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Highlights

- Mobile Radio-Technical Devices
- Manufacturing, Packaging and Handling
- Tracking of Photovoltaic Generator
- Linear Parallelepipedic Electric Machine

Discovering Thoughts, Inventing Future

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Development and Increase in the Reliability of the Small Storage Batteries, Utilized for the Nourishment of the Mobile Radio-Technical Devices

By F.F. Mende

Abstract- Given the description of construction are given the fundamental characteristics of the small storage batteries Li of group. The fundamental characteristics of the nickel metal hydride storage batteries are given Ni-MH. Development and application of such storage batteries significantly increased the reliability of small mobile radio sets, in particular, cell phones.

Keywords: storage battery, lithium, nickel, lithium-ionic storage battery, nickel-metalhydride storage battery.

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I. Introduction

The development of mobile connection, small flight vehicles and other movable radio-technical systems required new studies on the development of the small, energy-consuming and reliable power sources.

Movable radio-technical devices and small flight vehicles require the reliable and small power sources; therefore many firms and producers actively work in this direction. Reliability and safety of such sources has special importance. Development and production of the storage batteries of group is the especially promising trend of such Li studies. This group includes lithium-ionic storage batteries. In these storage batteries were used lithium cobalt and lithium manganese electrodes, and also electrodes from the iron phosphate of lithium. In addition to this were developed nickel-metal hydride storage batteries also characterizing by high paramerami. Studies in this direction made it possible to create storage batteries with the large energy content, by small overall sizes and safe with their use.

II. Construction and the Fundamental Characteristics of the Small Storage Batteries li of the Group

The high reactive activity of lithium is one of the essential obstacles on the way of developing the lithium storage batteries. The first models of lithium storage batteries were completely inflammable and dangerously explosive. Were not rare the cases, when they exploded during operation in the cell phones, inflicting injuries on their users. In addition to this, in such storage batteries were limited the cycles of precharge, average cyclability of was near 50 cycles. Storage batteries went out of order because of the fact that the dendrites of lithium germinated to the electrode with the opposite sign, which led to a short circuit inside the battery and its heating. In this case lithium reacted violently with the organic electrolyte, which sufficiently frequently led to the explosion.

In 1992 the year the corporation Sony undertook the attempt to develop new storage batteries on the basis of lithium. In this case metallic lithium was substituted with safer ionic form. For the purpose of the decrease of explosion hazard such storage batteries were equipped with the system the control of the regimes of charge and discharge, that it made it possible to sharply decrease the risk of appearance in the storage battery of metallic lithium. In this case as the positive electrode cobaltate of lithium was used, and negative electrode was executed on the basis of carbon. In this case was used the coke - the material, obtained with the heat the treatment of bituminous coal. In these storage batteries as the electrolyte the hexafluorinephosphide of lithium, dissolved in the organic solvent was used [1]. Other developers instead of the coke used graphite powder of different granularity. However, success was achieved not immediately, and it was necessary to conduct the large volume of studies on the selection of the correct structure of graphite powder.

Since the firm Sony patented lithiumcobalt positive electrode, other developers order study on the development the diverse variants on the base of lithiummanganese, lithiumironphosphate and many others chemical components [2].

In Fig. 1 the schematic of crystal lattice of lithium-cobalt electrode is shown.

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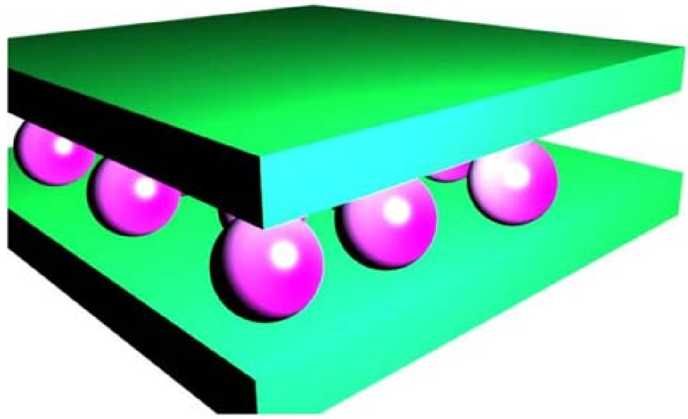

Fig. 1: Schematic of crystal lattice of the lithium-cobalt electrode

Whole the row of new electrodes they showed itself from the best side. At present the widest use obtained lithium-manganese, lithium-cobalt, lithium-ironphosphate and lithium-ionic storage batteries.

Stability of lithium-cobalt crystal lattice it is low. With this is connected the circumstance that the lithiumcobalt storage batteries do not allow large discharge currents, which narrows the framework of their application.

In Fig. 2 crystal lattice of the lithium-manganese electrode is shown.

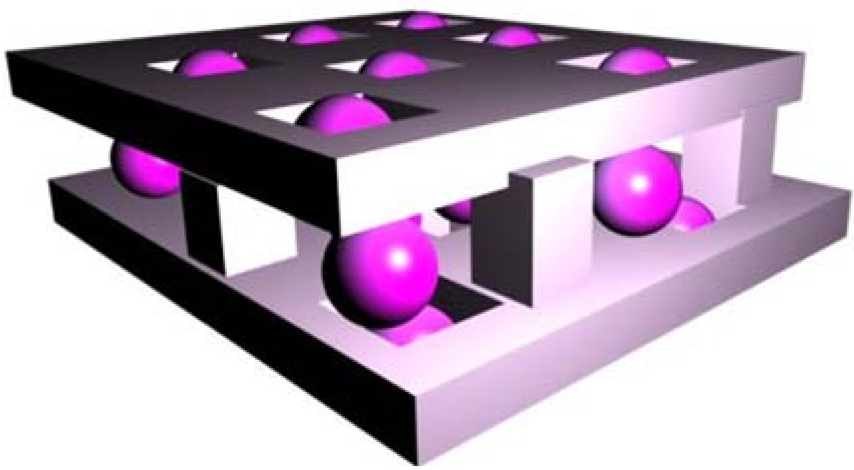

Fig. 2: Crystal lattice of the lithium-manganese electrode

On the lithium-manganese electrode the three-dimensional arrangement of lithium ions occurs. This circumstance gives the possibility to ensure the high currents of discharge and a good stability of electrode during this discharge.

Lithium-ironphosphate positive electrodes showed high operating characteristics. This connected with the fact that they have steadier crystal lattice, capable of passing lithium ions. Unfortunately, this circumstance leads to reduction in the ion mobility of lithium; therefore such electrodes are used relatively recently. Their widespread introduction began after it was possible to create the electrodes, on which the particles of the lithium-ironphosphate they had with size into hundreds of nanometers (particle size one hundred times less than in 3D lithiummanganese storage batteries). This led to the fact that their effective area increased almost by four orders, which radically improved the characteristics of lithium ironphosphate storage batteries.

In Fig. 3. The schematic of crystal lattice of ironphosphate of lithium is depicted.

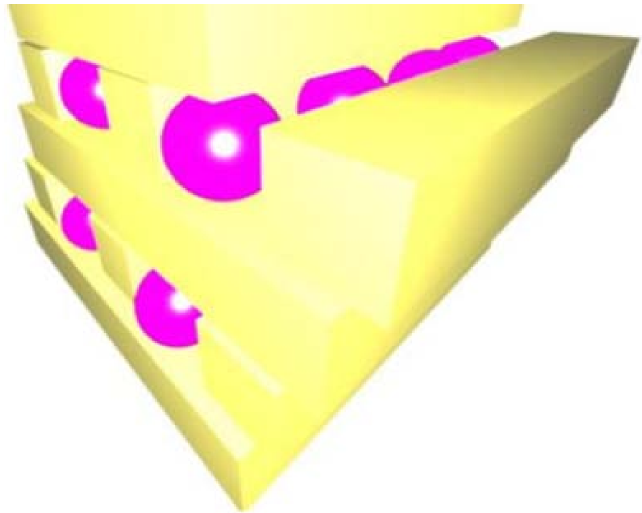

Fig. 3: Schematic of crystal lattice of ironphosphate of lithium

The positive qualities of lithiumironphosphate storage batteries led to their wide application in the systems, which require the high starting currents (for example, as the starter batteries in the automobiles)

It should be noted that not only the use of promising materials for preparing the negative electrode led to an improvement in the quality of storage batteries. Played the decisive role the use of the electrolytes, when the polymeric materials, which use the gelatinous lithium- conducting filler, were used as the electrolyte. Storage batteries with such electrolytes became basis for preparing their miniature versions.

Further improvement made it possible to create solid electrolyte. In this electrolyte lithium ions become conducting in connection with by the exchange of ions inside the matrix of electrolyte.

Developments in the field of polymeric electrolytes made possible to create the solid electrolyte, in which lithium ions become conducting in connection with by the exchange of ions inside the matrix of electrolyte. This electrolyte made it possible to restore the finished storage batteries with the electrodes from metallic lithium.

In the solid electrolyte is hindered the formation of the dendrites of lithium with the cycling, which excluded the possibility of fire and explosion of lithium storage batteries.

The problem of the use of lithium- polymeric storage batteries consists in the fact that their operating temperature is higher than 40 the degree Celsiuss. This connected with the fact that the ionic conductivity of solid electrolyte at room temperature is very small. This circumstance requires preheating storage battery, which substantially limits its applicability.

Today still remain the problems of negative electrode in the lithiumionic storage battery. Therefore developments on the base of titanate of lithium appeared. Combination of these electrodes with the positive electrodes on the basis of lithiumironphosphate made possible sharply to increase the lifetime and level of safety of lithium-ionic storage batteries.

NiMH batteries storage batteries is used as the second chemical-battery power supplies [3].

Studies on the creation of NiMH- storage batteries were begun still 1970 and were completed by the creation of storage batteries with the high energy density. In this case the new metal-hydride connections were used [4].

Such batteries have a larger capacity (about 20%) than nickel-cadmium batteries with the same dimensions. The disadvantage of such batteries is that they allow only 200 - 300 cycles.Self-discharge in these storage batteries also approximately in 1, 5-2 time is higher than in nickel-cadmium storage batteries.

The common form of NiMH- storage batteries is shown in Fig. 4.

Fig. 4: The common form of the NiMH- storage batteries

III. Conclusion

Only quick overview of the existing methods of improving the storage batteries is carried out, since to short article it is not possible to illuminate this capacious theme as chemistry of the second chemical-battery power supplies, based on lithium. One should hope that even this survey of the existing solutions will help the reader better to understand processes taking place in the systems examined and not to be tangled in the advertising communications. The rate of new developments now by such, that each half a year appear the new developments of lithiumionic storage batteries, and only time and test can give answers for questions of the correspondence of the operating characteristics, declared by producers, to real indices. In the article given the description of construction are given the fundamental characteristics of the small storage batteries Li of group. The fundamental characteristics of the nickel metal hydride storage batteries are given Ni-MH. Development and application of such storage batteries significantly increased the reliability of small mobile radio sets, in particular, cell phones.

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Why SEMI Standard E163 Should be Followed for the Protection of Extremely Electrostatic-Sensitive Semiconductors and Similar Devices During Manufacturing, Packaging and Handling

By Gavin C Rider

Abstract- Research into the damage sustained by the reticles (photomasks) used to print semiconductor devices is summarized. It is explained why ESD prevention alone does not necessarily provide adequate protection for such highly electrostatic-sensitive objects. The standard approach to ESD prevention used in the semiconductor industry is shown to increase the risk of other damage mechanisms than ESD to which reticles are far more sensitive. Insights gained from this research are then applied to the methods being used to protect sensitive electronic, optoelectronic and micro- electro-mechanical devices during their manufacture and handling. Similar weaknesses to those identified in the widely-established approach to reticle handling are found. Equipotential bonding is shown to expose field-sensitive devices to a heightened risk of damage and to reduce the effectiveness of essential static-reduction technology.

Keywords: ESD; EFM; ESDS; EES; field induction; device damage; equipotential bonding; grounding.

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Strictly as per the compliance and regulations of:

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Keywords: ESD; EFM; ESDS; EES; field induction; device damage; equipotential bonding; grounding.

Abbreviations:

ACLV: Across Chip Line width Variation (in the lithography process);
AMHS: Automated material handling system
CD: Critical Dimension (of features in a reticle);
CDM: Charged Device Model (of electrostatic discharge);
EES: Extremely Electrostatic Sensitive;
EFM: Electric Field induced Migration;
EMI: Electro Magnetic Interference;
EOS: Electrical Overstress (of devices);
ESD: Electrostatic Discharge;
ESDS: ESD Sensitive (of devices);
HBM: Human Body Model (of electrostatic discharge);
IRDS: International Roadmap for Devices and Systems;
ITRS: International Technology Roadmap for Semiconductors;
SEMI: Global semiconductor industry association (previously Semiconductor Equipment and Materials International)
TDDB: Time dependent dielectric breakdown (in semiconductor devices)
WIP: Work in progress (e.g. partly-processed wafer lots).

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I. Introduction

It has been well known for centuries that when certain dissimilar materials rub against one another especially insulating ones in a dry atmosphere – there is a generation of electric charge. This charge is referred to as "static electricity" and the process is called triboelectric charging. If an object that has been charged in this way comes close to another object, a spark can jump between them, which is known as an electrostatic discharge or ESD. Most people are very familiar with this effect since the development of man-made fibres used in clothing and carpets has introduced "the static problem" into homes and offices.

Semiconductor manufacturing environments are maintained at a relatively low humidity to prevent corrosion from taking place between wafer processing steps. The dry environment coupled with the continuous movement of machinery, materials and personnel makes the generation of static electricity very likely. If sparks take place when semiconductor devices are being manufactured or handled, the delicate structures within them can be destroyed by the current that flows into them through the spark. Machines can also malfunction if radiated energy from a spark induces errors in their control systems.

