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Performances of Wireless Sensor Networks

V. Dhanakoti*, N. Aarthi, Adithya** and V.C. Dharika****

ABSTRACT

The most significant goal in the magnetic sensor field was as soon as AMR sensor started to put back hall sensors in lot of applications where the better sensitivity of AMRs was a benefit. SDT and GMR sensors at last found the applications. We also reconsider the growth of efficiency of Fluxgate sensor and demote in brief to GMIs, SQUIDS, resonant sensors and magneto mechanical sensors. The sensor types casing electrochemical and chemical sensor, electric field and magnetic sensor, optical sensor with strain and mass sensors. The truth that grapheme have advantage over this complete choice of sensing modalities is an sign of its flexibility and significance

1. INTRODUCTION

1.1. A Introduction on sensor networks

The author explains about sensor networks (communication architecture) and moves to survey the current research pertaining to all layers of the protocol stack: Network, Physical, Data link, Application and Transport layers.

The large numbers of nodes that are arranged closely in secured proximity to the fact which are to be monitored are defined as sensor network. The data are collected by every single node and the main function is to link the data back to a sink. As the locations of the individual nodes are not preset, the network should possess self-organizing capacity.

In this form of network, Mutual aid among nodes is the foremost feature, where groups of nodes assist to circulate the information gathered in their surrounding area to the user.

The Major difference between ad-hoc and sensor networks:

1. The total number of nodes can be concern of magnitude superior.
2. Sensor nodes are closely deployed.
3. The nodes are prone to collapse.
4. Topology changes frequently.
5. Spread communication paradigm.
6. Restricted power capabilities and power dispensation.
7. Possible nonexistence of unique global detection per node
8. The author spot out that not any of the studies surveyed has a abundant integrated analysis of all the factors motivating the aim of sensor networks and proceed to present their own design factors and Communication architecture to be used as a tool and as a guideline to evaluate various protocols.

* Associate Professor,

** Student, Department of Computer Science and Engineering, SRM Valliammai Engineering college. Tamilnadu, India.

After surveying these literatures, this is our idea as well as we include it for future work based on the open research issues.

The mean factors listed:

Fault Tolerance: Individual node is levelled to unanticipated failure with a higher chance than other networks. The network should maintain information distribution despite of failures.

Scalability: order it in the number of thousands or hundreds .Protocols should be capable enough to scale such elevated degree and gain benefit of the high solidity from such networks.

Production Costs: The cost must be low, much less than $1.

Hardware Constraints: The sensor node is comprised of many subunits .and they are combined together must consume extremely low amount and power.

Sensor Network Topology: maintained even with very elevated node densities.

Environment: when Nodes are working in unreachable areas either because of they are embedded in a structure or antagonistic environment.

Transmission Media: optical, RF, infrared.

Power Consumption: The primary design factors are Power conservation and management

1.2. Physical Layer

It discusses about the choice of an inflection scheme that affects the power stores.

This is a largely unfamiliar area considered by the author. Open research issues: plan of simple and low control modulation schemes, strategies to raise above the signal transmission effects and in low amount hardware is being implemented.

1.3. Data Link Layer

Data Link Layer: In charge for creating the network communications self organizing ability and professionally sharing communication assets among sensor nodes.

Author’s dispute is that unique protocols need to be devised because updated solutions used in various wireless networks are not appropriate as sensor networks exhibit exclusive resource constraints and use requirements. Cellular systems have fixed communications. The main aim of MAC is bandwidth efficiency and QOS through devoted resource project. Mobile ad hoc network and Bluetooth are close to sensor networks, have orders of size less nodes and much higher communication power.[5]

Sensor systems on the other arrow need to handle with more regular topological modifications (not so considerable Because of flexibility, but generally as of nodes inadequate, working to sleep, being obstructed by environment interfering, etc) and require as primary aim to persist network period by power maintenance.

The protocols that the biographers measured are:

1.3.1. SMACS and EAR

In this ideal sensor nodes are generally stationary and there occurs a quantity of higher energy mobile nodes.[1] SMACS accomplishes system startup and link-layer association for the sensor nodules by linking neighborhood detection and channel transfer segments so that by the phase nodes receive totally their neighbors they have designed associated system. This is accomplished without the occurrence of total or limited master nodes.

Usages fixed distribution of duplex interval slots at stable frequency. Achievements large offered bandwidth associated to sensor records rate. Conserver power by arbitrary wake up all through setup and later time period distribution by rotating radio off but idle. EAR allows seamless construction of the portable nodes and is obvious to SMACS.

1.3.2. CSMA-Based Medium Access

The MAC protocol need be capable to maintenance variable but extremely interconnected and dominantly interrupted traffic. This ensures not fitting out-of-date CSMA-based systems which accept stochastically circulated traffic primarily for point-to-point movements.[2] This structure uses perpetual listening stages for energy productivity and presents arbitrary stays for strength. In demand to accomplish objectivity, an adaptive level control structure is used.[6]

1.3.3. Hybrid TDMA/FDMA CSMA-Based Medium Access

In this outline hybrid TDMA-FDMA is presentedto be extra energy capable than TDMA or else FDMA. This effort highlights that energy effective protocols used for sensor systems cannot be considered except physical layer then hardware concerns are taken into justification.[3] Protocols during the protocol loadshould be attentive of the physical level and hardware besides not delight them by way of black boxes.

1.4. Network Layer

Small Lowest Energy Communication Network: Generates a sub graph of the sensor system that holds the lowest energy path.

