International Journal of Pure and Applied Physics.
ISSN 0973-1776 Volume 14, Number 2 (2018), pp. 87-92
© Research India Publications
http://www.ripublication.com

On the Making and Testing of Magnetic Monopole Samples at Room Temperatures

David Y. Chung*

Retired Professor, Department of Physics and Astronomy,
Howard University, Washington, D.C.20059, USA
**Present Address: P.O. Box, #1270, ROCKVILLE, MD 20849, USA*

Abstract

The experimental evidence of the existence of magnetic monopoles has been published recently. It is important to note that the magnetic charges in a magnetic material can easily be measured by simple equipment. Further progress has been made in making samples of single magnetized poles at room temperatures. They are very stable and can be used for other measurements in characterizing the magnetic monopoles. It is believed that this may be the first time the samples of an isolated magnetic pole have been made at room temperatures. The method of preparing and measuring these monopoles will be given in detail.

Keywords: Magnetic monopoles, single magnetic charge, Maxwell equations, spin ice, single electric charges.

1. INTRODUCTION

One of the most basic problems of magnetism is that whether a magnet always has two poles, north and south which can not be separated into isolated poles i.e. magnetic monopoles (MMs for short).

The question of whether MM exist in nature, and if so, in what form, has been one of nature's deepest mysteries almost since the time of Maxwell, and remains so today. However there are strong theoretical reasons why MMs should exist [1, 2].

When quantum mechanics was developed at the beginning of 20^{th} century, it first appeared to be inconsistent with isolated magnetic charges. However Dirac [1] in 1931 showed that in fact, quantum mechanics allows certain quantized magnetic charges. The existence of magnetic charges would explain the quantization of electric charges.

Since the electric charges were indeed found to be quantized, that make the existence of magnetic charges should be true also.

By introducing the idea of MMs, the Maxwell's equations become symmetrical with respect to magnetic and electric fields [3].

This has led to an extensive search for MMs in recent years. There are many experiments suggested that the MMs have been found in so called 'spin ice' at very low temperatures [4,5,6,7 and 8]. On the other hand, it was established that the existence of MMs in magnetic materials were rather common at room temperatures and they can be measured with simple equipment [9].

It would be most useful if one has the sample artificially made with the single magnetic poles in the laboratory to do the experiments with. This also has important implications for the development of possible application of magnetic devices in the future. It is the purpose of this paper to address this particular problem.

In the present paper, we describe the procedure of making the single magnetic pole samples (MMs) at room temperatures. They are very easy to make and some are very stable in time and good for further measurements.

The paper is organized in the following way: the method of making and the testing of the MMs will be described in section 2. The results and discussions will be given in section 3. And conclusion will be given at the end.

2. EXPERIMENT PROCEDURE:

There are mainly two different shapes of sample one makes here: spherical shape balls and small coils.

2.1. We have made several single MMs with different interior in the shape of a ball. For example, we make use a Fe wires of about one meter long, winding on a small piece of paper in the shape of a ball randomly. The new ball is of the size of 11mm in diameter. After this ball is magnetized inside one end of a coil, (made of twenty turns copper wire with about one ampere DC current going through it), for about one minute and then removed. The ball holds a single magnetic charge by itself. One can measure the magnetic field all around the ball with a Gauss meter (Model 1, Alpha Lab. Inc.) and a compass (as shown in Fig. 1). Several of these wired balls were made with different materials inside the wire. For example, a steel ball (about 10 mm in diameter), iron powder wrapped in Aluminum foil, plain paper or wax, all work well (one of them is showing in Fig. 2). To obtain a MM of opposite sign, one just magnetized it in the other end of the copper coil with DC current. It was noticed that all balls get heated up during the magnetizing process.

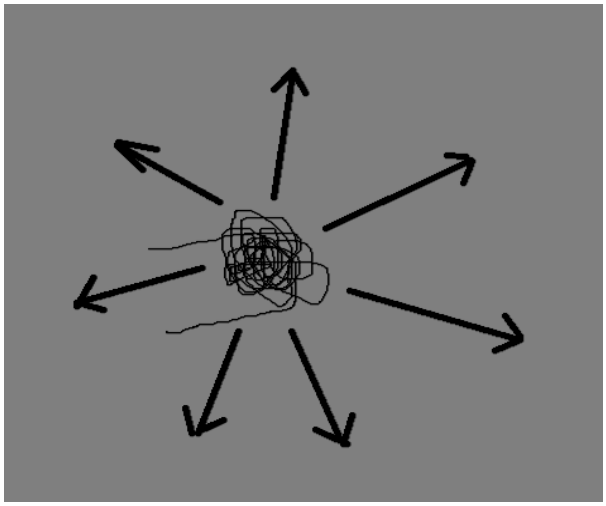

Figure 1. The magnetic field lines of a random coil, as a single magnetic north pole. (after magnetization)

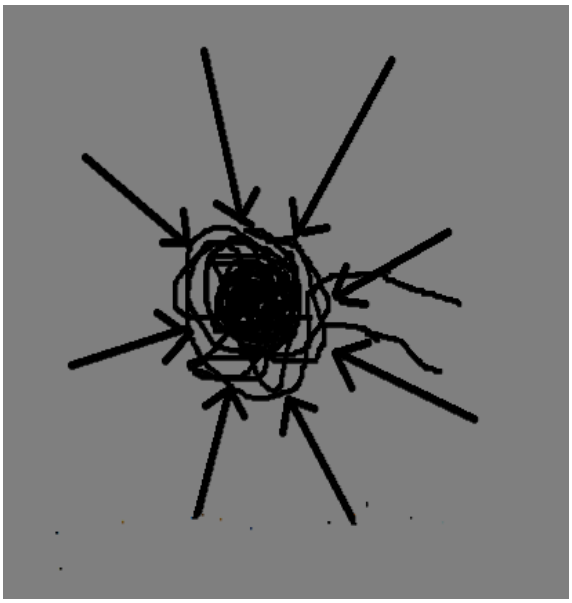

Figure 2. The magnetic field lines of a fandom coil on top of a steel ball as a single south pole, after magnetization.