Methods have therefore been developed to reduce the likelihood of sparks occurring in the manufacturing environment or in any place where the devices are subsequently handled. To protect sensitive devices against a spark striking them if any of the safety procedures fail, protective circuitry is normally built into them. Electrostatic discharges exhibit different characteristics depending on where they originate, and the two main classifications for discharges that are likely to affect semiconductor devices are referred to as the Human Body Model and the Charged Device Model.

Devices are now designed, tested and certified to be able to withstand discharges of a specified strength from either of these sources. The environments in which semiconductor devices are handled are controlled so that any electrostatic risk that might be created will be below the level that could cause the devices to be damaged. There are international standards in place defining how such environments should be controlled and how the operations within them should be conducted. An example is ANSI ESD S20.20 [1].

II. The Control of ESD in Semiconductor Manufacturing

The standard principles that have been applied for controlling ESD in semiconductor manufacturing are probably familiar to most people working in the industry, as anyone working with semiconductor devices will be trained in how to avoid static-related problems:

1. Eliminate all non-essential insulators because they can accumulate static electricity
2. Neutralize all essential insulators using methods such as air ionization
3. Connect all conductive objects to a common electrical potential, normally ground (which is known as “equipotential bonding”).
4. Personnel working within a factory are required to wear conductive clothing and to be connected to ground, either through conductive footwear or by a special grounding strap at a workstation.
5. Workstations are required to be grounded, to have static dissipative work surfaces and to have supplementary methods of charge neutralization, such as ionized air showers.

It is necessary to ensure that any material being transported within a factory is at the same electrical potential as its destination, to eliminate the possibility of an electrostatic discharge taking place when it is delivered. Hence it has become standard practice to ground objects while they are being moved, for example by employing drag chains on the carts used to carry wafers between processing stations, or by using a grounded AMHS. To avoid any risk of a high-power discharge taking place on connection to ground, resistive contact materials (otherwise referred to as “static dissipative”) are used. Wafer boats, chip trays and WIP transfer boxes are now generally specified to be made from static dissipative materials.

A focus in the design of automated equipment in semiconductor manufacturing in recent years has been to try and reduce the generation of static charge within the equipment anywhere near the handling path of the sensitive devices being manufactured. The presence of static charge is typically revealed during an electrostatic audit by detecting the electric field that the static charge produces.

Steady-state measurements can be performed using hand-held field meters, but inside fast-moving equipment such as pick-and-place machines it is necessary to use equipment with a fast response time, such as digital electrometers and storage oscilloscopes. However, as will be mentioned later, even some of the fastest field-recording equipment available is not able to detect all electrostatic risk. The limitations of the measuring equipment being used in any electrostatics audit must always be considered, since the failure to register electrostatic risk on a meter does not necessarily mean that there is no risk present.

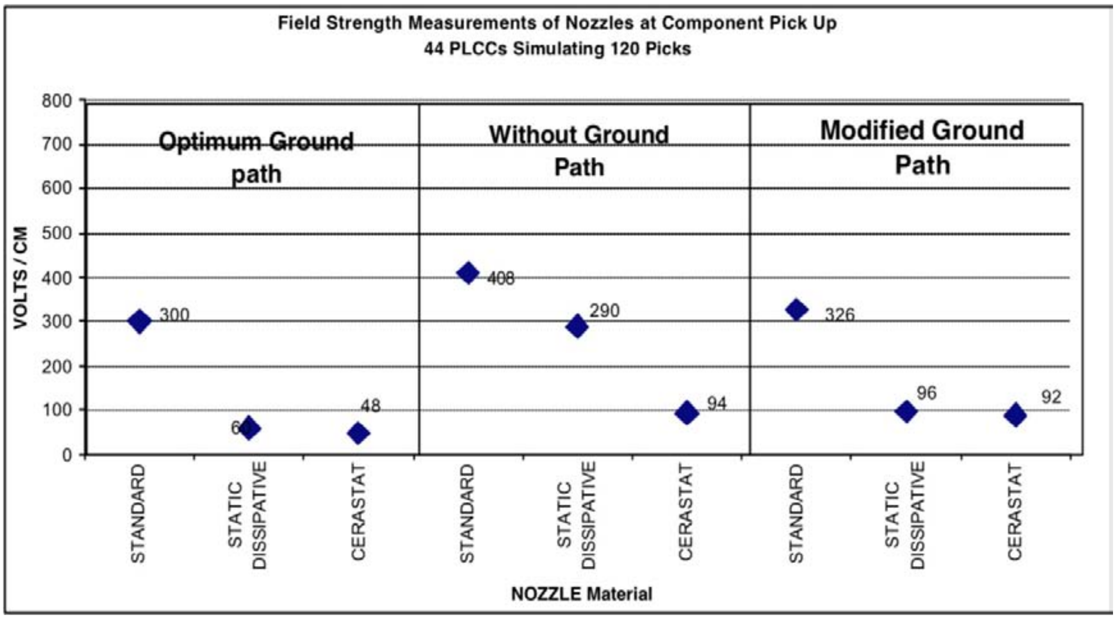


Figure 1: Reduction in the level of electric field generated within a piece of automated material handling equipment by optimizing the design of the ground path and changing the material of the vacuum nozzle used to pick and place the components. Reproduced from [2].

Figure 1 presents the result of a program of electrostatic risk reduction in automated handling equipment [2], showing that electric fields can be significantly reduced through suitable equipment design and material choices, but they are generally not eliminated completely. Hence, some electric field is always likely to be present in the environment around sensitive devices during their manufacture and handling. Furthermore, the author of this study states in his observations:

"the typical end user of components in their assembly work, whether Contract Electronic Manufacturing or Original Equipment Manufacturers, do not or cannot obtain accurate sensitivities of the components they are trying to handle with automated equipment".

This means that there is always likely to be some electrostatic risk present during semiconductor and electronic device manufacturing, but the degree of susceptibility to that risk is generally unknown.

III. An Overview of Reticle Electrostatic Damage Studies

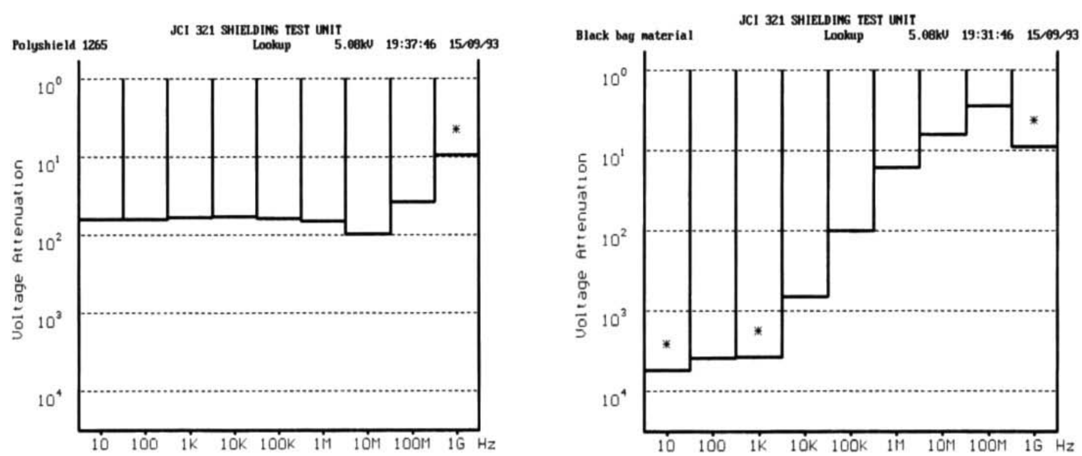
Electrostatic damage to the lithographic reticles being used to print semiconductor device layers has always been a problem, but it became critical at the end of the 1990s when around 50% of the reticles being returned to mask manufacturers for repair had sustained ESD damage. Since damage to semiconductor devices was already known to be caused by ESD events during their handling, it was presumed that reticle damage was being caused in the same way; by the transfer of static charge to or from the reticle while it was being handled. Hence, it was decided that protection of the reticle would be best achieved by adopting the methods that were already being used for device protection. Guidance was therefore published stating that reticles should always be handled using grounded conductive tools fitted with static dissipative contact materials [3].

However, research into reticle electrostatic damage conducted at International Sematech and other independent sites identified that reticles are susceptible to ESD damage simply by being exposed to an electric field [4]. It was found that damage can be induced within a reticle pattern by an externally generated electric field, without any charge transfer taking place to or from the reticle and without the reticle even being touched. Measurements of the strength of electric field that would cause ESD in typical production reticles in this way led to further guidance being published through the SEMI Standards program and through the ITRS (now replaced by the IRDS) to limit the level of electric field to which reticles might be exposed.

The program of risk reduction undertaken in the areas where reticles were handled followed the general principles described earlier, including the replacement of insulating plastic with static dissipative alternatives. The insulating plastic pods and boxes that were being used to store and transfer reticles were replaced with static dissipative ones, to reduce the likelihood of the box generating an electric field by being tribocharged during handling. This change, when introduced alongside all the other static-reduction measures being taken in lithography areas, resulted in a significant drop in the amount of reticle ESD damage. Since the problem appeared to be understood and controllable, most research programs studying reticle electrostatic damage were closed down. The International Sematech research project into reticle electrostatic damage was ended in 2003.

Unfortunately, the belief that reticle electrostatic damage would no longer be a problem was short- lived. Shortly after the introduction of static dissipative plastic reticle pods and boxes it was found that they are not able to adequately protect a reticle from electric field, because electric field can penetrate static dissipative materials. Levit and Weil [5] had measured the penetration of electric field into a reticle pod from an electrode positioned outside, simulating the charged hand of an operator carrying it. They showed that the pod was only partially effective at shielding the reticle from the electric field, and that the shielding effectiveness dropped rapidly as the frequency of the applied field was increased. It took almost a second for the static dissipative plastic pod in their tests to fully screen a constant external field, but any field that changed within that time would not be fully screened. If the field changed more rapidly than about 25Hz, the shielding effect was very poor indeed. The static dissipative material used to make the pod was acting as a high-pass filter, allowing rapidly changing electric fields to reach the reticle inside the pod.

This particular characteristic of static dissipative materials had been studied more extensively by Chubb [6], who quantified the field-shielding effectiveness of various materials that were being used for packaging in electronic component handling, at frequencies up to 1GHz. Figure 2 shows his measurements of field transmission through a metallized plastic "shielding bag" and also through a static dissipative bag. In both cases the conductivity of the material was insufficient to fully screen the bag's contents from electric field, and the shielding efficiency of the static dissipative bag fell away rapidly as the frequency of the field was increased (note the logarithmic scale). The behaviour as a function of frequency shown in b) is a characteristic of all static dissipative plastic materials.



a) *Shielding performance of metallised shielding bag* b) *Shielding performance of carbon loaded 'black bag'*

Figure 2: Chubb's measurement of the field penetration characteristics of different materials used to make static protective bags: a) Field attenuation by a metallised plastic bag; b) Superior field attenuation at low frequency by a carbon loaded (static dissipative) plastic bag, but inferior shielding at higher frequency.

Chubb noted:

"Electrostatic spark discharges involve current rise times and voltage collapse times down to below 1ns. Lower voltages shorter times. Transport packaging hence needs to provide >200:1 attenuation for frequencies to 1GHz."

The Sematech research had proven reticles to be extremely sensitive to field-induced damage, and they were known to require much more effective shielding from electric fields than packaged semiconductor devices, so Chubb's specification would not be sufficient for reticle protection. Based on Chubb's criteria and Levit's measurements of pod performance, reticles were certainly not going to be adequately protected from electric field by the static-dissipative reticle pods that had been developed in an effort to protect them.

Other research findings were published in December 2003 that also challenged the wisdom of the decision to end the Sematech project [7, 8]. It was shown that the predominant electrostatic risk to reticles is from field induction rather than conductive ESD as had previously been thought. Ironically, it was also shown that the grounding of reticles during handling – a practice that had recently been introduced to protect them – actually made the risk of field-induced damage worse rather than reducing it. Furthermore, a newly-identified form of field-induced reticle damage called EFM had been identified. Unlike ESD, which instantaneously causes very obvious damage to a reticle, EFM is a gradual degradation process that does not generate easily detectable damage, but it does interfere with the lithography process and cause yield loss. It progresses cumulatively, under levels of field-induction at least two orders of magnitude weaker than would be necessary to induce ESD (as determined for a typical production reticle in use at that time).

This new study, which had identified serious errors in the advice that had been given for reticle electrostatic protection, created disquiet in the electrostatics consultancy community. There was a great deal of scepticism expressed by ESD experts over the assertion that equipotential bonding increases the electrostatic risk to a reticle rather than reducing it. This had been identified through computer simulation, and it was believed by many electrostatics experts that the simulations were wrong, because the indications from the simulations were not in accord with their practical experience of ESD prevention in the semiconductor industry. However, the study's findings were subsequently confirmed by experimentation with production reticles and special test reticles [9], demonstrating that field induction is a subject that can confound even those who specialise in electrostatic protection and have many years of practical experience of it within the semiconductor industry. "Established wisdom" is not necessarily correct.

The evidence that static dissipative plastic reticle pods were probably not sufficient to protect reticles against field-induced damage, and the persistence of reticle electrostatic damage events in some facilities that were using them, led to efforts being made to increase the conductivity of the pod material. New "conductive" plastics were developed having carbon nanotubes embedded within the matrix to enhance electrical conduction, and a study conducted in 2006 [10] compared the field- shielding performance of a pod made with this new material against other types in widespread use. The results of the testing are shown in Figure 3.