Flooding: Transmit information to all neighbour nodes. Simplest sending protocol with serious shortages such as overlap, implosion and resource blindness.

Gossiping: Sends files to one casually selected neighbour. Avoids implosion problem but message transmission takes slower time.

SPIN: When a node has presented files, it transmissions a description of the files and sends it first to the sensor node that states the awareness.

SAR: the root of each tree generates the multiple trees is one stage neighbour after the sink. A sensor node chooses a tree for files to be directed back to the sink allowing to the additive Quos metric and energy resources

LEACH: It Forms a two level cluster hierarchy, then it is send to the cluster head then it send to the base station. Energy dissipation is regularly spread by melting clusters at systematic intervals and casually choosing the cluster heads.

Directed Diffusion: A sink directs out a concern which transmits in the system and sets up ascent for data to flow from basis to sink.

1.4.1. Problem

Compare with wireless network, the sensor network have different requirement. The essential for scalability and strength leads to the strategy of localized algorithms, where one sensor get interact with other sensors in a restricted area and have at finest an indirect world-wide view.

1.4.2. Approach

The authors claim in favor of manipulative localized algorithms and existing directed transmission as a set of abstractions that define the communication designs fundamental such algorithms.

The design structures differ from application-specific, data-centric and traditional wireless networks.[4]

Data-centric that defines the detail that in sensor networks we are generally interested in matching the certain attribute values with the retrieving information and very infrequently we will be involved only in data from a detailed node.

This method decouples data from the sensor that created it and the secondary importance is that unique identification of nodes. Application-specific states to the responsiveness across all layers of the particular application so that in-between nodes can accomplish informed forwarding, caching and data aggregation. The authors advance to define a two-level cluster formation algorithm, where based on available energy the cluster heads are elected. They existing a localized algorithm for object tracing to establish the problems that arise. The design is problematic because localized algorithms essential to produce a definite global actions with at best secondary global information. Additionally, localized algorithms incline to be searching in the choice of limitation values. In order to overcome these complications, they recommend the prototyping of adaptive fidelity algorithms and design, where the reliability of the regained data can be imported against network bandwidth, network lifetime and energy productivity. Additionally, by emerging techniques for describing the presentation of localized algorithms it is probable to compute those tradeoffs and yield the expected performance.

The authors suggest directed diffusion to be used as an concept to model the communication designs of localized algorithms.The data that each sensor produces is categorized by a amount of attributes. Other sensors that are interested in disseminate this interest to the network (in the form of attributes and point of interest) and certain type of data. As the interests circulate, inclines are recognized that through the diffusion of data after it becomes presented, i.e., reverse paths are recognized for data that contests an awareness.

2. GRAPHENE FABRICATION TECHNIQUES

2.1. Mechanical Exfoliation

Noveselov *et al.* used this method for the first time. [1] By using this method they produce high quality single crystal grapheme monolayer. Designed for this method, to peel thin flakes from a bulk graphite sample a high tack tap (Nitto™ tape) is used. Additional peeling reduces the width of the flakes pending they are finally taken on a sio2 surface. Originally, the sections of single crystal material attained in this technique were only limited tens of microns in extent. Using this technique, it is nowadays possible to produce millimeter sized flakes.

Fig. 1 shows such a flake on a 300 nm sio2 surface, which is a single-layer grapheme flake captured. In order to rapidly confirm the number of layers in a flake, individual can use Raman spectroscopy as single-layer graphemetakes a characteristic signature.

Fig. 2 shows the few layer grapheme (FLG) flakes and bilayer grapheme (BLG) compared with that for typical Raman signature for a single-layer flake. It is clear that has increased amplitude and both the 2D peak is sharper, though the G peak is condensed for the single-layer flake.

The information are collected by each and every node and the most important function is to link the information back to a sink. As the locations of the individual nodes are not predetermined, the network should have self-organizing capacity.

As well as interference contrast obtained by placing monolayer grapheme on select substrates [27], and The number of layers can also be obtained by the quantized (2.3%) light absorption of each grapheme layer.

