Letter to *Science*

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A recent paper in *Science* made the claim of 92% spin polarization for electrons injected into GaAs(110) from a Ni scanning tunneling microscope (STM) tip which, it was asserted, emits 100% spin polarized eletrons.[1] Such a claim, if substantiated, would be a development of great importance for the emerging field of Spintronics. If true, it would suggest that the field is rapidly closing in on the goal of injecting electrons with 100% spin polarization, which is a key to device applications. However, for reasons we discuss below, we believe that the actual injected electrons had a spin polarization much less than 92% and that emission of 100% spin polarized electrons from the Ni tip should not be expected.

The measured polarization of the emitted light, 11.5%, is connected to the spin polarization of the injected electrons by three conversion factors. These three factors are the ratio of the detected light polarization to the emitted light polarization, the ratio of the emitted light polarization to the polarization of the electron spin density, and the ratio of the polarization of the electron spin density to the polarization of the injected current. By ignoring the refraction of the light when leaving the GaAs, the authors both miss this first correction factor and overestimate the second. The final conversion factor depends strongly on materials parameters, which the authors have not determined, and which vary quite strongly in existing measurements.

Since the index of refraction for GaAs is 3.4, the light that is collected at the angle of 60º was emitted at angle of 14.8º. From the Fresnel formulae, the circular polarization decreases slightly on refraction, so the polarization of the emitted light is a factor of 1.06 greater than the measured light polarization. The circular polarization of the emitted light is related to the spin polarization of the electron density through matrix elements giving a factor of two divided by the cosine of the emission angle. This gives a conversion factor of 2/cos(14.8º)=2.07. The total conversion factor between the measured light polarization and the spin polarization of the electrons at recombination is thus a factor of 2.19. By ignoring refraction, the authors use a factor of 2/cos(60º)=4.0. Thus, the measured electron spin polarization at recombination is 25.2% rather than 46% as claimed by the authors.

The polarization of the electron spin density at recombination will be less than the polarization of the injected current due to spin flip scattering. The authors used values for the recombination and spin relaxation lifetimes based on published results, which through their Eq. 1, give an injected electron spin polarization a factor-of-two larger than the recombination polarization. However, the lifetimes depend on doping, temperature, and sample quality. Consequently, different groups using different samples obtain different values. Without reliable spin and electron lifetime values that pertain to the sample investigated, we do not believe that the factor-of-two larger value for the injected electron polarization claimed by the authors is justified. We feel that it is appropriate for the authors to claim a measured spin polarization of 25.2% and to point out that the injection polarization is likely to be larger, possibly by a factor even greater than two, but also possibly by a factor much closer to one.

It is not surprising that the injected electron spin polarization that can be inferred from the measured circular polarization of the emitted light is not close to 100%. The authors assert that the Ni(110) STM tip emits 100% spin polarized electrons because along the <110> direction in Ni, the density of spin-up states at the Fermi level is zero. In fact, both the spin-up and spin-down S_1 bands cross the Fermi level in mid-zone. In photoemission measurements that the authors reference, selection rules suppress photoemission from the S_1 states and hence achieve 100% spin polarization. These selection rules do not apply to tunneling. Furthermore, at the tunneling voltages used in the experiment, both the spin-up and spin-down states below the Fermi level are accessible for tunneling. As a consequence, it is incorrect to assert that the tunneling current from a Ni(110) tip is 100% polarized.

In summary, we believe an electron spin polarization at recombination of 25.2% can be inferred from these experiments. It is difficult to say definitively how much more than 25.2% the actual electron polarization is upon injection.

1) V. P. LaBella, et al., Science 292, 1518 (2001).