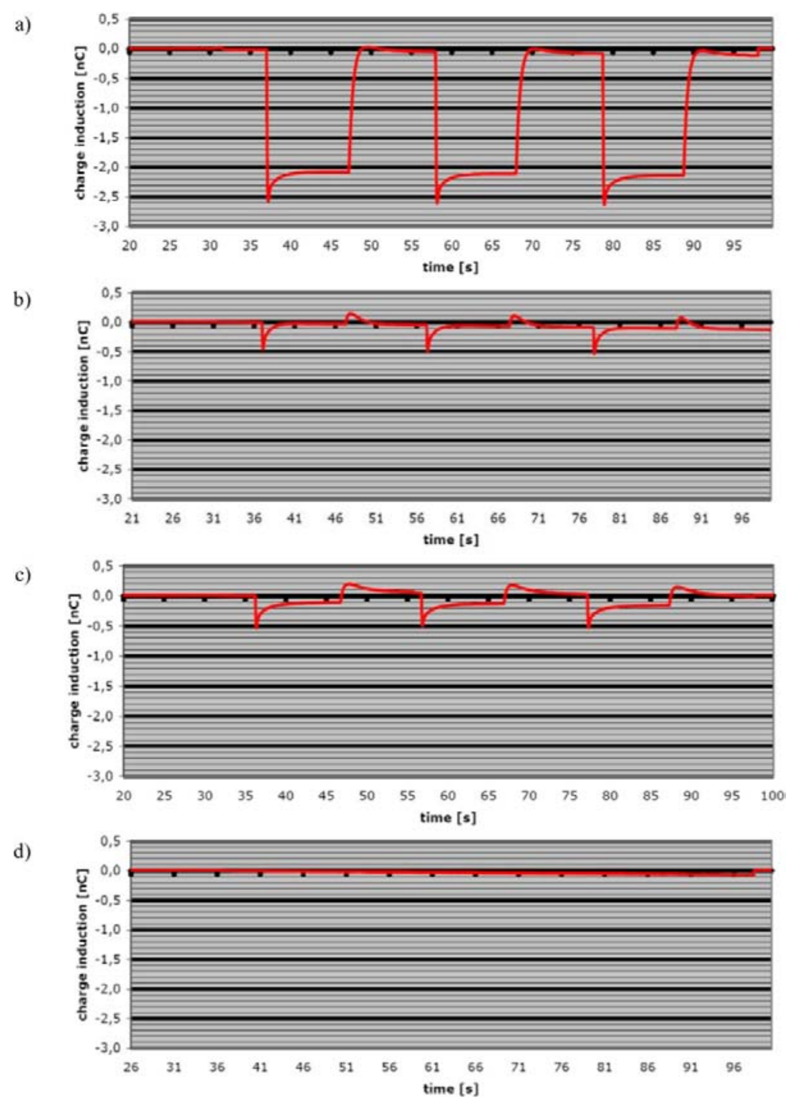


Figure 3: Helmholtz and Lering's measurement of field penetration into a variety of reticle pods with differing degrees of conductivity, from [10]. a) Applied field. b) ABS pod. c) PEI pod. d) Carbon nano tube loaded PEEK pods (two were tested and both were at the limit of detection).

The tests showed that increasing the conductivity of the plastic reduced the field penetration into the reticle pod to the limit of electronic detectability. However, even this degree of shielding did not prevent field-induced ESD taking place in a test reticle inside the pod. If field penetration into such a reticle pod was sufficient to induce ESD in the reticle inside it, it would certainly not offer adequate protection against other forms of field-induced degradation such as EFM, which takes place under much lower electrostatic stress. The research by Helmholtz and Lering also confirmed that because the conductive plastic reticle pods had conductive paths connecting the reticle to the grounded load port (a supposedly protective design following the principles outlined earlier) field induction was enhanced and the rate of reticle damage was actually increased by it.

In 2008 further experimental research into EFM was published [11,12] confirming the initial interpretation of the reticle damage mechanism as the field-induced migration of chrome. This study fully quantified the effect and showed that reticles were even more sensitive to electric field than had been estimated five years earlier when EFM was first identified. The degradation characteristics were illustrated with an atomic force microscope image of a damaged reticle structure, overlaid with an electric field computer simulation to indicate the local electric field strength corresponding with the different damage effects observed. This image is reproduced in Figure 4.

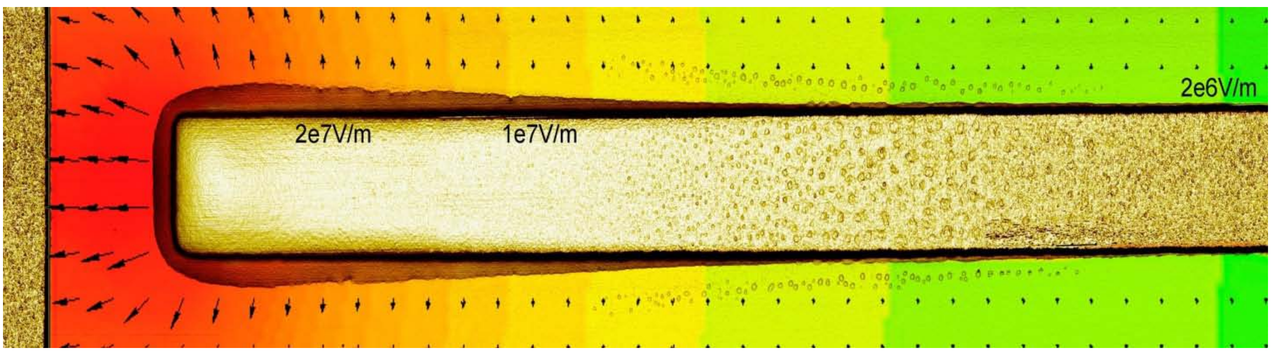


Figure 4: Composite atomic force microscope image of a field-damaged reticle structure, overlaid with a computer simulation to indicate the electric field strength corresponding to the observed damage effects, reproduced from [12].

Other research being conducted around the same time into reticle degradation in semiconductor production confirmed that as well as directly distorting the reticle features through chrome migration, EFM could also cause ACLV in the printed pattern by reducing the light transmission of the clear areas of the mask [13]. Device yield had been impacted by this subtle form of reticle degradation, even though the reticle had passed regular inspections with no defects being detected. It required the use of highly specialised surface analysis and destructive failure analysis techniques to unambiguously identify the cause of the yield loss as chrome migration [14]. This difficulty with first detecting and then correctly diagnosing such subtle reticle degradation effects perhaps explains why, more than fifteen years since its discovery, EFM is rarely being identified as a reticle damage mechanism in modern semiconductor production fabs – even though it is almost certainly happening.

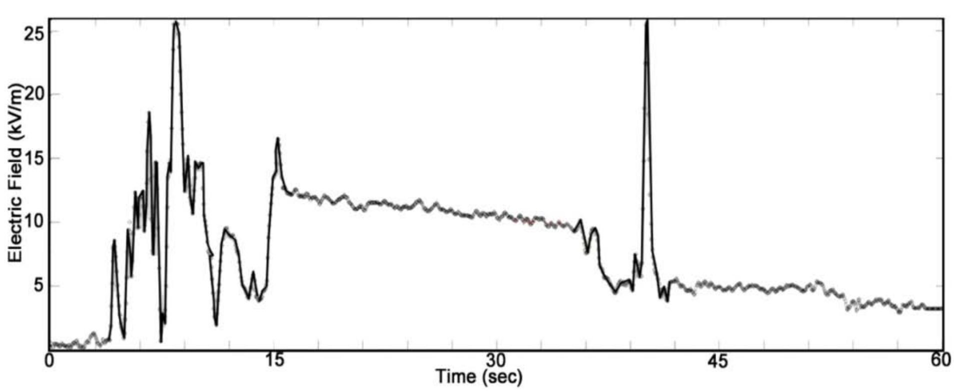


Figure 5: Measurement of a reticle's exposure to electric field while being carried in a static dissipative single reticle pod in a semiconductor production facility equipped with all the standard ESD countermeasures, including air ionizers.

A new sensor device had been developed following the discovery that reticles are extremely sensitive to electric field. This self-contained recording device had the same form factor as a normal six-inch reticle and it could record the electric field to which the sensor was exposed under the same conditions that would be experienced by a standard production reticle [15]. This sensor device has been extremely valuable in allowing hidden areas of electrostatic risk within semiconductor fabs to be identified. One of the first measurements made was of a normal handling sequence in a production facility using a static-dissipative single reticle pod. The measurement, which is shown in Figure 5, reveals that a reticle carried in a static dissipative reticle pod is repeatedly exposed to electrostatic stress from transient electric fields. The level of field penetration into the reticle pod was confirmed to be sufficient to cause cumulative damage in production reticles, following the earlier quantification of reticle sensitivity to EFM [11,12]. Another test carried out with the sensor reticle revealed that static dissipative reticle pods actually generate significant electric field transients through tribocharging during normal use, something that had previously been believed not to happen with static dissipative materials, mainly because of an inappropriate testing methodology using field meters with insufficient temporal response.

The most recent assessment of all the effects that can be produced by field induction in reticles [16] identifies the heightened risk posed by rapidly changing and transient electric fields, and concludes that very short-duration field transients and rapidly changing electric fields up to gigahertz frequencies and beyond would be capable of causing cumulative reticle damage. This is because electric fields cause charge displacement within the reticle pattern every time the field conditions within the reticle change. Rapidly oscillating, pulsed or transient fields are particularly hazardous, because one field cycle produces two charge displacements, once as the field increases and again as it decreases.

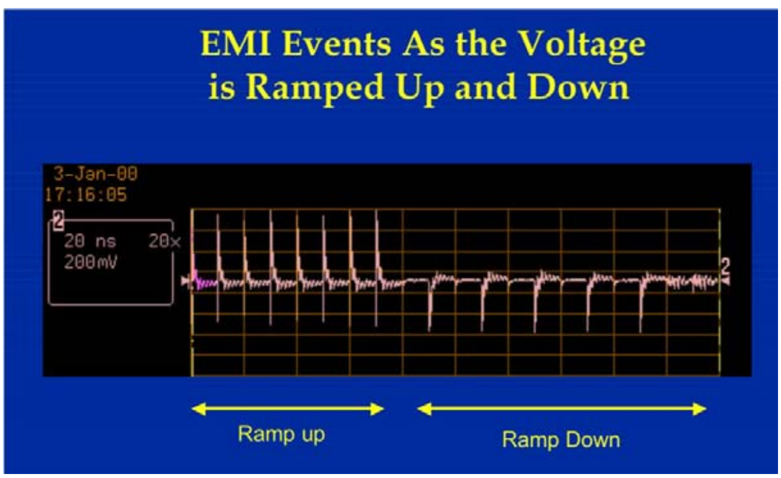


Figure 6: Measurement of multiple sequential ESD events induced within an electrically isolated reticle as the voltage on a nearby electrode is first increased and then decreased, from [17]. The opposite polarity of the signals as the field is removed indicates that the displaced charge that caused the initial series of ESD events is returning to its original location within the reticle and causing further ESD damage.

This characteristic was demonstrated during the field induction experiments conducted by Montoya et al [4,17]. Spark discharges induced within the reticle pattern by a high potential applied to an electrode held just above the reticle were detected using an RF loop antenna connected to a storage oscilloscope, as shown in Figure 6, which is from their presentation at the Sematech ESD Symposium of 2000. As the voltage on the electrode was increased, sequential discharges were detected within the reticle. Then, as the voltage was removed, discharges of opposite polarity were observed as the displaced charge within the reticle returned to its original location.

Extremely rapid field transients that are capable of being generated and transmitted by static dissipative and conductive plastics are responsible for the ESD damage in the test reticle reported by Helmholtz and Lering [10], yet neither their fast recording oscilloscope nor this new sensor reticle would have had sufficient sensitivity and response time to detect the threat they pose. There remains a significant level of electrostatic threat that can damage reticles but cannot be detected electronically.

The movement of charge that contributes to the reticle damage is induced entirely within the reticle pattern; the reticle remains electrically neutral throughout the process. The reticle inherently amplifies any electric field that is present in its environment by up to several orders of magnitude, the degree of amplification depending on the arrangement of the isolated conductors in the image. This field amplification results from the movement of electrons within the reticle's conductive structures so it happens almost instantaneously, and it explains why undetectable amounts of electric field penetrating a reticle pod [10] could be sufficient to induce ESD and other forms of cumulative damage. This field amplification characteristic is illustrated by the computer simulation of Figure 7.

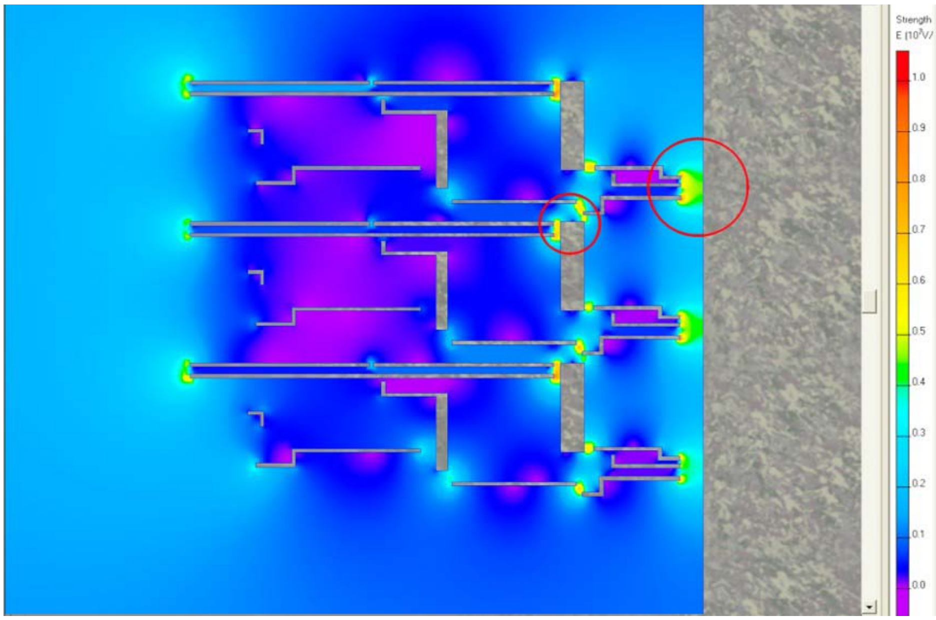


Figure 7: Two-dimensional finite element simulation of the interaction of an electric field with a reticle. The grey structures represent isolated conductive lines, with the large grey block on the right representing the border around the image area. A uniform electric field with a strength represented by the mid-blue tone at the left of the image is applied from left to right. The field strength is reduced in some areas but amplified at the ends of long lines, particularly between closely adjacent features near the edge of the image (circled).