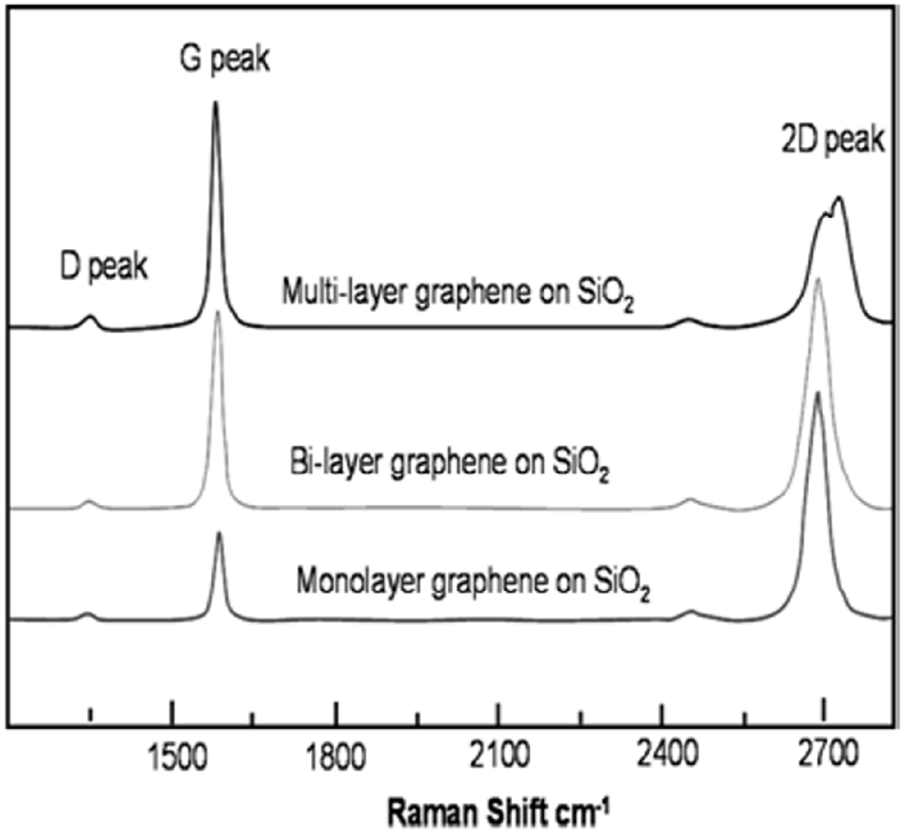

Figure 1: Single-layer, bilayer, and few layer grapheme curves placed vertically for clarity

3. TYPES OF SENSOR

3.1. Mass Sensor

In recent years there has been much concern in sensing changes in mass because of adsorbed molecules by their outcome on the resonant frequency of a cantilever or membrane [28]. These can be fabricated from grapheme membranes and cantilevers by viewing the alteration in resonant frequency of the pulsing grapheme, as molecules are adsorbed or desorbed from its outside surface. The classical molecular dynamics are utilized using theoretical studies, to examine the mass sensing potential of grapheme monolayer's, using gold as the model adsorbed atom. It was founded that to keep the factor suitably high over a useful range of operating temperature, tensile strain is required. The effects of atomistic dust and point mass on the essential frequencies have been considered in order to study the possibility of using single-layered grapheme sheets as sensors. The principal frequencies are highly sensitive variations of mass of the order which have been revealed from the results. In order to characterize the frequency response[30], work has been done on globular drum structures of few layer grapheme

The arrangement were found to have linear spring constants in the range 3.24 to 37.4 and can be triggered to about 18– 34% of their thickness prior to exhibiting nonlinear deflection. These studies specify the potential for making mass sensors, but only some experimental devices have been produced to date.

3.2. Strain Sensors

In common, it has been revealed that grapheme-based transparent conducting electrodes can survive enormous amount of strain (i.e.) up to 6% without substantial change in their electronic conductivity, which might propose that it is not the perfect material for strain sensors. The theoretical calculations expose that grapheme with a symmetrical strain distribution is always a zero band-gap semiconductor but asymmetric strain distributions in grapheme, result in opening of band gaps at the Fermi level. However, it is needed to have very large uniaxial strains, in order to open any, significant band gap. For a strain parallel to C-C bonds, the band gap constantly increases to its max of 0.486 eV as the strain increases up to 12.2 percentages. For strain perpendicular to C-C bonds, its band gap Continuously get increased only to a max of 0.170 eV as the strain increases up to 7.3%. However by using Raman spectroscopy[31] or a pseudo magnetic quantum Hall-effect, the opening of this band gap might be observed.

3.3. Photoelectric Sensors

A fixed 2.3% of the illumination passing through SLG over a wide range of wavelengths (300–2500 nm) is absorbed using Single-Layer Grapheme (SLG) . This absorption is a linear function of the number of layers. The transmission of SLG is correlated to the universal optical conductance. Thus, we have for the transmittance.[10] In photovoltaic cells and photoconductive sensors, the high electrical conductivity and near transparency make grapheme a supreme candidate for transparent electrodes. One of the initial business-related uses of grapheme may be in fabricating touch sensors, in touch screen applications where it has advantages over (1) metal-grapheme photo sensor (2) Inorganic solar cell (3) Organic solar cell. Indium Tin Oxide (ITO) is more compatible with flexible screens[29]. The achievable range of grapheme-based optoelectronic detectors is illustrated schematically in Fig 12. By converting the energy of the absorbed photons to an electrical current, grapheme-based photo detector (GPD) will measure photon flux. Since grapheme absorbs from the ultraviolet to the tetra hertz range, than conventional detectors based on group IV and III semiconductor devices, grapheme GPDs can have a much wider operating wavelength range. The carrier mobility restricts the reaction time of any photo detector. Since the mobility in grapheme is very high, the possibility exists for producing ultrafast optical sensors.

More theoretical and experimental work has been completed on the photoelectric response of grapheme.

The lane spectral reply expected due to the extremely wideband absorption in grapheme has been established by Xia *et al.* [61] up to 40 GHz Which was their capacity limit Such photo detectors will be

Restricted by RC time unvarying constant of the sensor. Xia *et al.* designed this limit to be 640 GHz for this sensor. The transfer time provides the superior limit for such sensors which is approximately1.5 THz. So these detectors, In case of high-frequency response could easily exceed exiting devices. With a much enhanced sensitivity, Mueller *et al* reported a grapheme based sensor relying on the electric field in close proximity to the metal electrode or grapheme interface to take apart the photo generated carriers, with typical efficiencies of 15% to 30%. Their device is illustrated in Fig. 13 which shows the inter digitized electrode arrangement to increase the metal to grapheme line Regions as the fields are partial to a region from.

