



Spin scattering in manganese doped nickel

K.R. Podolak^{a,*}, T.J. Betthausen^a, K.N. Altmann^b

^a State University of New York at Plattsburgh, 101 Broad St., Plattsburgh, NY 12901, USA

^b Elon University, 2625 Campus Box, Elon, NC 27244, USA

ARTICLE INFO

Article history:

Received 17 August 2012

Received in revised form

19 September 2012

Accepted 22 September 2012

Available online 27 September 2012

Keywords:

Ferromagnetism

Spin scattering

Nickel

ABSTRACT

Spin scattering characteristics of nickel doped with manganese are compared to nickel doped with iron and chromium in nickel. Conclusions are made based on the spin characteristics of the nickel samples doped with manganese with varying percentages in a host nickel crystal. Manganese doping increases the magnetic exchange splitting of nickel, similar to doping with iron and opposite to doping with chromium. On the other hand, manganese doping behaves different from iron with respect to the ratio of the majority to minority spin carriers and the ratio of their lifetimes. While iron doping affects both ratios strongly, manganese and chromium doping do not.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Spintronics is a field where a wide amount of applications are utilized inside today's devices [1]. In spintronics, spin currents replace electric charge as currents. These spin currents use multilayer structures as a filter to switch between high and low spin currents. Giant magneto-resistance (GMR) is an effect created by a multilayer spin valve structure that has high or low resistivity depending on the direction of an external magnetic field. This effect won the Nobel Prize in Physics in 2007.

A simple model of a GMR device has two ferromagnetic layers separated by a nonmagnetic spacer layer. When the ferromagnetic layers have their magnetization directions parallel, current is allowed to flow through the device. However, if the ferromagnetic layers' magnetization is aligned antiparallel, most electrons traveling through are scattered, giving a much higher resistance. This current is directly related to the mean free path of the electrons through the material, λ [2]. There has been considerable interest in studying the mean free path of majority and minority spin carriers [3,4].

One method to increase the current in the GMR effect is to increase the magnetoresistance ratio. By adding magnetic impurities to the ferromagnetic layers, scattering can be promoted and thereby increase this ratio. A large GMR magnetoresistance ratio is preferred for optimal data storage density in spintronic devices like hard disk drives.

The sp bands in materials used for GMR devices have a higher group velocity, but it is the d bands that have the larger contribution

to the magnetization. The sp bands hybridize with the d bands near the Fermi energy [5], resulting in a measurable magnetic splitting [6]. Therefore, these sp -hybridized bands are of interest in understanding how the magnetism relates to spin scattering in these bands [7].

There has been considerable interest in magnetic doping as a method to speed up data transmission. Recent studies in plasmon dispersion have found surface and bulk plasmon resonance peaks in manganese doped nickel that increase in strength of resonance with higher concentrations of manganese in nickel [8]. By understanding how the charge carriers interact with light can help further understand how to utilize manganese in nickel for future device applications.

2. Theory of band filling

Ferromagnetic behavior results from band filling. The spin of an individual electron can interact in one of two ways with an external magnetic field. Some electrons will naturally align parallel to an external field and others will align antiparallel to an external field. These are called the spin majority and spin minority bands respectively. When applying a magnetic field to a paramagnet at absolute zero, the spin minority electrons are raised higher in energy and the spin majority electrons are lowered in energy. This energy difference is $2\mu B$, resulting in a ferromagnet, where μ is the magnetic moment and B is the magnetic field. This unbalanced filling resulting from the energy difference makes a ferromagnetic material.

Remnant ferromagnets such as nickel have a band structure shown schematically in Fig. 1. In Fig. 1a, nickel above the Curie temperature (627 K) has a net magnetic moment of zero. This is

* Corresponding author. Tel.: +1 518 564 3193.

E-mail address: kpodo001@plattsburgh.edu (K.R. Podolak).