The field amplification is a function of the orientation of the reticle pattern relative to the electric field, so simply moving the reticle without changing the electric field it is exposed to will also change the field conditions within the reticle pattern, with a corresponding risk of the reticle being damaged. A similar situation occurs if conductive objects such as robotic arms are moved within the vicinity of a reticle in the presence of an electric field, because such objects perturb the electric field around and within the reticle. The perturbation of electric field by conductive robotic arms is illustrated by the recording in Figure 8, which was made using the field-sensing reticle mentioned previously [15].

The evidence from Figure 8 is that the ESD countermeasures such as equipotential bonding that have been introduced into semiconductor manufacturing facilities are not necessarily effective for damage prevention. If the static charge that grounding is intended to remove is located on an insulating part of the object being handled, which it most probably would be, grounding cannot remove it. As shown in this recording, the use of a grounded handling tool creates a risk from field perturbation that otherwise would not be experienced by the reticle. It also demonstrates that unless ionizers are correctly installed and maintained they can actually create an electrostatic risk – one that is accentuated by the use of equipotential bonding.

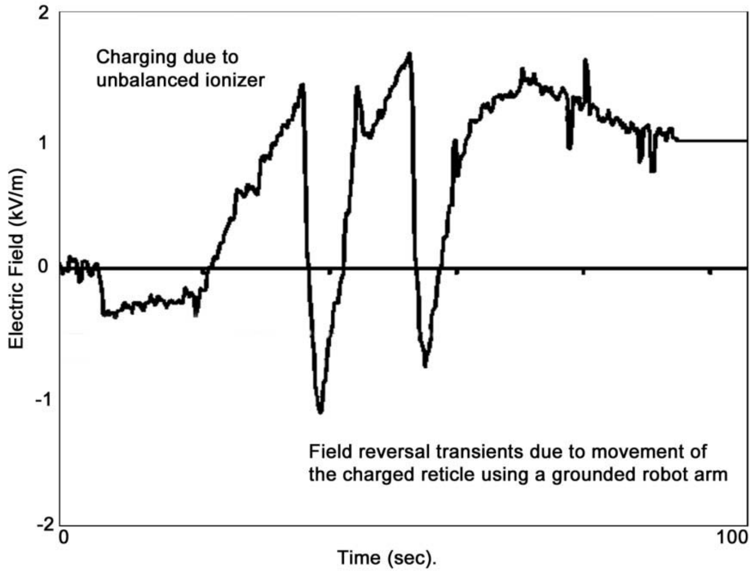


Figure 8: Electric field recorded by a sensor reticle introduced to a piece of reticle handling equipment fitted with an unbalanced ionizer and a grounded robot arm with static dissipative reticle contacts. The electric field generated by the charge on the reticle is strongly perturbed each time the robot arm approaches to move the reticle. Note that grounding the reticle through static dissipative contacts does not remove the charge.

This point is further illustrated by Figure 9, which shows the electric field recorded by the sensor reticle as it was being loaded into another piece of reticle handling equipment that had been fitted with an ionizer to neutralize incoming reticles at the loading station. The ionizer had been installed much too close to the reticle's handling path, so pulsed electric field from the ionizer tips was reaching the reticles as they passed underneath it. Every pulse of electric field from this ionizer was capable of causing field-induced damage in the reticle pattern, and after passing the ionizer the reticle had been put into a charged state, just as in Figure 8.

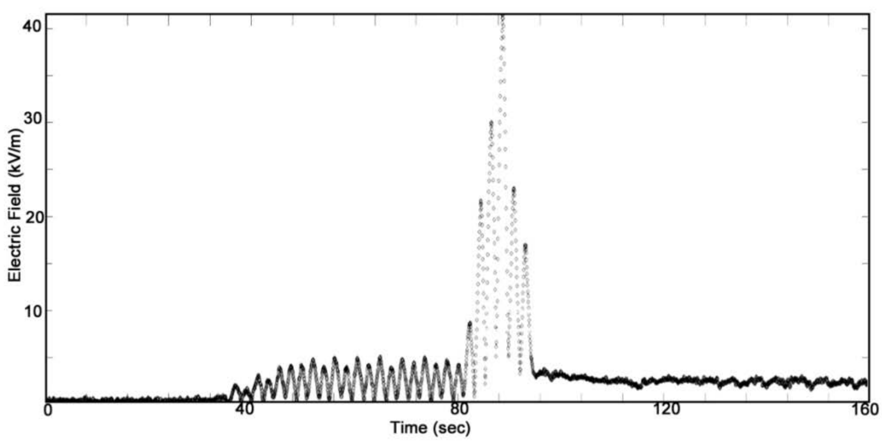


Figure 9: Electric field measured by a field-recording test reticle as it was loaded into equipment that had been fitted with an ionizer bar over the loading station. The ionizer was too close to the reticle path and it exposed every reticle loaded into the equipment to dangerous levels of electric field. The offset in the readings after passing the ionizer also shows that the reticle had been charged.

The studies into reticle electrostatic damage illustrated here have revealed shortcomings in the electrostatic protection principles adopted by the semiconductor industry and have also revealed errors in the implementation of them, the most significant two being the use of equipotential bonding and of making reticle pods and boxes from static-dissipative plastic. While equipotential bonding does indeed result in the elimination of conductive ESD events when material is being transferred from one manufacturing station to another, it does not protect field-sensitive items from the damaging effects of exposure to electric fields – it actually makes the damage worse. Static dissipative plastic reticle pods have been shown to allow hazardous levels of electric field to reach the reticle stored inside them, and such pods actually generate transient electric fields during normal use.

The conclusion reached here is that for absolute security no amount of exposure to electric field should be considered safe for any transmission reticle. The wisdom of making reticle pods from static dissipative or even "conductive" plastic is called into question, and because equipotential bonding increases the impact of any field exposure that might take place during reticle handling or use, it should not be used when handling reticles.

IV. Implications for the Safe Handling of Electrostatic Sensitive Devices

When material handling 'best practice' was being defined for the semiconductor industry decades ago the problem was addressed in a logical but somewhat over-simplistic way. It was apparent that semiconductor devices were being damaged by conductive ESD during handling and the deduction was that if the ESD could be prevented, so would the damage. Indeed, the control of ESD during semiconductor manufacturing has been accompanied by a corresponding yield improvement. However, it was not correct to believe that eliminating ESD meant that reticles would be safe, so it is probably not correct to think the same about the electrostatic safety of sensitive electronic devices.

The semiconductor industry almost exclusively characterizes device electrostatic sensitivity by means of discharge testing, for example as described by Diaz [18]. Diaz observes that there are two different forms of damage that can be caused to devices; thermal effects due to a current surge from an ESD event or from EOS, and field effects such as dielectric breakdown and latent hot-carrier damage. "Hot-carrier" damage refers to a reduction of the electrical resistance of dielectrics as a result of being exposed to an excessive electric field. Points of weakness in the dielectric caused by excessive electric field can subsequently break down completely during device operation, producing thermal damage that appears similar to EOS or ESD.

There is, unfortunately, a "grey area" wherein some of such electrostatic damage is classified as EOS and some as ESD, with no clear indication of the origin of it. Distinguishing between the two mechanisms after the damage has occurred is very difficult indeed, and it is almost impossible to determine the precursor state after breakdown has happened.

Identifying the root cause of the failure requires a detailed understanding of the physical mechanisms involved and very careful analysis of the damaged area. It was possible to do this quite easily in reticles, because the damaged features were easily accessible for AFM imaging, which meant that the subtle differences between ESD damage and that caused by EFM could be identified. They could then be characterized and quantified through controlled experimentation, as shown in Figure 4. Real-life damage signatures in semiconductor devices are far more difficult to deconvolve, because the damage is usually extensive and can completely destroy the damage site. It can also be necessary to expose the damage site deep within the device by carefully deconstructing it in order to analyze the damage, which is a laborious and difficult task that is not routinely undertaken. For this reason, a great deal of device electrostatic damage is probably being incorrectly classified, which also means that the root cause is not being correctly understood. Failing to correctly identify the root cause of electrostatic damage can result in inappropriate guidance being given to try and prevent it (as happened when equipotential bonding was recommended to prevent reticle electrostatic damage).

It is believed by many people that the spark between a charged device and ground results in the device literally becoming "discharged", meaning neutralized. For example, Diaz states in his article [18] "*Electrostatic discharge occurs whenever a charged object is grounded, resulting in the release and equalization of the static charge*." The impression that neutralization has occurred is reinforced when a device that has experienced such an ESD event is measured using a Faraday cup and is found to carry little or no net static charge. However, this impression is wrong in most cases.

The static charge on a charged device will most likely be present on an external insulating surface as a result of tribocharging during handling. The spark that jumps between ground and the charged device generally strikes one of the connector pins, which is why it injects a current pulse that damages the internal circuitry. So, what actually happens during such a CDM static discharge event is that an opposite charge to that present on the encapsulation enters the device circuitry from ground, attracted by the electric field from the static charge on the encapsulation. The opposite charges cannot physically recombine and neutralize one another as they are separated by insulating material. Hence, such balancing of the charge on the device as a consequence of grounding it results in the device being in an energized state, just like a charged capacitor. It contains electrostatic potential energy, just as a charged capacitor does, stored within the internal electric field. The same final energized state would be achieved whether the balancing charge flowed into the device rapidly through a spark or slowly as a reduced current through a resistive contact in an equipotential bonding scheme.

If the flow of balancing charge into the device is gradual, as in an equipotential bonding scheme where static dissipative contact materials are used, there is no initial current surge that can cause the thermal damage effects described by Diaz. Hence it would be correct to say that ESD damage had been prevented by the equipotential bonding scheme slowing down the transfer of charge – but field- induced damage effects that can result in latent dielectric damage could still occur if the internal electric field generated by the balancing charge exceeded the capacity of the dielectric layers in the device to withstand it.

ESD protection circuitry is generally designed to shunt an incoming current surge in order to protect the device's operational circuitry, but it will not change the final location reached by a balancing charge, as this will be determined by the physical layout of the device and the location of the static charge on the encapsulation. The balancing charge will move as close as possible to the static charge on the encapsulation, driven there by the internal electric field. Therefore, even if the ESD protection circuits do prevent an immediate thermal damage event by diverting the route taken by the charge as it enters the device, they may be ineffective at preventing any field-induced damage that occurs as a result of the injection of a balancing charge.

A similar risk from the generation of internal electric fields could also be created in a partly-processed silicon wafer should it become charged during processing, which is a common occurrence. If the partly completed devices on the wafer contain conductive layers separated by dielectric barrier layers, an electric field can be generated between the isolated layers. If a balancing charge were introduced to the substrate from ground during handling, attracted by static charge on an outer insulated layer of the partially-completed wafer, the balancing charge would distribute itself within the wafer until it approached as close as possible to the static charge, after which any further charge movement (and ultimately, static charge neutralization) would be prevented by the interposed insulating layer(s). Like the device in the previous scenario, the wafer would appear to be electrically neutral but it would be in an energized state, just like a charged capacitor.

An excessively strong electric field can damage the structure of dielectric material, resulting in the rearrangement of the atomic bonds, which degrades its insulating strength. The mechanism by which dielectric degradation happens is described by Azizi and Yiannacouras [19]. It has been shown by Pey and Tung [20] that this mechanism and the degradation it produces are independent of the dielectric composition. Hsu et al report that the dielectrics being used in latest-generation devices exhibit degradation that is dependent on the field strength within the dielectric [21]. Another field- induced damage process in semiconductor devices involves the diffusion of dopants and contaminants [22]. This can alter the electronic properties of devices that rely on a particular dopant profile within their active features, or create conduction barriers at interfaces.

So, it is conceivable that enhanced electric fields produced within a device while it is being manufactured, as would be likely to occur as a result of using equipotential bonding, could potentially cause any of the above described damage effects.

Some devices may continue to operate as they were designed to, but the robustness of a damaged dielectric to EOS or TDDB (which is a life-limiting aspect of many semiconductor devices) will be reduced. Any material degradation that has the capability to cause premature failure is classified as a "latent defect", and it is evident that the practice of equipotential bonding has the capability to introduce such defects into devices and wafers that have become charged during handling or processing.

Clearly, any procedure that can generate an uncontrolled internal electric field within a device containing thin dielectric layers must be considered potentially hazardous – and that is exactly what equipotential bonding can do. The ultimate consequence of a device being stressed in this way would be dependent on the type of device and would also be affected by how it was subsequently handled and operated. When failure eventually happened, it would not be apparent that the use of equipotential bonding during the manufacture of the device could have contributed to its demise. It would be practically impossible to identify the root cause of such a delayed failure.

V. Discussion

At this point, it is perhaps worth reflecting on the fact that the potentially harmful outcomes described previously rely on a combination of two factors, one of which is avoidable:

a) Charging of the device (which is not always avoidable, but is not itself damaging) and
b) Grounding of the device.

It is not possible to directly observe the described effects in a semiconductor manufacturing environment, so there is currently no empirical evidence from semiconductor manufacturing sites to analyze. Such effects could only be observed and measured if carefully designed experimentation were carried out, in much the same way as reticle electrostatic damage was extensively studied at Sematech. Even then, it would be necessary to analyze the results very carefully to avoid the risk of reaching false conclusions, as initially happened with the analysis of the Sematech data. Re-evaluation of the Sematech reticle damage data ultimately led to the completely unexpected discovery of both EFM and identification of the detrimental effect of equipotential bonding. Similar studies could potentially reveal previously unidentified field-induced damage effects in semiconductor devices.