The electrode and exterior of this region combination of the Carriers will take place. The electrodes are also prepared of different metals to shatter the symmetry of the field which would else lead to a whole photocurrent of zero. A max reaction of 6.1 was achieved which represent a 15-fold increase on prior devices.

On the other hand, this is still small compared to semiconductor sensors and is mostly due to the small absorption of single-layer grapheme and the relatively small dynamic photo current generation area near to the electrodes. Evidently, further improvements are necessary such as the use of some layer grapheme in order to enhance theeffectiveness even at the charge of some loss in bandwidth. There is some importance at present concerning the role played by the photo-thermoelectric effect on grapheme. This is the construction of a current because of the thermoelectric effect formed by the translation of photon energy into heat. We have studied a bi layer or single-layer grapheme interface where the current beginning from photon agitated carriers is noticeable from that generated by thermal effects. At the interface the thickness of states for the bi layer differs from that of the single-layer and not only produces an electric field because of band bending

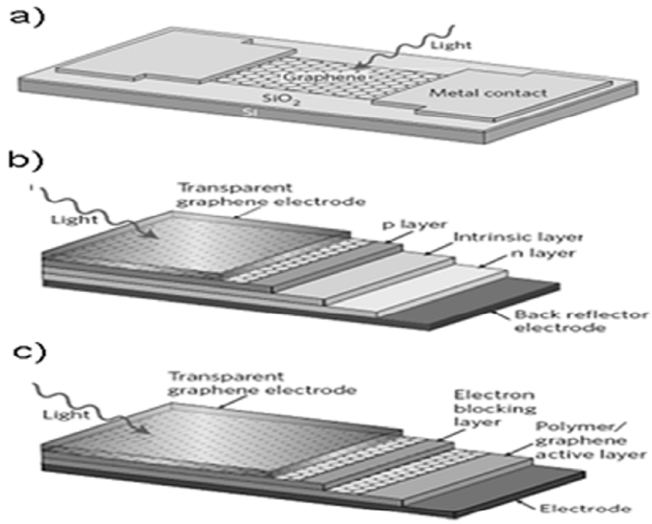

Figure 2:Graphene fabrication techniques using electrodes.

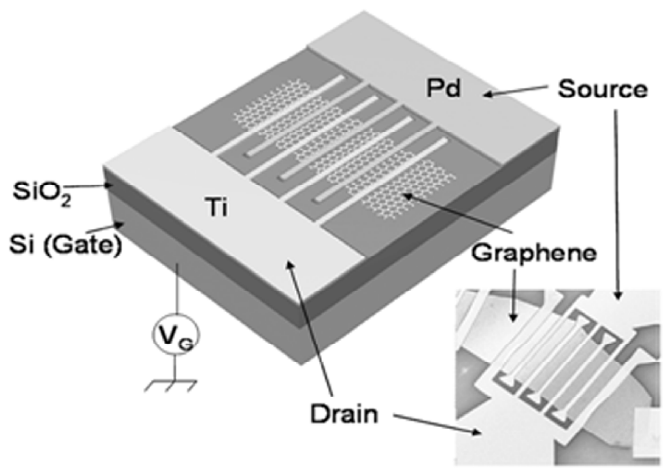

Figure 3:Graphene layer is viewed from Si and SiO2

and the photoelectric energized electrons flow from the bi layer to the single-layer. on the other hand, the thermally generated carriers will spread to the superior entropy region which will have the superior density of states. Thus, the thermally generated carriers scatter to the bi layer region. The results point out a flow towards the bilayer region and hence the thermal effects are having an importantrole. This opens up the opportunity for photo-thermo electric Detectors made from grapheme.

3.4. Chemical Sensors

Grapheme offers the best surface to amount ratio of any material, to the point that each atom in grapheme is completely a surface atom. This implies that every

Atom in grapheme is a practical target for reactive variety. The strong point of this interaction could diverge the complete range from weak Van der Waals to strong covalent chemical bonding. All these communications, to some extent, will trouble the perfect nature of the grapheme structural and electronic system, which then form the base for the detection of such interaction or binding events.

Gas sensors based on grapheme could make use of the alteration in electrical conductivity of grapheme, when gas molecules adsorb on the grapheme's face and act as donors or acceptors of electrons. Such sensitivity can be pushed to the eventual limit of detecting a single gas molecule, i.e., the fewest quantum of resulting change in conduction can be measured in grapheme[32]. This ultimate sensitivity can be credited

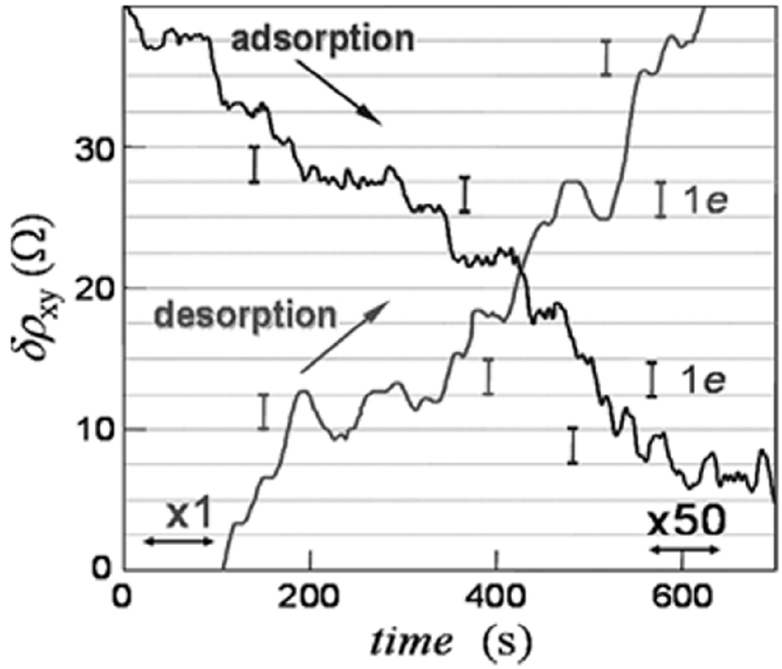

Figure 4: Chemical sensor which relates the combination of adsorption and desorption.

