid or gaseous helium-3 or other noble gases, which have a nuclear magnetic moment. Another im-

---

<sup>1</sup> E-mail: george.mamin@ksu.ru

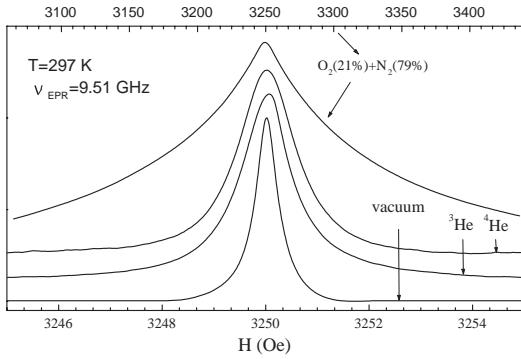


Fig. 1. The EPR spectra of paramagnetic centers in coal at room temperature.

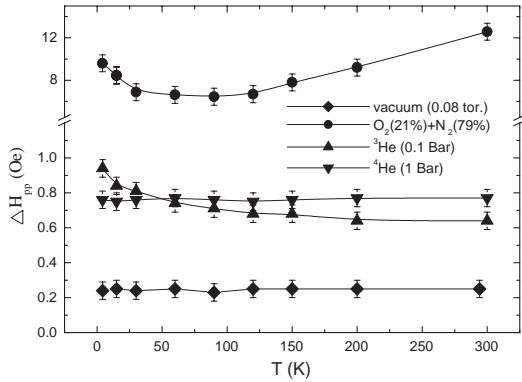


Fig. 2. The EPR line width temperature dependence of paramagnetic centers in coal.

portant physical values for successful obtaining hyper polarized helium-3 are numerical values of  $^3\text{He}$  nuclear spin-lattice relaxation, electron spin relaxation time of paramagnetic centers and its ratio. The saturation of EPR line of coal paramagnetic centers at vacuum has been measured (Fig. 3). The EPR line is saturated by microwave power and relaxation time estimate is 100 mS. Preliminary results of developing method for obtaining of high polarization of helium-3 and other noble gases create fruitful background for the further investigation of electron and nuclear spin kinetics of binary system - coal of the paramagnetic centers on the surface and nuclei of absorbed noble gases.

### Acknowledgements

This work was performed with financial support from REC-007 and Netherlands Organization for Re-

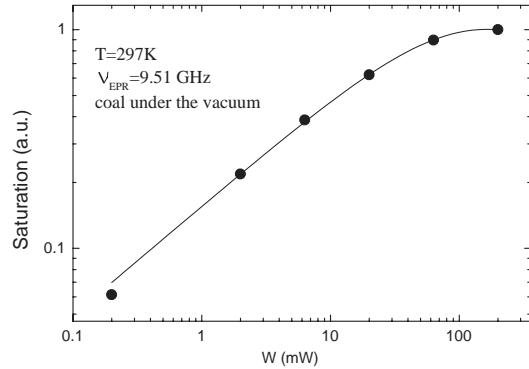


Fig. 3. The saturation of EPR line by microwave power. search Scientific Research (NOW, Grant 047-008-015).

### References

- [1] M.S. Tagirov, D.A. Tayurskii Sov. Phys. JETP lett., **61** (1995) pp. 671.
- [2] A.V.Klochkov et al. Appl. Magn. Reson., **19** (2000) pp. 197.
- [3] V.A. Atzarkin, G.A. Vasneva, V.V. Demidov, F.S. Dgeparov, B.M. Odincov, R.B. Clarkson. Sov. Phys. JETP's letter, **72** (2000) N. 7, pp. 530.