There have been some heated discussions about the sensitivity of semiconductor devices to electric fields and the effectiveness of equipotential bonding for device protection in online discussion groups, following the research into reticle damage. The perspective of most electrostatics consultants working in the semiconductor industry seems to be that packaged devices are not field-sensitive. They also state that their experience gained over decades working in semiconductor manufacturing proves that equipotential bonding is protective, because damage rates are improved when using it. However, as mentioned previously, the avoidance of immediate thermal damage from an ESD event by using static dissipative contacts to ground a device does not mean that the grounding of the device is an inherently safe procedure. Grounding does not remove static charge from an insulating part of the device and it does not actually neutralize the device, but it does inject a balancing charge that creates an internal electric field. Since the purpose of grounding the device is actually the removal of static charge and the neutralization of the device, it does not seem to be a particularly valuable result to avoid an ESD event while failing to achieve either of these objectives. Not grounding the device would achieve the same outcome, but it would also avoid the generation of potentially hazardous internal electric fields through the injection of a balancing charge.

While the disagreement continued about whether or not devices are susceptible to damage from electric fields, Smallwood [23] conducted a simple experiment. He demonstrated that it is possible to damage ESDS semiconductor devices through field induction alone, without a conductive ESD event taking place. His simple experiment confirms that the principles presented in this paper are valid and that the concerns expressed here are justified.

One further unforeseen negative consequence of using equipotential bonding to try and remove static charge from devices during handling is that grounding a charged device virtually eliminates external electric field, by balancing the charges held on the device. Ionizers are the only practical way of neutralizing static charge on an insulator, and they are widely adopted in semiconductor manufacturing to help control static charge accumulation. Airborne ions of the appropriate polarity respond to the presence of static charge by being attracted by the electric field it creates, while ions of opposite polarity to those needed for neutralization are repelled. If the external electric field emanating from a tribocharged device is nullified by the injection of a balancing charge into the device from ground, it removes the mechanism through which charge neutralization by an air ionizer is achieved. Thus, grounding is not only incapable of safely neutralizing a charged device or wafer, it acts against the only feasible method of doing so.

The importance of understanding and controlling all forms of device degradation, going beyond those typically caused by ESD, has been emphasized by Sonnenfeld et al [24] who state:

"…it is not widely known how degradation mechanisms propagate as a function of environmental conditions and various stressors. The attainment of such knowledge is critical for advancements in the field of power electronics health management and prognostics. The ability to perform large scale experiments and characterize the degradation signatures of such semiconductor devices under various scenarios is of great interest…

The assumption of new functionality will also increase the number of electronics faults with perhaps unanticipated fault modes. In addition, the move toward lead-free electronics and microelectromechanical devices (MEMS) will further result in unknown behaviors."

The study of field induction in reticles and the computer simulations performed to help the understanding of field induction on a nanometer scale, which cannot be directly measured, have demonstrated that measurements of charge and voltage on a macroscopic scale during typical ESD audits in a factory environment tell only a partial – and often misleading – story. It is necessary to consider the physics that operate on the scale of the device structures themselves, or even at an atomic level, to fully appreciate the varied detrimental effects that may be caused by electrostatic imbalance. This requires shifting the focus of attention from the traditional approach of controlling voltage on a macroscopic scale to managing electric field on a microscopic scale.

One might wonder why focusing on electric field management might lead to a different treatment of electrostatic risk than other approaches, such as those like equipotential bonding that are designed to control electrical potential. After all, electric field is measured in volts per meter, so if voltage is controlled, electric field will be controlled too, no? Intuitively the two approaches might seem to be the same. However, the reason for the fundamental difference can be understood by looking at a graph of field induction between conductive structures on the scale of the features found in reticles and semiconductor devices.

Figure 10 is a graph of computer simulation results showing the electric field and voltage that would be present between two isolated conductors, when exposed to a constant electric field, as a function of their separation. It was produced to help explain the observed effects of field induction in reticles. The simulations show that as the separation of conductors is reduced (as reticle patterns and the structures in semiconductor devices become further miniaturized following Moore's Law) the voltage that is induced between adjacent features by an external electric field rapidly falls, while the electric field concentrated in the gap between them rapidly rises. The effect is highly nonlinear.

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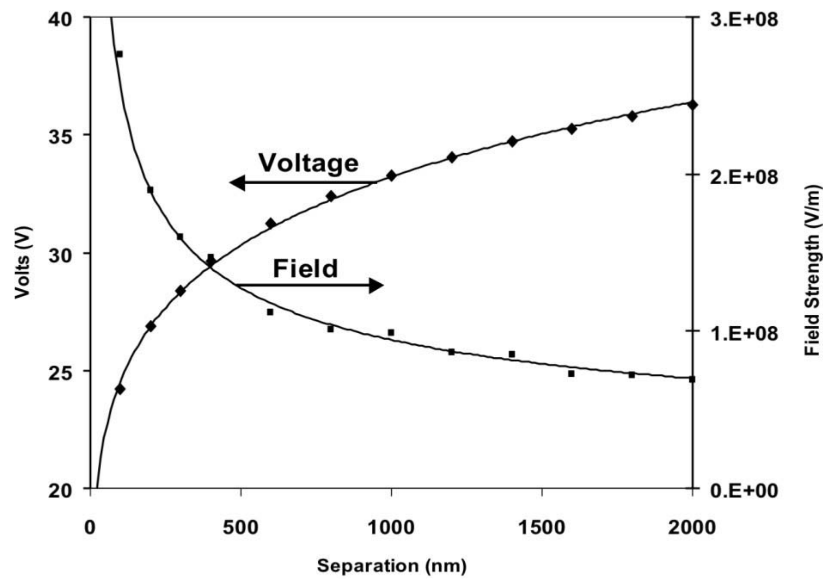

Figure 10: Two-dimensional finite element analysis simulation of the induced potential difference and field strength between two isolated conductive lines as a function of their separation in a constant external electric field.

By the time the separation of conductors reduces to the scale of the structures in semiconductor devices it becomes extremely difficult for an electric field to induce high voltages between them, which many people might believe automatically reduces any risk arising from field induction. However, a high induced voltage is not the stress factor that causes the damage. It can be seen from the graph that on this dimensional scale low induced voltages can be accompanied by very strong electric fields, and this fact is further illustrated by the simulation shown in Figure 11. This computer simulation was produced to show that the guidance published in the ITRS specifying the maximum electric field to which a reticle should be exposed to control ESD risk was actually unsafe when considering the risk of EFM. It shows that on this scale, with only a small fraction of a volt induced between the adjacent conductors, the local electric field strength can be dangerously high. The ITRS guidance was subsequently updated and the figure for the maximum electric field to which a reticle should be exposed was significantly reduced, in recognition of the newly identified risk of field-induced damage.

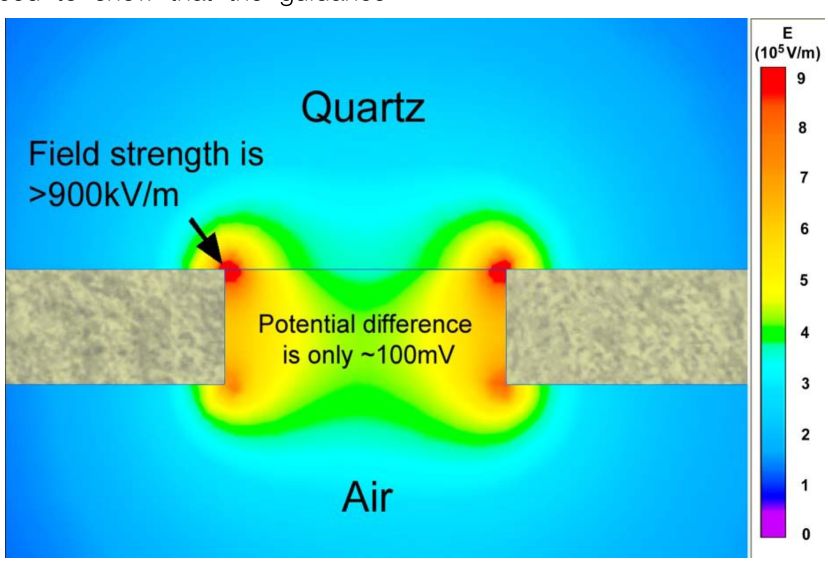

Figure 11: Computer simulation of field induction in a metal-on-glass reticle with a feature separation of 250nm. The concentration of the field at the edge of the line in contact with the quartz substrate produces field strength above 900kV.m^{-1} with a potential difference of only around 100mV induced between the features.

The pursuit of Moore's Law, with the consequent reduction of the separation between isolated conductive elements in a circuit, therefore acts to accentuate any risk from electric field. Having polarizable dielectrics present between the conductive features, as in semiconductor devices, would further increase the local electric field strength at any induced voltage by comparison with the situations modelled in Figure 10 and Figure 11. Such points of field amplification, as indicated in Figure 7, are the very locations that would be susceptible to damage by the generation of an excessive local electric field.

It is impossible to measure the potential differences and local electric fields that are induced between different internal parts of a semiconductor device, so one cannot measure this kind of risk directly. It is also practically impossible to simulate field induction effects in such complex three- dimensional structures, so the only way of estimating the risk is to base the risk assessment on what is already known from the study of field induction in reticles. One crucial aspect of this is that grounding through an equipotential bonding program that is principally designed to reduce ESD during material handling accentuates any risk to devices and wafers from electric field.

When considering all the matters that have been discussed, injecting a balancing charge into a semiconductor device or wafer through equipotential bonding, which cannot achieve the intended neutralization but will inevitably create a strong internal electric field, does not seem to be a very prudent thing to do.

VI. Conclusions

It was first shown theoretically and subsequently proven experimentally that using equipotential bonding to prevent ESD during the handling of reticles has negative consequences for the safety of the reticle. Even though equipotential bonding is intended to be protective, is a recommendation given by many electrostatics consultants, and even forms the core of several semiconductor industry patents, it is definitely not protective for reticles. Detailed investigations of damage effects in reticles have revealed that as well as increasing the risk of ESD within the reticle, rather than reducing it, equipotential bonding enhances other field-induced damage mechanisms that until recently were completely unknown. These cumulative damage processes take place under conditions of electric field exposure that are orders of magnitude weaker than those that cause ESD, but their cost implications to semiconductor production are more severe than ESD [16].

Extending this understanding to an assessment of the handling of semiconductor devices leads to the conclusion that equipotential bonding may also have negative consequences for their security. Experimentation to validate the concerns expressed herein has been performed only on a very limited and simplistic scale, but the result shows that concern about this is justified.

Consequently, it is recommended that the extensive experimental research described as being "of interest" by Sonnenfeld should urgently be undertaken, to investigate whether electrostatic damage processes are capable of being enhanced in devices by equipotential bonding - a practice that is universally applied in the semiconductor industry and is presumed to be protective. Even if current semiconductor devices are found to be sufficiently robust to withstand stresses of the kind that have been described in this paper, it does not mean that creating such stress is advisable; neither is it guaranteed that all future electronic, optoelectronic and micro-electromechanical devices would be able to withstand such treatment.

If it is confirmed that significant risk of device electrostatic damage is being created through the use of equipotential bonding, as has been proven to be the case for reticles, this does not create an insurmountable challenge for the semiconductor industry. A methodology for handling extremely electrostatic sensitive (EES) devices without exposing them to increased risk by grounding them through an equipotential bonding scheme has already been described in SEMI Standard E163 [25], and the technology that would be required to implement such a handling scheme is already available.

Further experimental research, and the willingness of the industry to change its way of working if it should be found to be beneficial, are urgently needed in order to assure the future electrostatic security of ESDS and EES devices that are yet to be developed.

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Evaluation of Maximum Power Point Tracking of Photovoltaic Generator

By Amal Zouhr & Ismail Boumhidi
Sidi Mohammed Ben Abdellah University

Abstract- This paper presents the Maximum Power Point Tracking (MPPT) Modelling and control of Photovoltaic Generator (PVG). The model contains a detailed representation of the main components of the system that are the solar array, boost converter, and the grid side inverter. The system adopted by a digital MPPT control "disturbance and observation". This system includes a photovoltaic generator (PVG), boost converter, MPPT "disturbance, and observation" command as well as a load. For optimum system operation, the maximum power operation of the PV array must be ensured regardless of the climatic conditions, especially the solar irradiation and the temperature of the PV module. Power control, as well as modeling and simulation, were perform.

Keywords: *PVG, photovoltaic arrays, MPPT, modelling, simulation.*

GJRE-F Classification: *FOR Code: 090699*

EVALUATIONOFMAXIMUMPOWERPOINTTRACKINGOFPHOTOVOLTAICGENERATOR

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Evaluation of Maximum Power Point Tracking of Photovoltaic Generator

Amal Zouhr [α] & Ismail Boumhidi [σ]

Abstract- This paper presents the Maximum Power Point Tracking (MPPT) Modelling and control of Photovoltaic Generator (PVG). The model contains a detailed representation of the main components of the system that are the solar array, boost converter, and the grid side inverter. The system adopted by a digital MPPT control "disturbance and observation". This system includes a photovoltaic generator (PVG), boost converter, MPPT "disturbance, and observation" command as well as a load. For optimum system operation, the maximum power operation of the PV array must be ensured regardless of the climatic conditions, especially the solar irradiation and the temperature of the PV module. Power control, as well as modeling and simulation, were perform.

Keywords: PVG, photovoltaic arrays, MPPT, modelling, simulation.

