Comparative tests of conventional and retarding-potential Mott polarimeters

V. N. Petrov,[a)] M. S. Galaktionov, and A. S. Kamochkin
St. Petersburg Technical University, 29 Polytechnicheskaya Street, 195251 St. Petersburg, Russia

(Received 18 April 2001; accepted for publication 25 June 2001)

The performance of a spherical field-free and a conical retarding-potential Mott polarimeter is compared. The stability of the detector signal with respect to a change in the position of the incoming electron beam is studied for two different primary electron beam energies. Shifting the incoming electron beam by 0.6 mm does not change the counting rate in the spherical field-free detector but induces a 7% or 18% change in the conical retarding-potential detector when using 1600 and 500 eV electrons, respectively. This may result in an error of the measured electron spin polarization. © *2001 American Institute of Physics.* [DOI: 10.1063/1.1396658]

I. INTRODUCTION

Currently there is increasing interest in experiments with spin analysis and therefore also in spin sensitive detectors. There are different opinions with respect to the advantages and disadvantages of different types of detectors usually with regard to efficiency, size, simplicity of design, cost, etc. Unfortunately one of the most important parameters is often missing: the influence of the electron beam position, shape, and intensity on the measured counting rates and asymmetries. These parameters might change during an experiment and could result in an artificially modified asymmetry. For example, when studying magnetic materials it might be necessary to magnetize a sample in two opposite directions. This could lead to distorted trajectories of the primary (if the excitation is caused by electrons) and the secondary electron beams. Also, a temperature induced change of the magnetization might influence the electron trajectories. When using an energy analyzer in front of a Mott detector the electron beam properties at the entrance of the Mott detector might become energy dependent. This could induce artificial modifications in the measured electron spin polarization spectra. These effects occur in spite of the fact that the asymmetry is a normalized value.

Nevertheless, the sensitivity of different types of Mott polarimeters to a shift of the incoming electron beam on the target or to changes of the beam diameter and density has not been studied so far. Therefore we tested these properties for two different types of Mott detectors using identical experimental conditions.

II. DESIGN OF MOTT POLARIMETERS

We constructed and tested two Mott detectors which are now actively used in scientific research.[1–3] Model 1 is a "conventional" spherical polarimeter[4–7] in which the scattering target (gold foil) and detectors [surface silicon barrier (SSB) or passivated implanted planar silicon (PIPS) detectors] are held at the same potential. Therefore scattering of the electrons occurs in a field-free environment. Energy selection is achieved with the help of the SSB or PIPS detectors. Model 2 is a retarding-potential detector[8–10] using Rice type of geometry. In this type of polarimeter the electron energy selection is done in a retarding field between the scattering target and detector. Electrons are registered by channeltrons or multichannel plates which are held close to ground potential. Table I shows the most important working parameters for these two instruments.

Figure 1 shows a schematic drawing of the spherical field-free polarimeter. Its main components are the two concentric polished metal hemispheres. The outer hemisphere works at or close to ground potential. A potential of about 60 kV is applied to the inner hemisphere. Inside the inner hemisphere there are four PIPS detectors with large sensitive surfaces, the 800 Å gold foil evaporated onto a thin free Formvar film and directing apertures. Detectors and amplifiers are at the same electric potential of about 60 kV. After amplification the PIPS pulses are discriminated at a certain level so that only the elastically scattered electrons are counted. Energy resolution of the PIPS detectors and the charge sensitive amplifiers is about ≈10 keV. For further processing the sig-

TABLE I. Parameters of the Mott polarimeters presented.

Parameter	Spherical field free	Retarding potential in Rice type geometry
Efficiency	2.5×10^{-4}	4.5×10^{-5}
Size	450×250 mm^2 comprises a self-dependence UHV system; does not need a high-voltage feedthrough	135×100 mm^2 must be mounted inside the UHV system; needs a high-voltage feedthrough
Maximum count rate	10^6 counts/s at 80% efficiency of electron registration; 4×10^5 counts/s at 100% efficiency of electron registration	5×10^4 counts/s
Possibility of self-calibration (rather relative)	By extrapolation to a high level of discrimination[a]	By extrapolation to zero energy loss[b]

[a]Reference 1.
[b]Reference 11.