It was found that the life time of these balls are quite long, even though they decay slowly in time of several days. However the steel ball has shorter life time as compared with the others. The magnetic fields of the steel ball decay to a lower value within few hours. Also the magnetic fields are not very uniform around the ball. However they can all be recharged with the same procedure described above.

2.2. They are small coils (using for sensing the signals with an oscilloscope) made of iron wires. For example, one coil of ten turns was about one cm long, and 0.4 cm in diameter. It shows only one magnetic charge throughout and can be recharge also with the same process as above. Same for the other small coils with slightly different number of turns, size and length, they are very stable in time.

The stability of these single magnetic poles (MMs) depended on the way they were charged up with the coil. The duration, the location, the amount of dc current (in the coil) and the materials being used, all effect the resulting life time of the artificial MMs.

It should be noted that all the magnetic monopole samples made this way are consistent so long as the magnetic history of the samples are carefully monitored. The memory of the magnetic effect may change the samples in an unpredictable way. For example, if the sample has unintentionally exposed to a nearby permanent magnet, even for a very short time, the outcome could be very different.

3. RESULTS AND DISCUSSIONS

Even though some of the single pole sample are not that stable for a long time, but it is still possible to do some important experiments with some of them before they decay into a less magnetic charge state. Also it is important to note that all these new samples can be recharged again and again, but the charges may not be exactly the same each time.

The results of these experiments on the MMs so produced in the laboratory indicated that it is possible that their magnetic flux lines not only form loops but also can be a source or sink as was demonstrated by the nature of the isolated single magnetic poles (See Fig. 1 and 2). As we have observed the Coulomb types of forces between MMs which indicated that they are truly concentrated point like magnetic charges of different signs. The magnetic charges can be estimated from the measurements using Gauss theorem. They are around 0.5-1 A-m for most samples. The calculated n= 1.5-3X 10 (exp 9), which is very large in turns of magnetic flux unit [10]. However the force between them is still relatively small and we have not completed the measurement so far. It is hope that larger single poles can be made in the future, so that more applications and measurements can be made.

With the easy access of the artificial MMs, many experiments become possible to study them with different probes, such as neutron diffraction, electron beams, x-ray, optical scattering, muon decay, etc.

One of the important experiments to do is the interaction with a superconducting ring to prove the possible magnetic flux quantization with the sensitive SQUID at low temperatures. [2, 11]. These experiments will further prove that the MMs are what Dirac proposed in 1931. [1, 2].

4. CONCLUSIONS

It is important to demonstrate the existence of single MMs in nature. It has great theoretical interests and implications in many different field of physics.

In this paper we report the successful attempt to create solid samples of single magnetic monopoles, with either north or south magnetic charges. They have been successfully tested with relative simple equipment. It is believed that this is the first time such a single isolated MM is being produced in a laboratory at room temperatures.

Since it is easy to make these isolated MMs in any laboratory, it is now possible to make many other measurements with these MMs for the purpose of learning more about the physical properties of these entities.

5. ACKNOWLEDGMENT

The valuable discussions with Professors Thomas T.K. Hsieh, C.M. Fou and J. X. Lin are highly appreciated. I received no funding for this work.

REFERENCES

[1] Dirac, P. "Quantized singularities in the electromagnetic field". *Proc. Roy. Soc.* (London) (1931) **A 133**, 60.

[2] Preskill, J. "Magnetic monopoles", *Ann. Rev. Nucl. Part. Sci*. (1984). **34**: 461-530 .

[3] Song, J. S. "Theory of magnetic monopoles and electric-magnetic duality: A prelude to s-duality". *J. Undergrad. Sci*. (1996)**, 3**: P.49, Eqs. 7-10.

[4] Kaiser, V. Bloxsom, J. Bovo, L. et al, "Emergent electrochemistry in spin ice: Debye-Huckel theory and beyond". (2018), arXiv: 1803.04668v1, [cond-mat.str-el].

[5] Chares, A. Barra, A. and Carman, G. P., "Voltage control of magnetic monopoles in artificial spin ice". (2018), arXiv: 1803.08598 [physics.app-ph].

[6] Paulsen, C. Giblin,S. R. Lhotel, E., etal , "Experimental signature of the attractive Coulomb force between positive and negative monopoles in spin ice", (2017), arXiv: 1603.09720v2 [cond-mat.str-el].

[7] Sarte,P.M., Aczel,A.A., Ehlers, G. etal, "Evidence for the confinement of magnetic monopoles in quantum spin Ice" J. Phys.: Cond. Matter, (2017) **29**, 451. T01.

[8] Castelnovo, C.; Moessner, R.; Sondhi, S. L. "Magnetic monopoles in spin ice" *Nature (2008)* **451**: 42–45.

[9] David Y. Chung, "The experimental evidence on the direct measurements of magnetic monopoles in magnetized materials at room temperatures" Int. J. of Pure and Applied Physics,(2017) Vol. 13,No.1, pp.143-154.

[10] Errede S, UIUC Physics 435, E. M. Fields and Science 1, Lecture Notes 18 (2007)

[11] Yuan, Y.H. “Search for monopoles using SQUID”, arXiv: physics/0512220v3. (2006)