I. Introduction

Currently the consumption of energy is increasing because of the trend of rapid industrialization and demographic evolution, which leads to the consumption of energy sources stock come from fossil fuels (oil, natural gas etc ... .), leading to the research and development of new sources of renewable energy. Solar energy is the most important source because photovoltaic converters directly convert the energy of solar radiation into electrical energy. In the last decade the energy solar, photovoltaic became a remains strategic source of energy. For example in Morocco, national energy consummation increase with increase the population. In the south of Morocco stands Noor 3, the largest solar energy tower in the world that propels Morocco into the future of renewable energy. In the middle of the lunar landscape of Ouarzazate, the Noor 3 tower looks down from its 243 meters to the thousands of mirrors dancing around it to the rhythm of the Moroccan sun, once a year, these thousands of mirrors are tested by focusing sunlight on two points in the sky, creating the "two moons" effect that surrounds Noor 3. This optical effect is the product of a test on the mirrors that supply the tower with light. Once a year, and only for a few hours, the rotating mechanism of the mirrors is tested by directing all the Sun's rays that they reflect to two focal points in the sky, creating the two moons of Noor 3. In operation since October 2018, this Concentrated Solar Power (CSP) tower is currently the most powerful in the world, with a power output of 150 megawatts (MW) - this corresponds to the energy consumption of about 65. Thanks to a heat storage system, the station can produce electricity even at night, hours after sunset. The tower not only produces a lot of clean energy, but also recycles the water vapor it generates in order to reduce the use of blue gold as much as possible. Thus, the steam is recovered after having been used to produce electricity and it is condensed again thanks to fans that cool it to return to the state of water, then reused to make steam a true closed circuit where the fans use the energy produced on site. With its large capacity to produce clean energy and low water consumption, Noor 3 is propelling Morocco into the future of renewable energy. A photovoltaic system will therefore consist of the previously described generator [2-3], usually associated with one or more of the following elements:

- An orientation or tracking system (rarely encountered in our latitudes),
- Electronic management (storage, current shaping, energy transfer),
- Storage to compensate for the random nature of the solar
- source,
- DC/AC converter
- A low-voltage direct current or standard alternating current load. The most commonly used PV systems are of three types:
- PV systems with electrical storage (electrochemical storage battery). These supply power to operating devices :
  - * Either directly by direct current
  - * Either in alternating current via a DC-AC converter; or (inverter)
- Direct coupled systems without batteries (also known as "sunlight operation").

The devices are connected either directly to the solar generator or, possibly via a DC-DC converter (adapter) [4] or a DC-DC converter (adapter impedance) [5-9]. For battery less systems, there is the possibility of using a form of storage that does not require a battery, or not of an electrochemical nature. - Systems connected to the local grid via a frequency-controlled inverter of the network, with the network serving as storage. The study of photovoltaic systems

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comes down to the study of load adaptation. The aim is to optimize the system to have the best system adaptation efficiency (ratio of the electrical energy supplied to the use to the electrical energy that could have been supplied by the generator still operating at its maximum power point). Among the solutions available, electrochemical storage by battery pack offers a good reversibility between discharge and recharge, Lead acid batteries, currently offering one of the best compromises between service rendered and operating costs. In summary, the operating point of the solar module is determined by the battery voltage and the sunlight. The terminal voltage of the solar module is slightly higher than that of the battery (during charging). Under these conditions, the solar module can be considered as a current generator whose value is proportional to the amount of sunshine. Moreover, the property of the PV panels are very sensitive to climatic variations such as illumination and temperature. The observation and disturbance are very replied for the controlling and command the system photovoltaic connected to the grid. This method is very slow when there is a fast modified in illumination [10]. This paper is organized as follows: In section 2, the modeling a photovoltaic generator are presented. The simulation are displayed in section 3 to overcome the simulation results validating our approach. A conclusion ends the paper in section 4. Our work objective is the study of the impact of some parameters on a photovoltaic generator from the modeling of the latter under Matlab simulation.

II. Modeling a Photovoltaic Generator

a) Modeling a cell

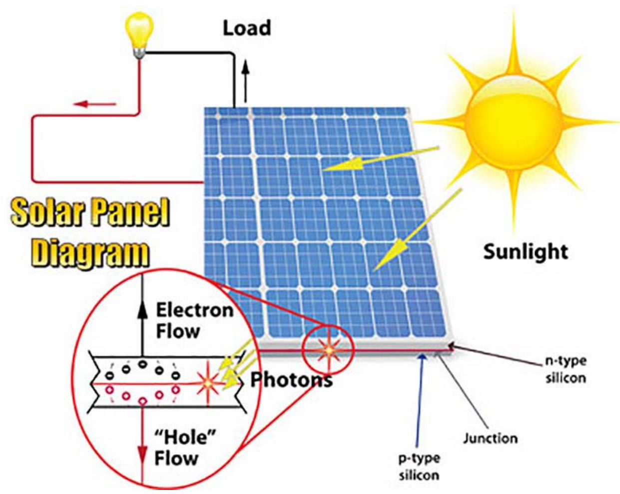

Fig. 1: Photovoltaic panel

The physics of the PV cell is very similar to the classical p-n junction diode as it presented in the figures 1 and 2.

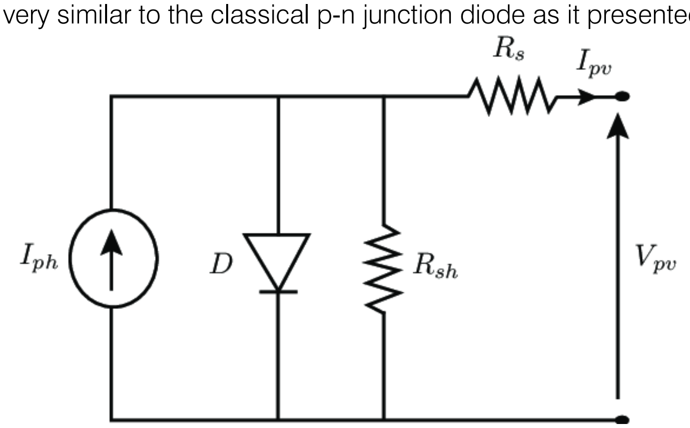

Fig. 2: Model of a photovoltaic cell

Fig. 2 represents the equivalent diagram of a photovoltaic cell:

$$I = (Iph - Id-)\ Ish \qquad (1)$$

A block diagram Fig.3 comprising four parameters can present the equivalent electrical diagram of the photovoltaic generator (PVG). Two input variables, which are the isolation in the plane of the panels E, the junction temperature of the cells Tj and two output variables: current supplied by the PVG Is, voltage at the terminals of the PVG Vs.

Fig. 3: Photovoltaic generator block diagram

To generalize our calculation for various illuminations and temperatures, we use the following model:

$$I_{CC}(T) = I_{cc}(T_{ref}).\left[1+\alpha(T-T_{ref})\right]$$

$$I_{ph} = I_{cc}\left(\frac{G}{1000}\right) \qquad (2)$$

$$I_{sat}(T) = I_{sat}\left(T_{ref}\right).\left(\frac{T_{ref}}{T}\right)^{\frac{3}{n}}\left[\exp\left(\frac{q.E_{\theta}}{nk}\right).\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)\right]$$

With:

n reprents the quality factor of the diode, normally between 1 and 2, α represents the coefficient of variation of the current.

The Table 1 represents a electrical characteristics of FVG.

Table 1: Electrical characteristics of PVG

Standard illumination, G	1000 W/m2
Standard temperature, T	25°c
Maximum power Pmax	60W
Voltage at Pmax or optimal voltage	17.1 V
Current at Pmax or Optimal current	5.5 A
Short-circuit current Isc	3.8 A
Open circuit voltage Vco	21.1 V
Number of cells in series	36
Forbidden band energy	1.12 ev
Temperature coefficient Isc	65 mA/°c
Temperature coefficient Vco	-80 mV/°c
Power temperature coefficient	(0.5+-0.05)%/°C
Saturation current Isat	20 nA

b) Modeling a module

An elementary cell does not generate enough voltage: between 0.5 and 1.5 according to technology [11]. It usually takes several cells in series to generate a usable voltage.

The module voltage is therefore

$$V_m = N_s.V$$

V_m: the voltage of the module.

N_s: number of cells in series per module

The Module photocurrent depends on solar irradiation and temperature according to (1). Kirchhoff's law gives the current generated by the module

$$I_{cell} = I_{ph} - I_d - I_{sh} \qquad (3)$$

Iph current is directly dependent on the solar illumination Es and the temperature Tj of the cell according to

$$I_{ph} = P_1.E_s\left[1+P_2(E_s-E_{ref})+P_3(T_j-T_{jref})\right] \qquad (4)$$

The cell temperature can be calculated from the ambient temperature and the radiation as follows

$$T_j = T_a + E_s\left(\frac{N_{oct}-20}{800}\right) \qquad (5)$$

The current in the diode is given by the formula

$$I_D = I_{sat}\left(e^{\frac{q(V_{cell}+R_s I_{cell})}{AKT_j}} - 1\right) \qquad (6)$$

With Isat is the saturation current strongly dependent on temperature. It is given by equation

$$I_{sat} = P_4.T_j^3.e^{-\frac{E_g}{K.T_j}} \qquad (7)$$

The current of the shunt resistor is given by

$$I_{sh} = \frac{V_{cell} + R_s I_{cell}}{R_{sh}} \quad (8)$$

The current generated by the cell is given by:

$$I_{cell} = I_p(E_s, T_j) - I_d(V_{cell}, I_{cll}, T_j) - I_{sh}.V_{cell} \quad (9)$$

c) Model of a photovoltaic

For modules mounted in series and in parallel one can write as [12]

$$I_{chaine} = I.N_p \,,\; V_{chaine} = V_m.N_{s-module} \quad (10)$$

With: I_{chaine} the current delivered by a module chain Photovoltaic.

N_p represent number of modules in parallel.

N_{s_module} represent number of modules in series.

V_{chaine} represent the voltage at the terminal of the chain (V).

III. Simulation Results

The photovoltaic generator scheme in the Matlab-Simulink environment is represented by [13-18]

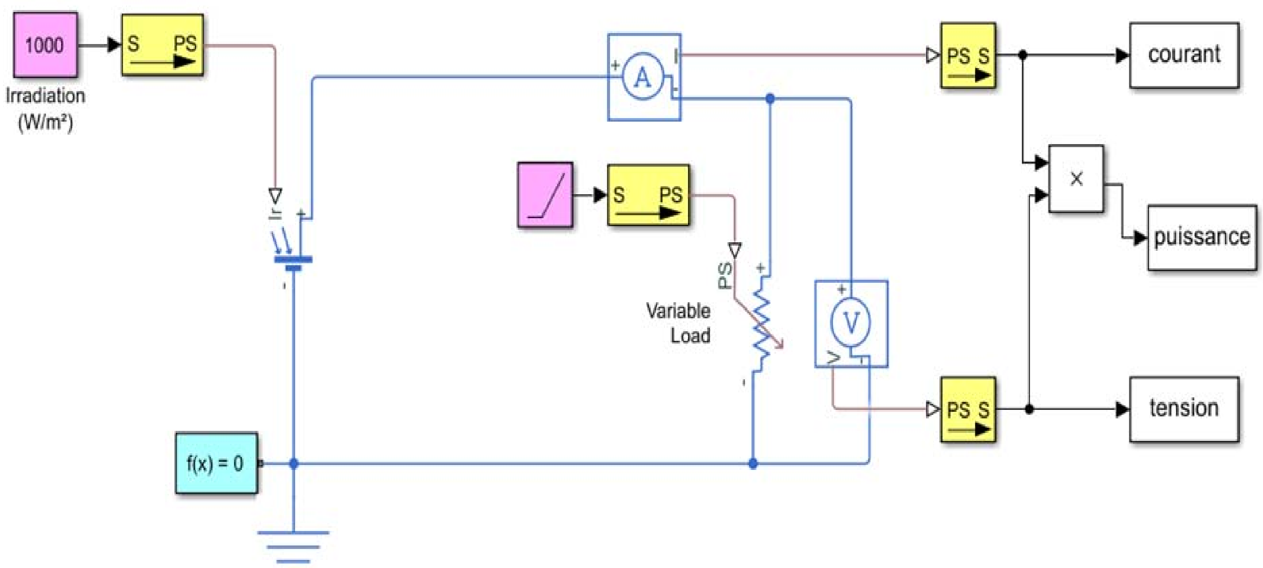

Fig. 4: PVG scheme in MATLAB-SIMULINK

The simulation results of the photovoltaic generator are represented by figures 5 to 11. These figures represent the current-voltage and power-voltage characteristics for various illuminations.Figures 5 and 6 present the impact of illumination on current/voltage and power/voltage characteristics. At a constant temperature, it is found that the current undergoes a significant variation, but against the voltage changes slightly. Because the short circuit current is a linear function of illumination while the open circuit voltage is a logarithmic function

a) Impact of temperature

Define Figure 7 presents the impact of temperature on the characteristic $I = f(V)$ It is essential to understand the effect of changing the temperature of a solar cell on the characteristic $I = f(V)$ in Fig.7. The current depends on the temperature since the current increases slightly as the temperature increases, but the temperature has a negative impact on the open circuit voltage. When the temperature increases the open circuit voltage decreases. Therefore, the maximum power of the generator is decreased.