[a)]Electronic mail: petrov@tuexph.stu.neva.ru

 © 2001 American Institute of Physics

Downloaded 06 Nov 2004 to 130.60.164.75. Redistribution subject to AIP license or copyright, see http://rsi.aip.org/rsi/copyright.jsp

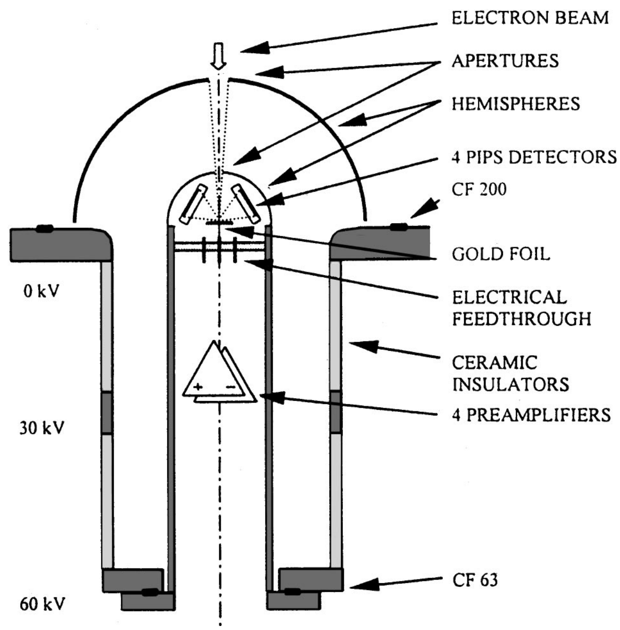

FIG. 1. Schematic of the spherical field-free polarimeter.

nals are transferred with a fiber-optical system to the input of pulse-shape amplifiers that are at ground potential. A special compact stabilized source for 70 kV was designed to provide power for the analyzer and all the amplifiers.

Figure 2 shows a schematic drawing of the retarding-potential polarimeter with Rice type geometry. The main components of the analyzer are two metal hollow polished truncated cones. The outer cone works at ground potential. A potential of about 30 kV is applied to the inner cone. Inside the smaller cone is a gold foil with a thickness of 100 μm. Electrons with a scattering angle of 120° from the gold foil pass through symmetrically positioned apertures and enter the retarding field in front of the channeltrons. An energy resolution of a few eV can be obtained. The amplifying electronics operate at ground potential.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Stability check experiments were made according to the scheme shown in Fig. 3. They involved the scattering geometry which is typical for many real electron spectroscopy experiments with spin analysis. Excitation was performed by

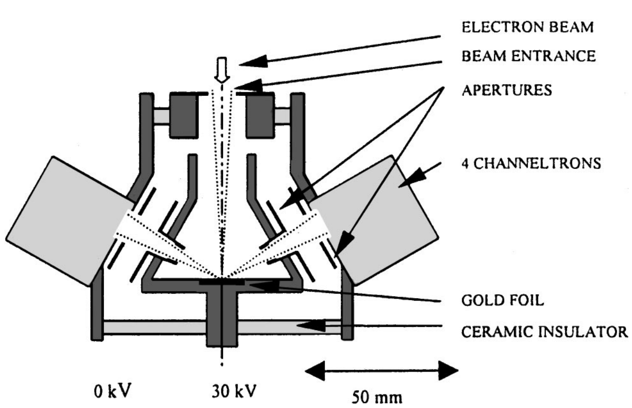

FIG. 2. Schematic of the conical retarding-potential polarimeter.

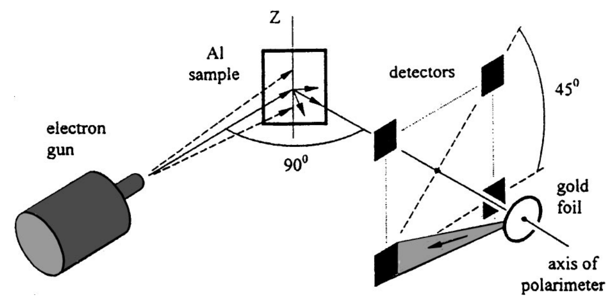

FIG. 3. Scheme of the experiment.

an electron gun positioned 60 mm from an Al target. A polycrystalline Al sample was used to exclude unnecessary effects caused by the spin–orbital interaction and crystallographic structure of the target. Electrons scattered 90° were registered by the Mott polarimeter. The experiments were performed sequentially: first with one instrument, then with the other one counted at the very same position, so that the input conditions were identical for both detectors. The distance from the Al target to the input apertures of the polarimeters as well as the diameter of the orifices in the apertures were identical for the two settings. No electron optics were used at the input of the two polarimeters and the input elements of both detectors were grounded. No energy selection was performed on the secondary electrons from the Al target. The Mott polarimeter were oriented so that the scattering plane on the Au foil includes an angle of about 45° with the scattering plane on the Al sample.

Scanning of the electron beam was performed along the normal of the scattering plane on the Al sample (axis *Z*; see Fig. 3). The shift of the beam was ±1 mm.