to numeral factors. Grapheme is a tremendously low-noise material yet in the boundary of no carriers and even a small number of extra electrons can cause a clear change in the carrier concentration. Grapheme also allow for the production of four-probe devices on mono crystals which ensures that any control of the contact resistance in restraining sensitivity is eliminated.

4. ADVANCES IN MAGNETIC SENSOR

4.1. AMR sensor

AMR sensor is unique of the best turns for its procedure such as Non-contact shifts for mobile devices. Anisotropic magneto resistive (AMR) sensors with *feedback coils and integrated flipping* have developed standard off-the-shelf strategies for usage in medium-accuracy applications such as ranges for mobile devices.

AMR sensor consume an integrated circuit to sense changes the External Magnetic field that affect the magnetic Resistance of a Magneto resistive element. Single-domain ferromagnetic thin films display AMR: their electric resistance is developed by about 2% in the direction of the magnetization than in the perpendicular direction (this outcome exists in non-magnetic metals, and then it is far weaker). Hall sensors are less sensitive than AMR sensors, and they display better offset stability for theydgrao not hurt from the piezo effect.

The growth of AMR sensors was determined by the need to substitute inductive reading heads in hard disks. In this use, they were later changed by SDT and GMR sensors, as these permitted higher loading densities due to their lesser size. Linear AMR sensors are at current produced mainly by Honeywell and Sensitise, NXP (Philips). They can consume 10 nT resolution, then, unlike Hall sensors, the signal processing electronics and driving cannot be combined on the same chip. Almost all commercially offered AMR sensors use a "barber pole" arrangement, in which aluminium stripes gasped on perm alloy strips deflect make the characteristics linear and the direction of the current by 45. Four such meander-shaped elements are linked into a Wheatstone bridge.

Where, the measured field H^y The field component Hx Fig. 2. (Bottom) Temperature offset drift of three Honeywell HMC sensors 1001 with periodical flipping. (Top) Temperature offset point of three Honeywell HMC 1001 AMR sensors without flipping.