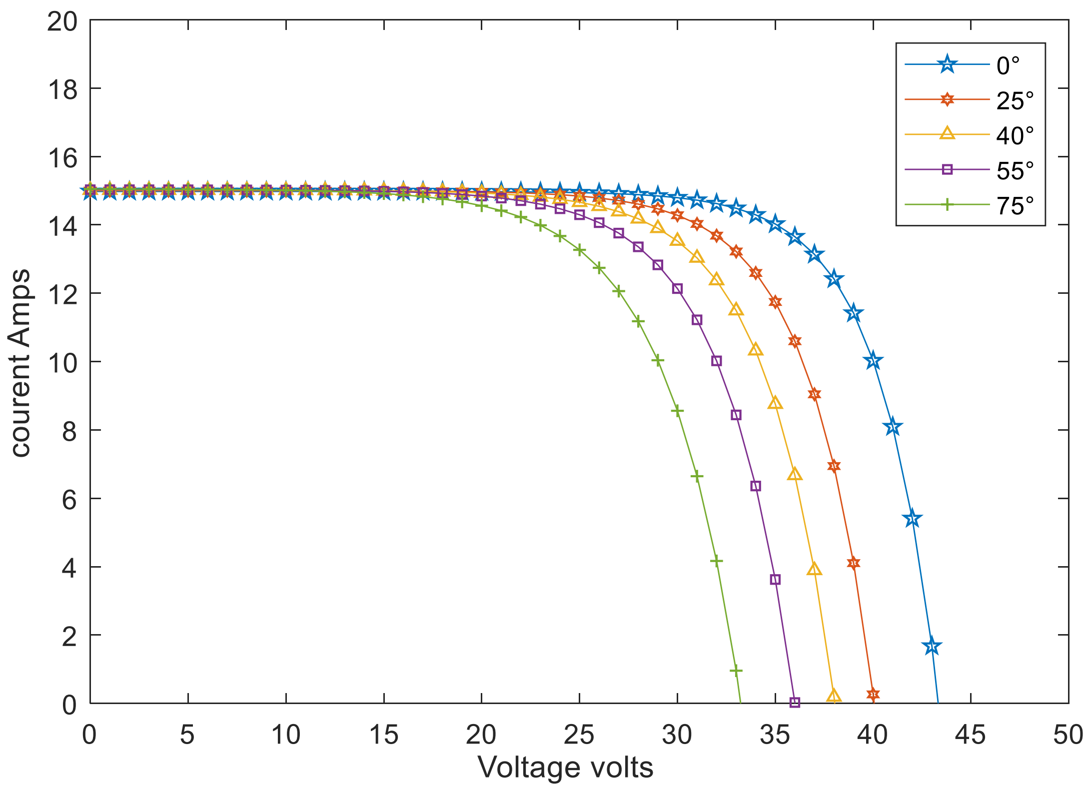

Fig. 7: Characteristic current-voltage for various values of the temperature $I = f(V)$ E=1000W/m^2

Fig.8 illustrates the variation of the power delivered by the generator as a function of the voltage for various values of the temperature, which allows us to deduce the impact of the temperature on the characteristic $P = f(V)$.

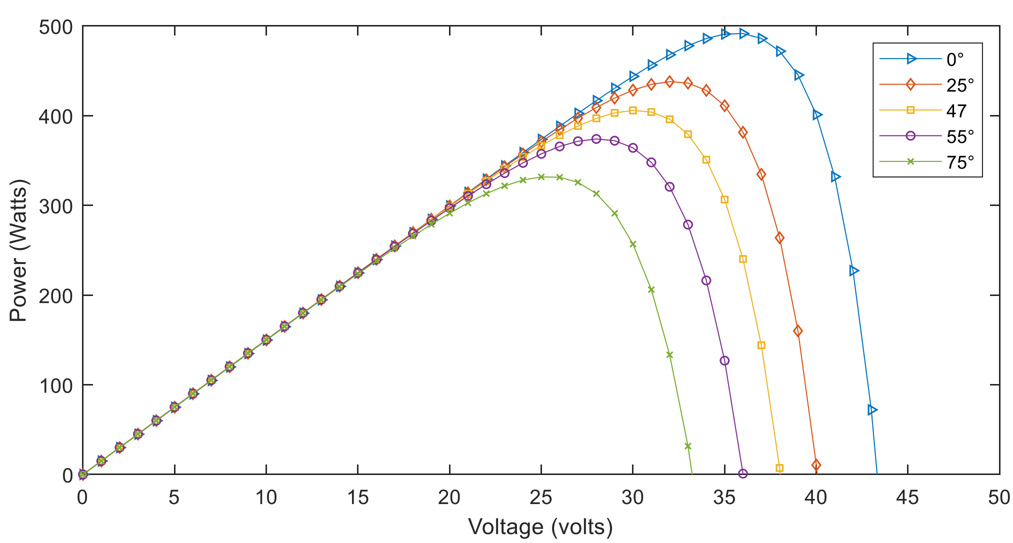

Fig. 8: Characteristic power-voltage for various values of the temperature $P = f(V)$ $E = 1000W / m^2$

Fig. 9 illustrates the variation of the power delivered by the generator as a function of the current for various values of the temperature, which allows us to deduce the impact of the temperature on the characteristic $P = f(I)$.

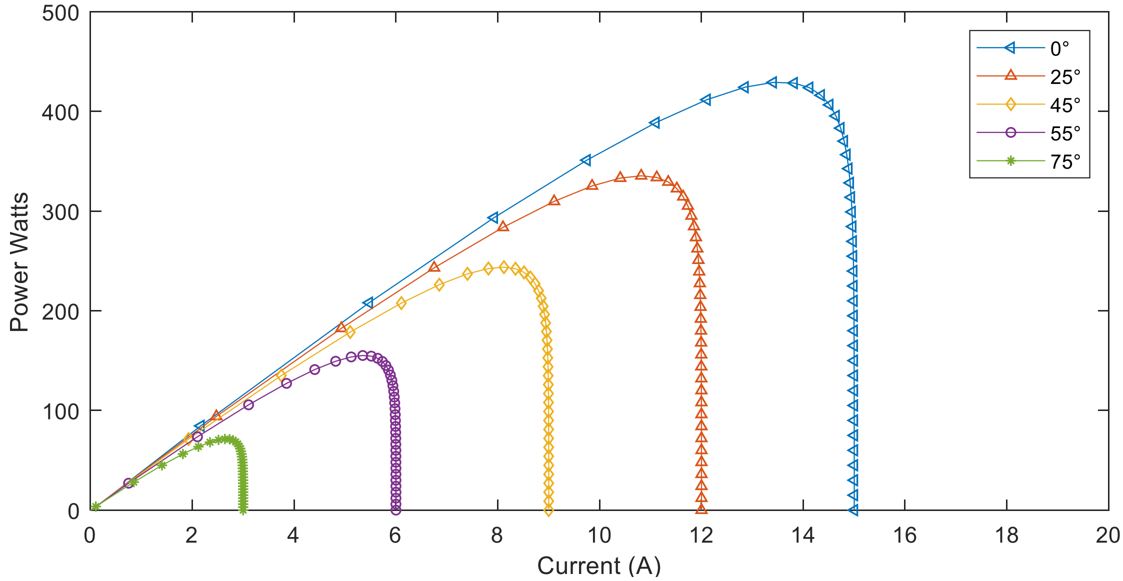

Fig. 9: Characteristic power-current for various values of the temperature $P = f(I)$; E = 1000W / m²

b) Impact of solar radiation

Fig. 10 represents the characteristic I-V of a module reflecting the impact of various radiation at a fixed temperature, the current of the module is proportional to the radiation, while the open circuit voltage changes slightly with the radiation, the optimum power is also proportional to the radiation.

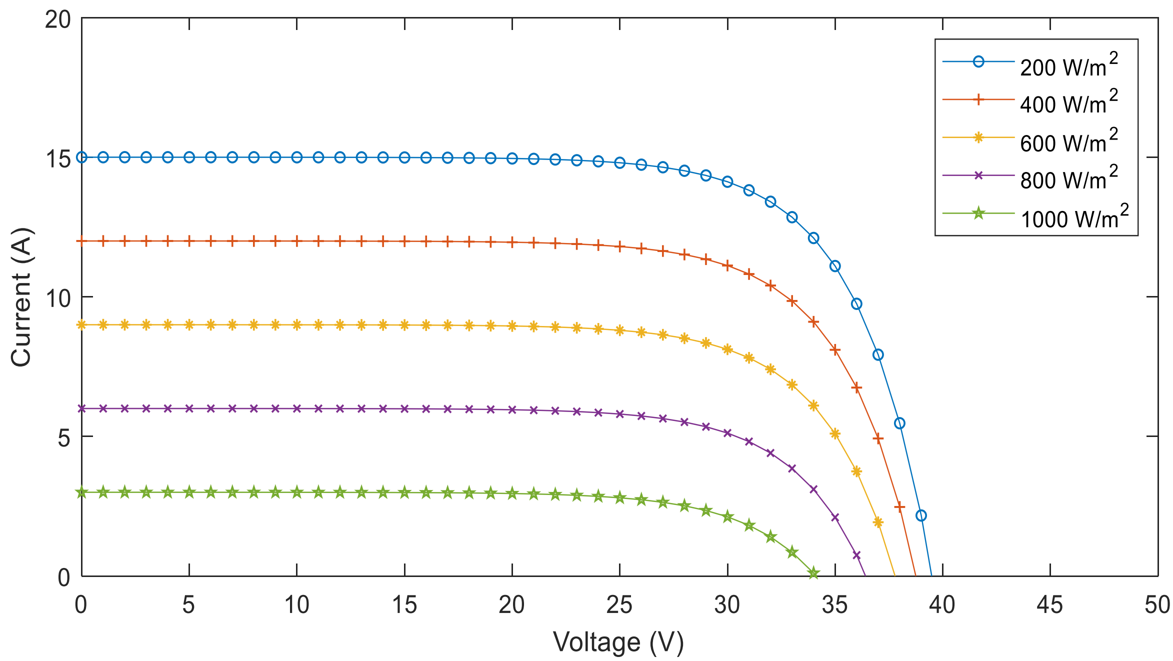

Fig. 10: Current-voltage characteristic for various radiation values $I = f(V)$; T = 25C

In Fig. 11, we represent the variation of the power transmitted by the generator as a function of the voltage for various illumination values, which allows us to deduce the impact of the illumination on the characteristic P (V).

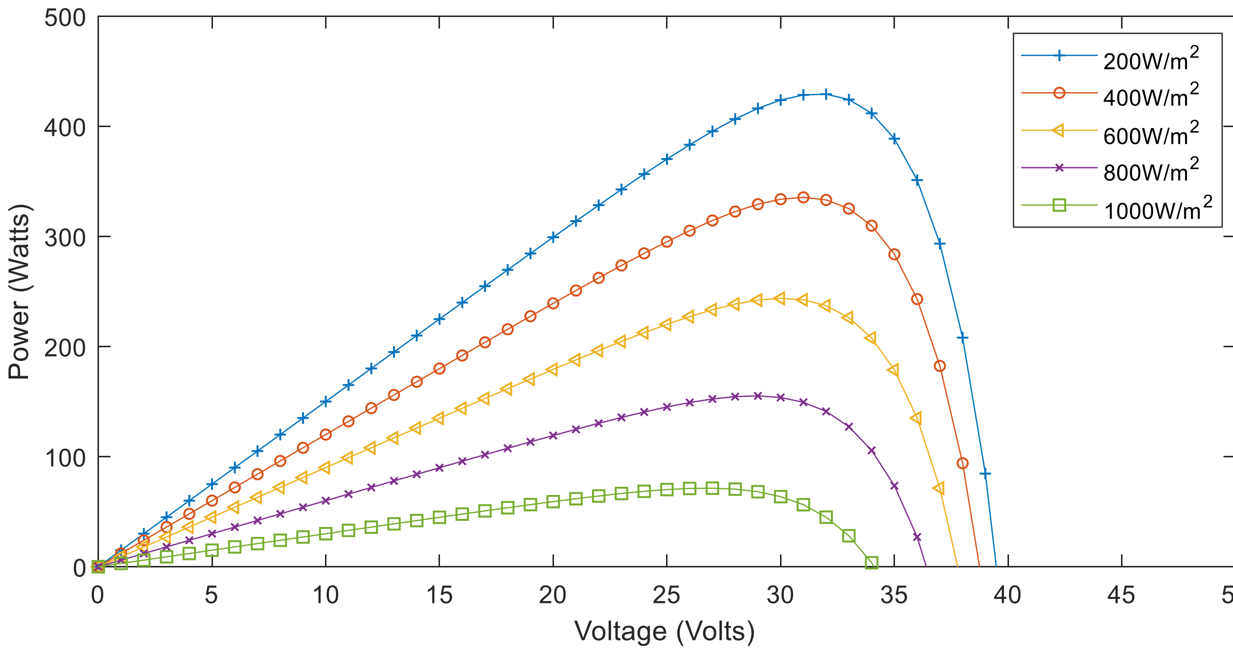

Fig. 11: Power-voltage characteristic for various radiation values $P = f(V)$; T = 25C

IV. Conclusion

The analog and mathematical modeling of a one-diode photovoltaic generator with two series and shunt resistors was the essence of the first part of our work in this paper, which allowed us to start the simulation part under Matlab / Simulink with a more objective methodology.

The simulation results show the impact of the parameters that come into play in the performance of solar energy production systems such as solar irradiation, temperature, Rs series resistance, shunt resistance Rsh, panel inclination.

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Linear Parallelepipedic Electric Machine: Static Study of the Moving Plate

By Pierre Kenfack, Abraham Dandoussou & Stève Ngoffe Perabi
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Abstract- Magnetic suspension, which replaces a mechanical guide means with a magnetic guide system, allows much lower losses. Magnetic suspension is a perfect candidate for holding and guiding the moving plate (rotor) of the linear parallelepipedic electric machine. It is an innovative solution to replace either conventional ball bearings or very sophisticated and expensive active magnetic bearings. The passive centering device with permanent magnets is used because it is combined with a system for compensating friction forces. In order to master the stable control of the centering device, we need to know all its static characteristics (without rotational movement). The normal force is calculated by the finite element method using the ANSYS MAXWELL software.

Keywords: magnetic suspension - mechanical guidance - magnetic guidance - linear machine.

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Linear Parallelepipedic Electric Machine: Static Study of the Moving Plate

Pierre Kenfack [α], Abraham Dandoussou [σ] & Stève Ngoffe Perabi [ρ]

Abstract- Magnetic suspension, which replaces a mechanical guide means with a magnetic guide system, allows much lower losses. Magnetic suspension is a perfect candidate for holding and guiding the moving plate (rotor) of the linear parallelepipedic electric machine. It is an innovative solution to replace either conventional ball bearings or very sophisticated and expensive active magnetic bearings. The passive centering device with permanent magnets is used because it is combined with a system for compensating friction forces. In order to master the stable control of the centering device, we need to know all its static characteristics (without rotational movement). The normal force is calculated by the finite element method using the ANSYS MAXWELL software.

Keywords: magnetic suspension - mechanical guidance - magnetic guidance - linear machine.

I. Introduction

The solutions envisaged to keep the moving plate (rotor) in translation at very high speed can be hydrodynamic or magnetic.