The results of the experiments are shown in Fig. 4. Square and circular dots correspond to opposite scanning directions of the electron beam. The results of the normalized

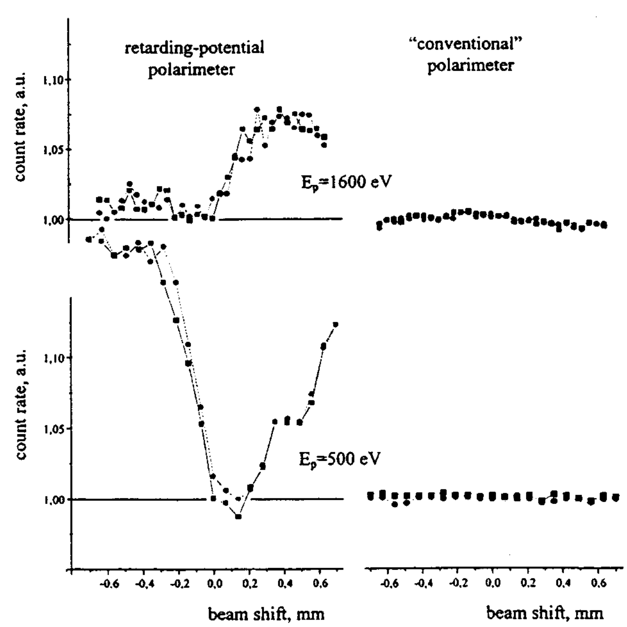

FIG. 4. Normalized count rate vs beam shift from the axis of the Mott polarimeter (axis *Z*; see Fig. 3) for two primary electron energies, 500 and 1600 eV.

Downloaded 06 Nov 2004 to 130.60.164.75. Redistribution subject to AIP license or copyright, see http://rsi.aip.org/rsi/copyright.jsp

counting rates for two energies of the primary electron beam (500 and 1600 eV) are presented. Similar measurements were performed for other energies. One can see that a shift of the primary electron beam by 0.6 mm induces practically no change in the counting rate of the conventional polarimeter. However the counting rate in the retarding-potential detector changes by ~18% for 500 eV electrons and by ~7% for the 1600 eV electrons. Moreover the character of these changes is different. The curve corresponding to 500 eV looks symmetric around the zero shift, but the curve corresponding to 1600 eV is asymmetric. Here we are not aiming at explaining this behavior but only trying to demonstrate the low sensitivity of the spherical field-free polarimeter to a shift of the electron beam at its input compared with the retarding-potential polarimeter.

Our opinion is that the following are the basic reasons for this difference (arranged in order of importance).

(1) The existence of the retarding field may cause considerable changes in the trajectories of electrons scattered from the Au foil, which is not the case in the spherical field-free polarimeter, where electrons move in a field-free space after the scattering process.

(2) In contrast to the field geometry in the retarding field detector, the spherical accelerating field in the spherical field-free detector focuses the electron beam onto the Au foil well.

Therefore at the design and experimental setup stage, when one chooses the type of spin analyzer, one should take into consideration not only such parameters as maximum efficiency, minimum size, or simplicity of the design. One should also take into account the fact that in some experiments a shift of the electron beam at the input as well as a change in its diameter and density may cause a change in the counting rate measured and therefore, the scattering asymmetry. It is evident that electron beam polarization in this case will result in measurements with an error.

The authors gratefully acknowledge A. Vaterlaus for useful discussions.

[1] V. N. Petrov, M. Landolt, M. S. Galaktionov, and B. V. Yushenkov, Rev. Sci. Instrum. **68**, 4385 (1997).
[2] C. Stamm, F. Marty, A. Vaterlaus, V. Weich, S. Egger, U. Maier, U. Ramsperger, H. Fuhrmann, and D. Pescia, Science **282**, 449 (1998).
[3] Yu. Yashin, Yu. Mamaev, and A. Ambrazhei, Proceedings of Low Energy Polarized Electron Workshop, St. Petersburg, 1998, p. 27.
[4] D. F. Nelson and R. W. Pidd, Phys. Rev. **114**, 728 (1959).
[5] M. Kalisvaart, M. R. O'Neill, T. W. Riddle, F. B. Dunning, and G. K. Walters, Phys. Rev. B **17**, 1570 (1978).
[6] M. Landolt, R. Allenspach, and D. Mauri, J. Appl. Phys. **57**, 3626 (1985).
[7] M. Getzlaff, J. Bansmann, and G. Schönhense, J. Magn. Magn. Mater. **131**, 304 (1994).
[8] L. G. Gray, M. W. Hart, F. B. Dunning, and G. K. Walters, Rev. Sci. Instrum. **55**, 88 (1984).
[9] F. B. Dunning, L. G. Gray, J. M. Ratliff, F.-C. Tang, X. Zhang, and G. K. Walters, Rev. Sci. Instrum. **58**, 1706 (1987).
[10] S. Qiao, A. Kimura, A. Harasawa, M. Sawada, J.-G. Chung, and A. Kakizaki, Rev. Sci. Instrum. **68**, 4390 (1997).
[11] T. J. Gay, M. A. Kahkoo, J. A. Brand, J. E. Furst, W. V. Meyer, W. M. K. P. Wijayaratna, and F. D. Dunning, Rev. Sci. Instrum. **63**, 114 (1992).

Downloaded 06 Nov 2004 to 130.60.164.75. Redistribution subject to AIP license or copyright, see http://rsi.aip.org/rsi/copyright.jsp