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Muon spin radiography of sediments

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In this paper, we propose a method to use muon spin radiography as a non-destructive testing method to evaluate the magnetic properties of materials. Muon particles have the ability to penetrate matter ranging from a few mm to a few km, depending on the energy levels. Gigantic objects, such as volcanoes [1], have been imaged using muon absorption radiography by measuring the internal density distribution of the structure. This technique exploits very high energy muons in cosmic rays. It is also possible to produce muons artificially in particle accelerators. These produced muon particles are inadequate (in terms of energy) to penetrate structures as thick as a volcano. However, a higher degree of control over both momentum and polarization is possible and this advantage can allow new applications of muon radiography to be developed. By controlling the momentum of the muon particles, we can control the depth of penetration with greater precision. As a next step, we can also create a three dimensional scan of a specimen by employing a fabricated muon beam with a collimated, narrow spatial spread. Another possibility is to combine muon spin spectroscopy with the mentioned three dimensional scan in order to obtain information about the magnetic properties, also in three dimensions. Muon spin spectroscopy is conducted by using muon beams that have nearly perfect spin alignment in relation to the beam direction. Since muons experience local magnetic fields in their surroundings when they stop in the specimen, they can provide useful information on the local structure of the magnetic domain. This principle is similar to nuclear magnetic resonance, however in this case we implant muons (light protons) instead of using protons that already exist in the material. One of the benefits of muon spin radiography in contrast to conventional techniques is that information is collected from within the structure of the specimen instead of from the outside. In this forum, we demonstrate how muon spin radiography works for a specimen from a banded iron formation (BIF) as the first step application. This can be a good target because the local domain structure of hematite grains in BIF could potentially record the past geomagnetic field. In order to strictly control the muon momentum, a surface muon beam was used in this experiment. The surface muons are produced via decay of pions at rest, therefore they have a momentum of 30 MeV/c. We can calculate the range at which the muon stops and decays to be 0.3 g/cm2 for rock by using the muon energy range relationship. As a result, muon spin asymmetry was measured at this specific depth of the BIF specimen and rapid spin precession due to the internal magnetic field was measured. Results were consistent with the fact that the hematite has parasitic ferromagnetism. The amounts of non-magnetic substances or local magnetic alignments can be calculated by comparing these results with Fe to measure the amount of the non-relaxation component. With the reasonable success of this experiment, there is the potential to extend this concept to applications such as three dimensional tomographic measurements of local magnetic alignments.

References

[1] H.K.M. Tanaka et al., High resolution imaging in the inhomogeneous crust with cosmic-ray muon radiography: The density structure below the volcanic crater floor of Mt. Asama, Japan, Earth and Planetary Science Letters 263 (2007) 104.

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