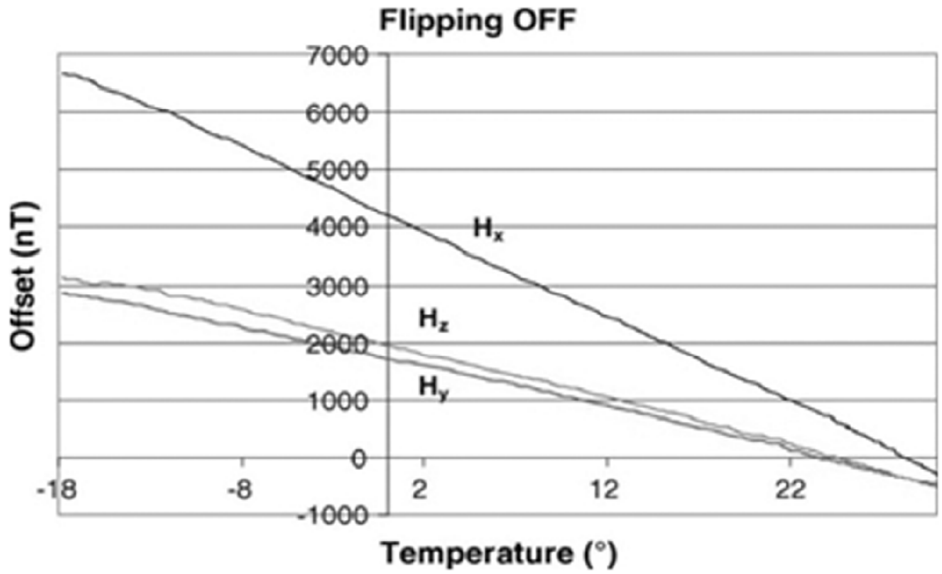

Figure 5: Flipping OFF

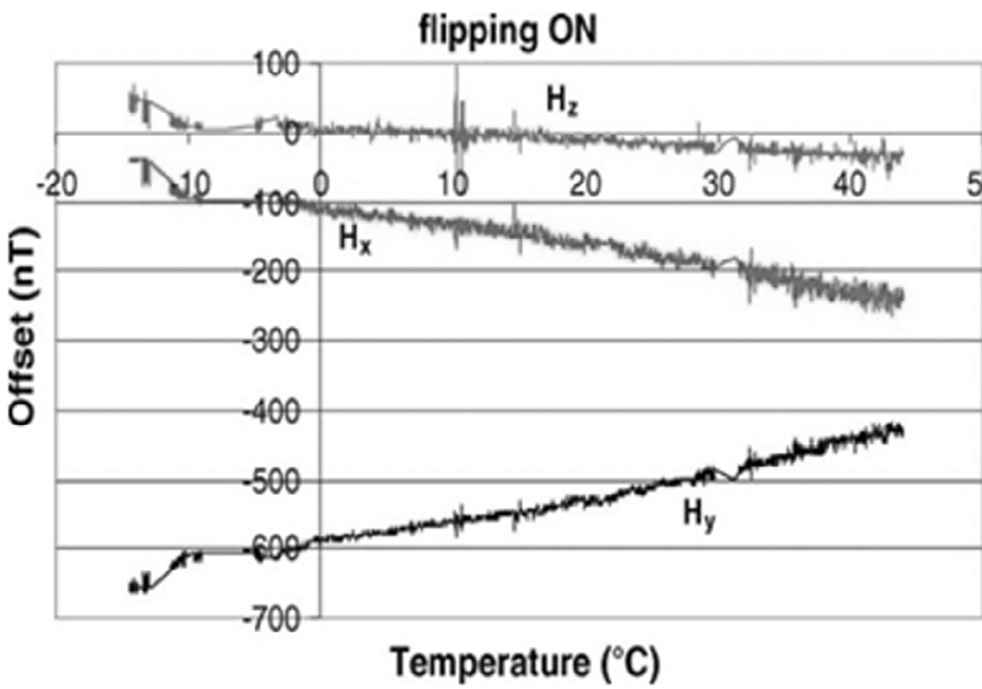

Figure 6: Flipping ON

The principles of AMR sensors are labeled in[11], relative measurements of the noise of several magneto resistors are presented in [12]. The greatest AMR sensors have a noise of 200 pT/√Hz@1[13]; still, it is difficult to attain pT noise values with the entire AMR magnetometer; realistic resolution is 10 nT[14].

4.1.1. Flipping

The suitable function of an AMR sensor is created on the single domain state of the magnetic layer. A good method for guaranteeing this is periodical "flipping" – demagnetization of the sensor arrangement by short pulses into a coil (which is usually combined on the chip). Bipolar flipping is used for low-field sensors, for it also decreases the cross field error and sensor offset. Fig. 2 shows the offset drift of flipped sensors in a tri-axial AMR magnetometer: without flipping, the drift was characteristically 100 nT/°C.

4.1.2. Magnetic Feedback

Alternative technique for enlightening the accuracy of any magnetic sensor is *feedback compensation of the measured field*. Up-to-date AMR sensors have an *integrated flat feedback coil*, which shortens the magnetometer design, then may also basis new design problems, as the recompensing field is much fewer homogeneous than that of a solenoid–this may reason linearity error. The temperature coefficient of sensitivity of a characteristic

AMR sensor may be condensed from 0.25%/K to 0.01%/K by means of negative feedback with a enough gain; the outstanding temperature dependence is due to the temperature coefficient of the field factor of the feedback coil. The temperature coefficient of the offset rests the same (typically 10 nT/K, but varies from piece to piece, even between sensors from the same batch), as feedback has no result on this parameter. With feedback compensation, the linearity error may be below 300 ppm of the full-scale, as shown in Fig. 3[15].

4.1.3. Cross field Error

AMR sensors hurt from cross-field error: the output voltage *v* depends not only on the measured field, H_y but similarly on the field component Hx, perpendicular to the sensing direction, V = 2I□ΔR Hy/Hx+H0,

Where ΔR is the maximum resistance modification and I is the bridge current.

From the earlier equation, we can see that the cross-field error (response to H_x) is zero for The magnetic feedback that repeatedly compensates can achieve this (Method 1). Though, in some cases this is not imaginable due *to limitations of speed, circuit complexity or power*. Honeywell has out new sensors with "reduced cross-field error" by increasing the (Method 2); but this also decreases sensitivity and thus rises sensor noise in field units.

Cross-field error may cause a 2.4-degree azimuth error for the AMR compass. This error can be rewarded numerically if we know and *better in three directions or measure the field in two directions*, (Method