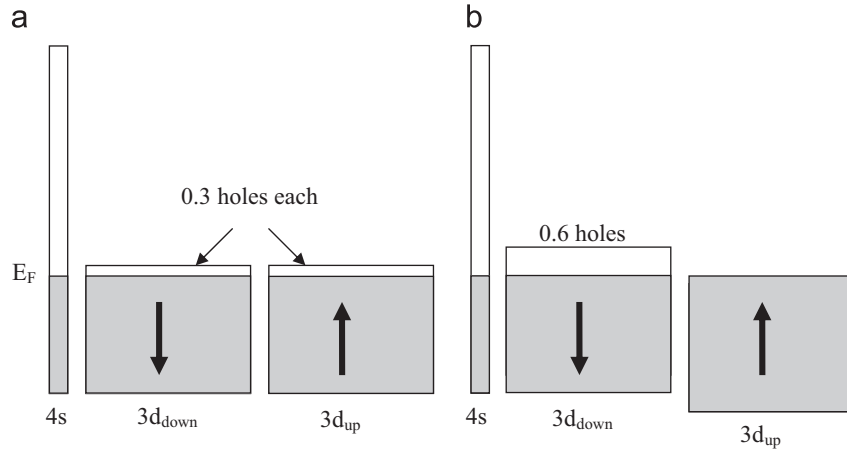


Fig. 1. Pictorial relationship for nickel (a) above the Curie temperature showing how the band filling results in zero magnetic moment and (b) at 0 K showing a net magnetic moment resulting from holes in the spin minority band.

shown in the band filling, having equal spin majority and spin minority carriers above the Fermi energy. However, if we are to cool the sample to 0 K, the spin majority fills up, leaving an excess of 0.6 holes in the spin minority that are unmatched. The magnetization of nickel arises from these spin-polarized holes in the spin minority band [9].

3. Previous work

Previous work in our group has been done on differentiating copper and nickel's sp bands near the Fermi energy. In the first work, nickel, cobalt, copper, and permalloy ($\text{Ni}_{0.8}\text{Fe}_{0.2}$) were studied [10]. The spin majority (up) and minority (down) peaks were imaged crossing the Fermi energy, 0 eV. These bands match well with theory developed by Bansil [11]. We also note that the intensity is not the same for each spin polarized majority or minority band. This is an indication that the lifetimes of spin polarized electrons in the spin majority or minority states are not the same and varies with alloy composition and material [12].

4. Preparation and methods

For these synchrotron-based experiments, a single crystal of nickel (1 1 0) was used instead of an evaporated film to reduce scattering by defects, as reported by Gilman [13]. Fig. 2 shows a picture of this second preparation chamber, complete with evaporators on the right hand side and LEED on the left. A small concentration of doping material is deposited onto 'perfect' single crystal surfaces using evaporators made in house. The sample is then heated to around 700 °C to allow the top doping layer to diffuse into the surface layers of the substrate. The concentration of the dopant is checked through atomic core-level scans. Peaks were verified to be a nickel 2p core level and a manganese 2p core level. The penetration of the synchrotron radiation at the energies used is 10, which is less than the diffusion depth of the dopant. It is assumed the concentration did not change appreciably over the probed thickness.

Our experimental results are compared to previous similar measurements performed by Altmann et. al [14]. In the latter experiment, a nickel host had impurities of chromium or iron diffused into the nickel. In our experiment, manganese is diffused into the host nickel. The sp-states of the nickel are measured in either case using an electron spectrometer with energy and angle (momentum) multidetection with p-polarized radiation.



Fig. 2. Sample preparation chamber used for spin scattering experiments at the SRC. In the center are up to five sample mounts. On the right hand side is a quartz crystal oscillator (QCO) and the sample evaporators. On the left hand side is a LEED to check crystal structure.

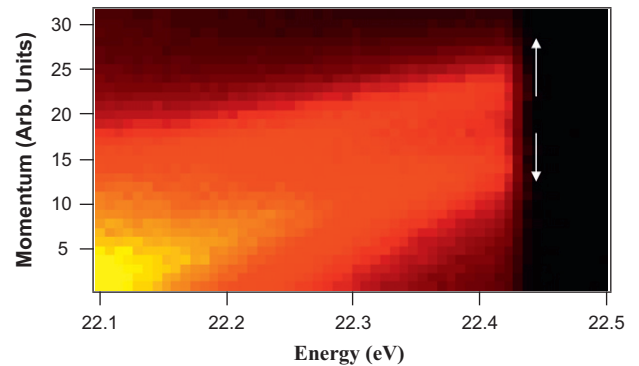


Fig. 3. Momentum (arb. units) vs. Energy plot (eV) for 7% manganese diffused into nickel. The color shows the intensity or number of photoelectrons. The arrows indicate the strong splitting between the spin majority (up arrow) and spin minority (down arrow). The Fermi energy can be seen at 22.42 eV. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

The Fermi energy, 22.42 eV, at 4 K can be seen in Fig. 3 where the intensity drops to zero. We can see that the sp bands continue 0.15 eV below the Fermi energy to which they broaden out and

Download English Version:

<https://daneshyari.com/en/article/1810412>

Download Persian Version:

<https://daneshyari.com/article/1810412>

[Daneshyari.com](https://daneshyari.com)