LF noise in cross Hall effect devices - geometrical study

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The aim - **to optimize the shape** of the cross-shaped Hall devices with regard to conductivity noise generated on sensing contacts

The result – **conductivity noise reduction** due to pure geometrical effect applicable to Hall sensors based on various physical structures like:

- **AlGaAs/InGaAs/GaAs magnetic sensors** - attend to [5115-26] !
- **FD-SOI magnetic sensors** - attend to [5115-27] !

Related to [5115-26] & [5115-27] (oral session 6, Ballroom North, Tuesday 3:35 to 4:55 pm)

[5115-26] - 3:35 pm: "**Intrinsic low-frequency noise in AlGaAs/InGaAs/GaAs micro Hall sensors**"

[5115-27] - 3:55 pm: "**Low-noise SOI Hall devices**"

Work done:

Idea - to smooth horizontal current flow and cut corners of the standard cross-shaped Hall device:

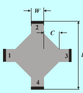


Figure 1. Shape of the Hall effect device. ***w, l, c*** are parameters which determines the shape of our samples with square symmetry.

Calculations:

- adjoint network approach
- calculations of current and adjoint current distributions
- geometrical factors

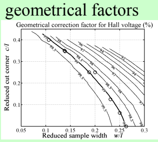


Figure 2. Contour plot for dependence of the geometrical correction factor for Hall voltage on parameters *c/l* and *w/l*.

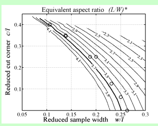
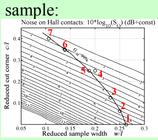


Figure 3. Contour plot for dependence of the equivalent aspect ratio $(L/W)^*$ on parameters *l, w, c*.

- conduction noise generated on sensing and on driving current contacts (S_Q and S_D, respectively) is a function of the current density and adjoint current density distributions in the sample:



$$S_{V_H} \equiv S_Q(I) = \frac{\langle \Delta R \rangle^2}{I^2 \Delta f} \int_S (\mathbf{j} \cdot \tilde{\mathbf{j}})^2 d\sigma = S_\rho \cdot I^2 \cdot \iint \frac{(\mathbf{j} \cdot \tilde{\mathbf{j}})^2}{I^4} dxdy$$

$$S_{V_{in}} \equiv S_D(I) = \frac{\langle \Delta R \rangle^2}{I^2 \Delta f} \int_S (\mathbf{j} \cdot \mathbf{j})^2 d\sigma = S_\rho \cdot I^2 \cdot \iint \frac{(\mathbf{j} \cdot \mathbf{j})^2}{I^4} dxdy$$

Figure 4. Contour plot for noise power density for sensing contacts for samples with unified length and with unified polarization current. Units are decibels (dB) plus arbitrary constant i.e. only differences between isolines counts. Comparing these results with those depicted in Fig. 2 and 3 enable us to reduce the noise power density by more than 5 dB as compared to a Hall cross with sharp 90° angles. The modification of the geometry of the 2-dimensional sample while keeping the geometrical correction factors at required levels is shown as distinguished line with geometrical correction factor for Hall voltage G_M=99%.

Experimental

Samples

we let the sensor shape continuously evolve from a plain Greek cross (1) with sharp angle to a diamond-shape with small contacts (7)

Sample name	Length l (μm)	Width w (μm)	Cut Corner c (μm)	Reduced width w/l	Reduced cut corner c/l	Sample number	Shape
LWC42	320	84	0	0.263	0.000	1	
LWC40	320	80	20	0.250	0.063	2	
LWC37	320	74	40	0.231	0.125	3	
LWC72G	720	144	180	0.200	0.250	4	
LWC30	320	60	80	0.188	0.250	5	
LWC22	320	44	112	0.138	0.350	6	
LWC17	320	34	128	0.106	0.400	7	

Table 1. Geometrical parameters of the samples. Denotations are explained in Figure 1. *l* is the length of the sample.

Measurements

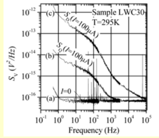


Figure 5. Power spectrum density of the voltage noise collected for sample LWC30. Curve (a) is collected for current equal to 0 and is the thermal noise of our sample. Curves (b) and (c) are collected on sensing and current driving contacts, respectively. Bias current passing each sample is equal to 100 μA.

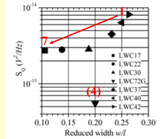


Figure 6. Experimental data for conductance noise power density S_Q collected on sensing contacts after subtracting the thermal noise level. Driving current was equal to 100 μA and the noise values were taken for frequency 10Hz.

Summary of the Results

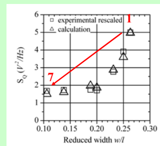


Figure 7. Comparison of normalized experimental data for voltage noise power density on sensing contacts S_Q (from Fig. 6) with results of calculations.

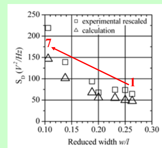


Figure 8. Comparison of normalized experimental data for voltage noise power density on current driving contacts S_D with results of calculations. The experimental data has been rescaled by the same factor as the data presented in Figure 7.

In this study we let the sensor shape continuously evolve from a plain Greek cross with sharp angle to a diamond-shape with small contacts. The output voltage noise power spectrum density first starts to decrease sharply, and then tends to level out, around a set of dimensions corresponding to the shape denoted as LWC30 in this study. Since no further benefit can be expected by further decreasing the contact width, LWC30 most probably corresponds to an optimal shape.

Conclusions

We have performed a systematic study of the noise level for series of devices with constant equivalent aspect ratio for resistance and geometrical correction factor for Hall voltage. The influence of the device geometry on the noise level is well predicted by the approach of adjoint network theory. The optimization of the shape of four terminal Hall device with regard to noise power density observed on its sensing contacts can reduce the noise power density by more than 5 dB while keeping the same overall lateral device dimensions. On the other side this means that, with an optimized shape, the surface occupied by the sensor (and thus the semiconducting material costs) can be reduced by a factor of almost 4 as compared to a standard Greek cross, while keeping the same level of electronic noise of the device.

References

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