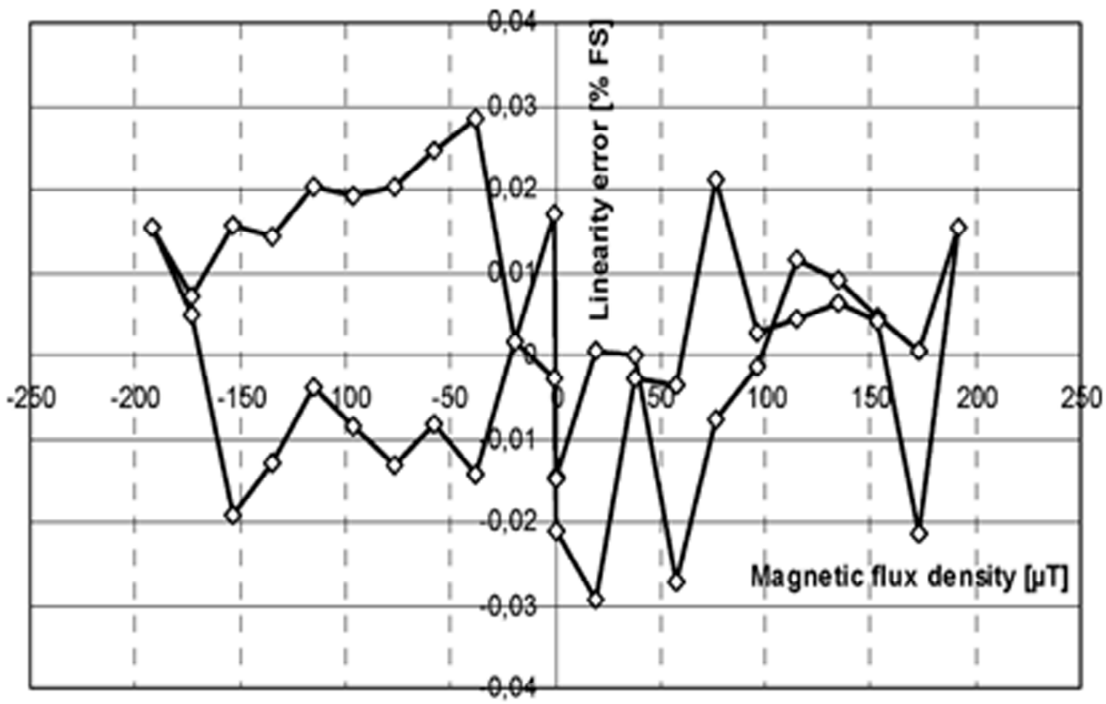

Figure 7:Feedback compensated by using an internal coil, Linearity error of a Philips KMZ 51 AMR sensor. Hysteresis is also observable from the extent cycle .

3)[16]. If periodic flipping is used and each output is read separately, the cross-field error can be *suppressed simply by averaging the outputs for the "RESET" and "SET" flipping polarities* (Method 4). More difficult calculations may lead to better correction of the cross field error (Method 5), and, in approximately cases, two components of the external field can even be restrained using a single sensor[17]. Methods for overwhelming the cross-field error are shortened in Table I.

4.2. GMR and SDT sensors

SDT and GMR magneto resistors are through of magnetic multilayer's parted by very thin non-magnetic insulating (SDT) or conducting (GMR) layers. The electrical resistance of these arrangements depends on the direction of their magnetization. In overall, if the magnetic layers are influenced in the same direction, the resistance is smaller than for layers influenced in opposite (anti-parallel) directions. The other "pinned" layer has fixed magnetization, while the external restrained field usually controls the magnetization direction in the "free" layer.

Inorder to recompense the basic temperature sensitivity, these devices are through as Wheatstone bridges. A bipolar response of the GMR bridge branches can be accomplished by a DC bias field or, in the circumstance of a spin valve, by altering the orientation of the magnetization of the magnetically hard pinning layer[18]

The magnetization direction of the free layer of the spin-valve is revolved by the permanent magnet. The most capable industrial application of GMR sensors is in angular sensing. If the free layer is soaked, the sensor output does not depend on the magnet distance, single on the restrained angle.[8]

Newly developed GMR sensors have improved their temperature stability: Hitachi has described only a 20% sensitivity modification between C to C, and 30 minutes of survival at 250 C. Conversely, large magnetic fields—particularly at elevated temperatures—can extinguish GMR spin valves due to alterations in the magnetization of the pinning layer. This threat does not occur for AMR magneto resistors and Hall sensors.

In the instance of SDT sensors, low linearity and high coercively persist a serious problem[19]; conversely, a digital magnetometer with a SDT sensor informed in exhibited[20] 1 μT resolution and a linear range of ±@mT.[9]

SDT and GMR sensors have @/f noise with cutoff frequency in the order of MHz, and the informed noise levels are relatively high[21]. Picots-detection predictions are typically based only on thermal noise, and they did not take magnetic @/f noise into explanation[22]. Fig. 4 indications that magneto resistors in overall have much higher noise than fluxgate sensors. Conversely, their main benefit, especially in the instance of SDT sensors.

HMC 1021 and 1001 are AMR magneto resistors, NVE SDT is a prototype of a spin-dependent tunneling device, and NVE AAxx are GMR magneto resistors.The data for a "cheap fluxgate" denote typical noise of Applied Physics Model 533 and comparable devices. The data for "low-noise fluxgate" is taken and adopted size and thus high three dimensional resolutions.

This is serious when calculating small substances such as magnetic micro beads for remedial applications[23], and also where ansignificant distance from the magnetic cause is essential.

4.3. Hall Sensor

Most of the magnetic sensors obtained use the Hall Effect. The silicon sensor's hall sensitivity is typically 1 mV/mT for a 1 mA current. If it is InSb (typ. 5 mV/mT) or InAs (typically, 2 mV/mT). Higher sensitivity can be achieved with thin-film. The dependence of the Hall voltage compared to Si and InSb, where InAs exhibits lower temperature and the working range of InAs devices is also superior: it exceeds the C to C

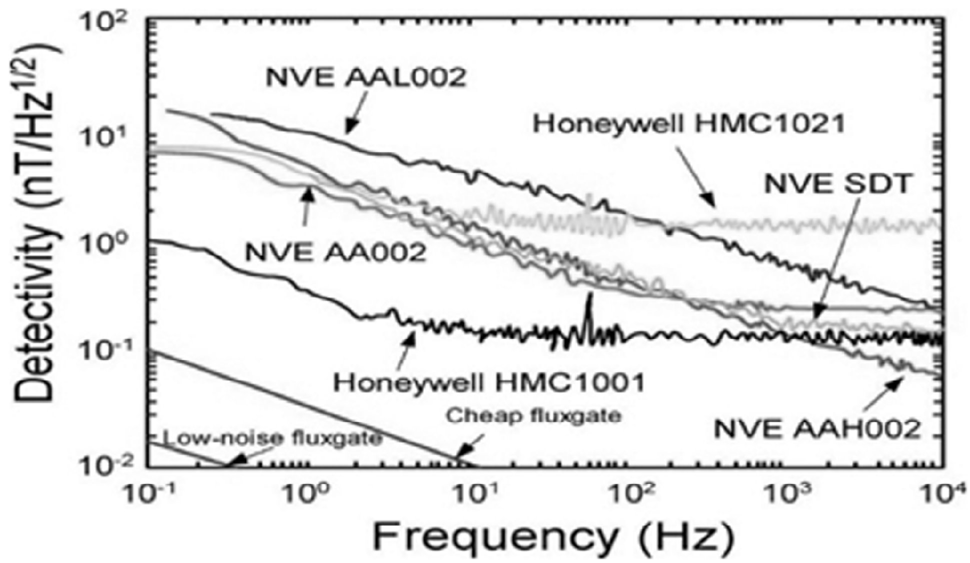

Figure 8: Noise spectrum of fluxgate sensors and magneto resistors.

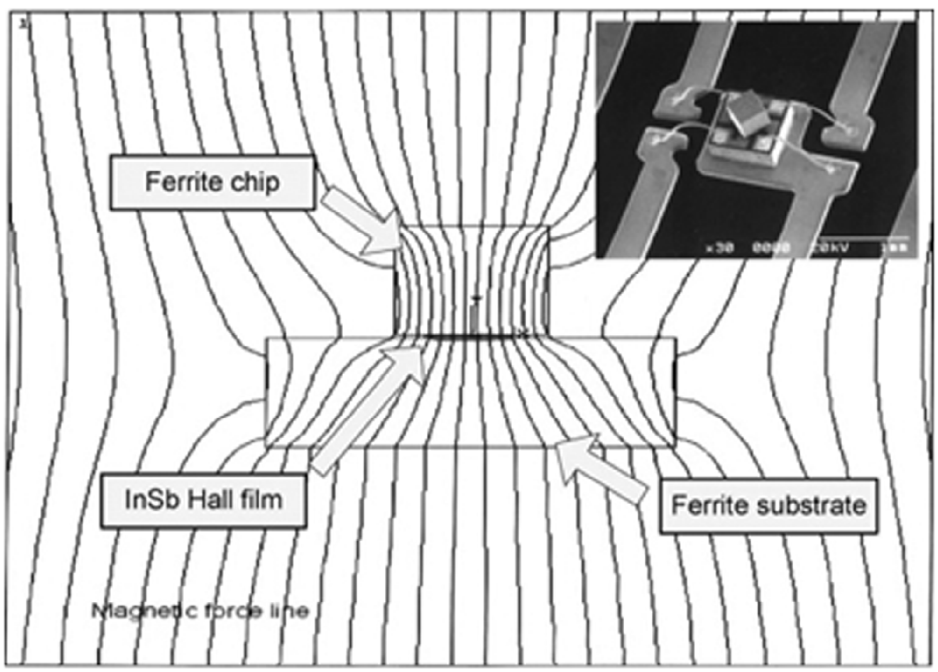

Figure 9: Magnetic force line of field concentrators for a thin – film hall sensor (FEM simulation)

range necessary for automotive applications. A promising Hall sensor was completed using silicon-on-insulator (SOI) technology.[24]

4.3.1. GaAs

Based on GaAs, Two-dimensional quantum-well multilayer hetero-structures are promising for low-noise and the noise was achieved with exterior spinning-current electronics[25], by using leakage-free switches which was further improved threshold.

Fig. 1 shows an off-the-shelf InSb Hall sensor with an integrated ferrite concentrator the InSb thin-film Hall sensor is sandwiched between two ferrite pieces. The figure shows the flux lines simulated by FEM and a microphotograph of the device. The integrated micro-Hall plate sensor supplied by the spinning current has noise of 300nT/sqrt (Hz)@1 Hz [26]. CMOS technology allows making intelligent Hall sensors, these sensors can interact digitally and perform complicated error corrections. The Example is the ability to give back not only the temperature dependence of the sensor itself, and also the temperature of the magnetic circuit enclosing the sensor (temperature coefficient of the permeability, change in the air gap, etc.)

4.4. Other devicesMagneto-electric Sensor [7]

A artificial magneto-electric sensor with 130 V/T sensitivity was presented. It contains a pack in made from piezoelectric and magnetostrictive materials. The calculated field which causes strain in the magnetostrictive constraint. This strain is attached with the piezoelectric layer and the output is obtained. The achieved sensitivity for a 10-cm-long Metsglas-PZT fiber laminate was 3000 V/T .

Other sensors relay on altering the resonance frequency of free-standing elements manufactured by MEMS technology. The initial results on huge-range models of a “xylophone magnetometer” were hopeful, but till now low noise has not been achieved using MEMS polysilicon technology.

The Lorentz force magnetic sensor achieved field resolution of 10 nT/$\sqrt{H}_H$ for a 100 μA measuring current. The Lorentz force, which is proportional to the considered field and measure the current, deflects the detached MEMS structure. The motion is obtained periodically by applying an AC measuring the current**.** The advantage is their high linearity and also the possibility to change their range by choosing the measuring current. It can work up to 50 T and discussed.

Magnetic sensors used for measuring electric current, position, and mechanical torques’s are described, hence does not appear in this review. The significant achievements in these devices are the AMR gradient bridge for current sensors current sensors and polarized-band torque sensors for the application of automotive. A sensor for magnetic nondestructive testing has been verified.

NOTE

1. Complementary Metal-Oxide-Semiconductor.

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