Hydrodynamic solutions can be implemented within the linear electric machine requiring high translation speeds. The principle is based on the use of a fluid carrier located between the rotor and the stators on which the part in translation will be supported during its movement. The fluid in question can be a liquid lubricant such as oil or a gaseous carrier such as air under pressure. In both cases the film thus formed between the two fixed stators and the moving plate of the machine is very thin in relation to the total system. The capacities of this solution are very high. For example, the large alternators of the turbines of the Grand Maison dam, located in the French Alpes, have a vertical axis of rotation and are equipped with axial oil stops for rotational guidance.

Magnetic fields are used to generate forces in many actuators. These actuators only operate with one degree of freedom. In the case of a linear machine in translation, for example, only magnetic forces that allow the moving plate (rotor) to move are used. When all the degrees of freedom of a moving plate in magnetic solution are controlled by electromagnets, the magnetic solution is said to be active as in figure 1 (the current is servo-controlled to keep the moving plate in a fixed position. The magnetic solution needs a power supply to operate, a power supply, a control and position sensors are required). In order to simplify some solutions, magnetic solutions based on magnets can be used. Stability will be ensured by one or more active bearings. These solutions are called passive solutions (passive solutions are autonomous and very simple to realize. They are with permanent magnets or variable reluctance).

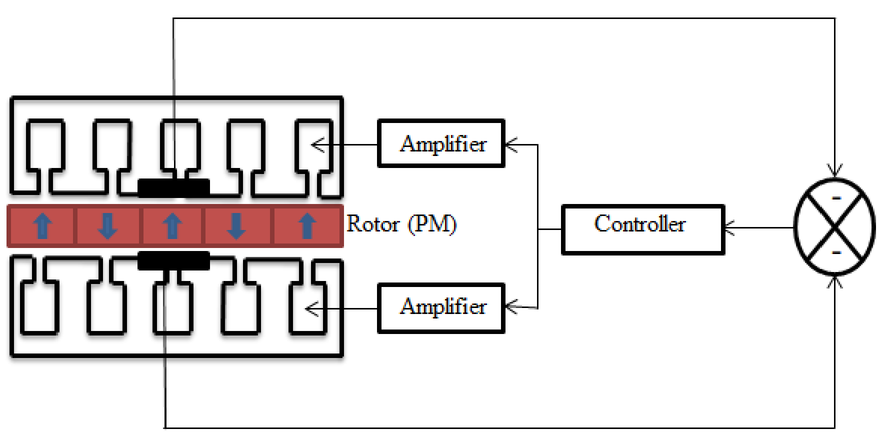

Fig. 1: Active principle

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Magnetic solutions are used in areas where mechanical systems reach their limits: high speed range (the absence of contact in a magnetic solution makes it possible to reach very high speeds); a range in which friction and wear must be minimized (friction is almost non-existent in a fully magnetic solution because there is no contact between moving and stationary parts and the bearing life is unlimited) ; a range in which high precision is required (an active magnetic solution, controlled by a servo drive, allows the moving plate to be positioned with great precision) and, a range in which temperature variation is significant (a magnetic solution, made of suitable materials, is capable of operating at extreme temperatures) [1][2].

Magnetic solutions are used in very different fields. They can support parts weighing a few grams such as electric meter disks up to machines weighing several tons such as linear electric machines. The main applications are: the application of magnetic solutions in space is the use of flywheels to stabilize a satellite or to store energy. Magnetic solutions can be used to equip machining spindles (Figure 2) and turbo molecular pumps can be used to obtain a very high vacuum thanks to a turbine rotating at high speed, (Figure 3).

Fig. 2: Milling [Canadianmetalworking.com]

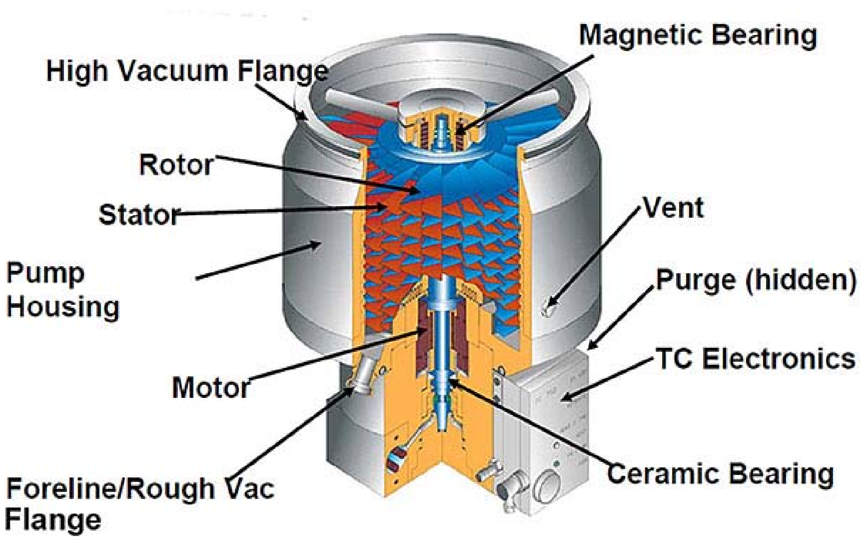

Fig. 3: Turbo molecular pomp [Kurt J. Leskercompagny]

Industrial solutions are more focused on the hydrodynamic regime. There are self-lubricating plates or plates on the market, impregnated with specific oils and coated with a solid lubricating film: molybdenum disulfide (MoS_2). The self-lubricating plates allow a continuous operation. The performance and safety of the self-lubricating plates depend on the grade of metal alloy and the nature of the lubricant. The performance is related to operating and environmental conditions: dynamic load; speed; temperature; atmosphere and corrosive or non-oil compatible liquids. Maintenance is almost non-existent; the operation of the plates requires no maintenance. The presence of the lubricant film is permanent, resulting in a good coefficient of friction, silent operation and good corrosion resistance.

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II. Linear Electric Machine Description

Linear machines have been and continue to be designed considering a large variety of topologies. Linear machines are flat or tubular. They have a long stator: the mover is shorter than the stator or a short stator: the mover is longer than the stator. The stator slots are of single layer type or double layer one.Beyond energy efficiency, linear machine concepts exhibit: high velocity, high acceleration, high accuracy of the position sensing and high lifetime with less maintenance [3] [4].

The stators of the linear electric machine are made of a magnetic circuit in M300-35A rectangular form, in laminated sheets equipped with the slots intended for three-phase winding aluminum bars. The magnetic circuit is laminated in stacked plates cut to their thickness. The number of stacked plates is proportional to the width of the magnetic circuit. The plate is punch-cut in a single operation from a strip of sheet metal, first insulated on both sides by a phenolic class H varnish. The plate hole profile has a circle shaped that will help stack plates for the appropriate height of the magnetic circuit to be dipped in the oven. The side of the plate bore has 36 slots intended to receive the winding bars after stacking [5].

The winding is three-phase-series bar star. Each bar is a rectangular aluminum section to ensure transverse field compensation of Roëbel slot process. Bar winding has several advantages over traditional winding: good slot filling factor (greater than 95%); minimization of solid insulation and the potential difference between bars; better performance; and good thermal behavior in the slot.

Linear electric machine is protected by an aluminum cover called enclosure against ingress of moisture, dust, atmospheric impurities and any foreign materials.

The moving plate consists of a permanent magnets made of NdFeB (alternating North-South), which are magnetized in the transversal direction. The magnets are glued to a brass frame. The friction sheet is made of bronze 0.1 mm thick to ensure strength and mechanical rigidity. Anaerobic glue (polymerized in the absence of air) of acrylic type is used. The linear electric motor is a parallelepipedic structure with two air gaps (Fig. 4).

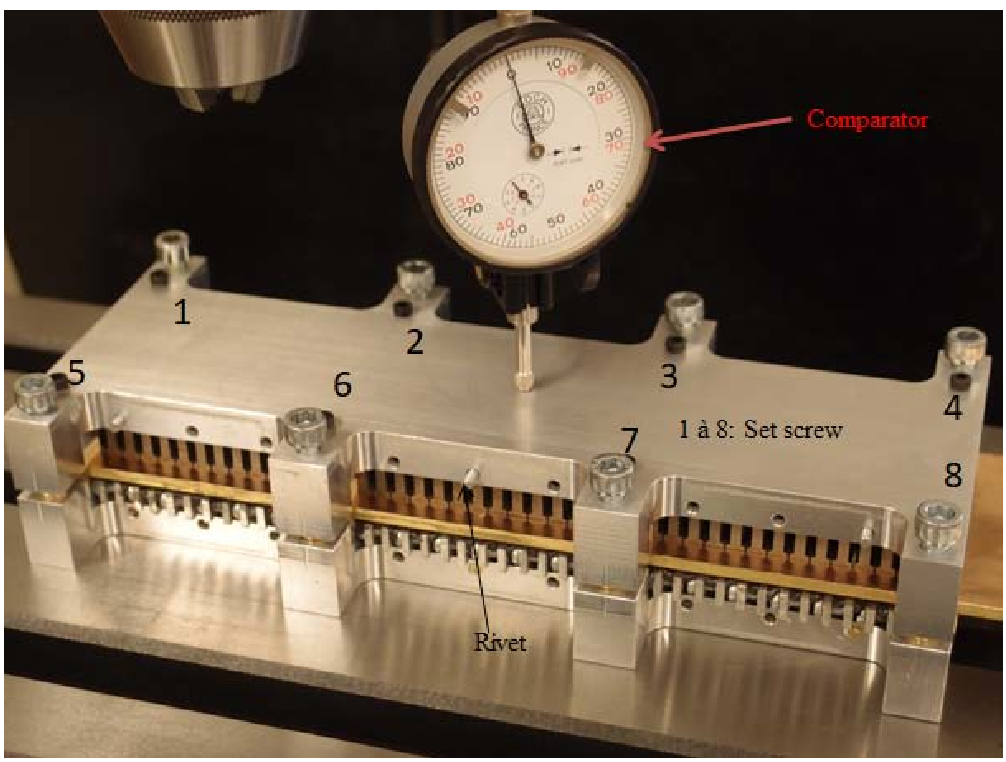

Fig. 4: Linear electric machine

III. Centering and Plating Forces

The main problem encountered in the design of linear electrical machines with a parallelepipedic multi-air gap structure is in the control of the mechanical clearances necessary to allow the permanent movement of the moving plate [6], [7], [8]. This problem is very difficult to control due to the magnetic gap which must be as small as possible to avoid penalizing the tangential magnetic pressure. The moving plate is thin in the multi-air gap structure and therefore not very rigid. Moving plates made of magnets, therefore, tend to rub against the fixed stators. It is necessary to control the forces that are perpendicular to the active surfaces. In each position, figure 5, we have: $e + e = e_1 + e_2 = 2e$; $e_1 = e - e_y$; $e_2 = e + e_y$; e theoretical mechanical air gap; e_1 upper air gap; e_2 lower air gap and e_y offset; F_1 attraction force created by stator 1; F_2 attraction force created by stator 2; F the sum of the forces applied to the moving plate. Each of the two stators exerts an attractive force on the moving plate (rotor). These two oppositely directed forces have a modulus which is related to the size of the air gap facing each other, as well as to the current flowing through the coils necessary for position control. Let us consider the equilibrium of the moving plate, i.e. the sum of the forces along the y-axis.

Under ideal conditions, normal forces are the same and counteract from side to side (the weight of the moving plate is neglected) (Figure 5a). Force F_1 should be of the same modulus as force F_2, the equilibrium position of the moving plate being centered in the middle of the two stationary stators.

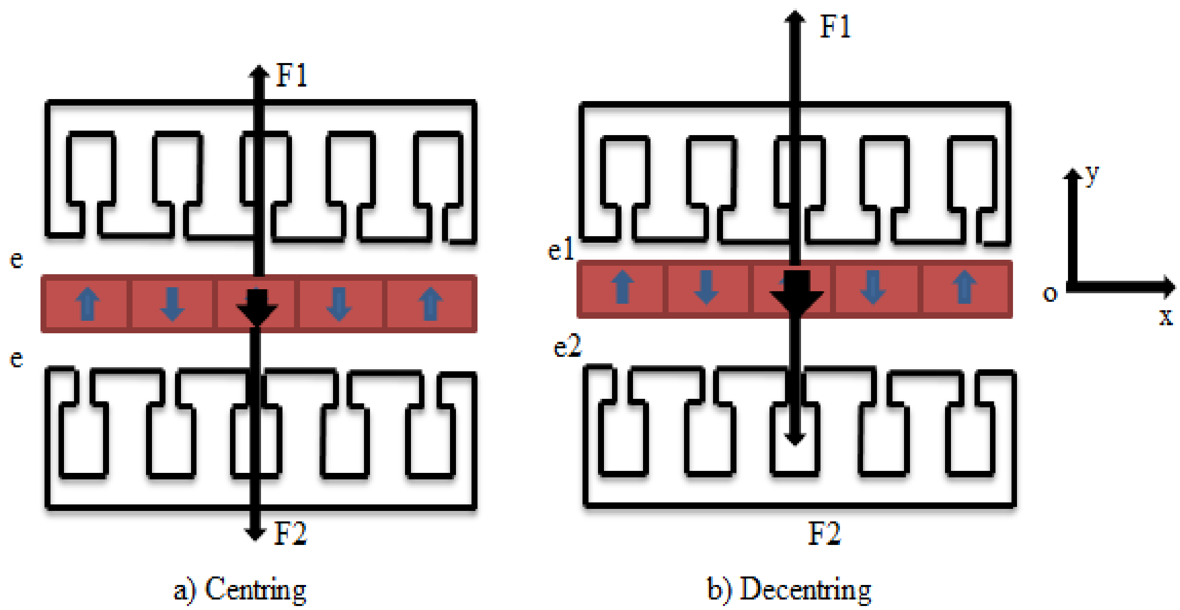

Fig. 5: Centring and decentring force

There is no perfect centering in practice. The air gap exists and a driving force is created giving rise to a normal force which will influence the performance of the linear electric machine. This asymmetrical position generates a force difference, applied perpendicularly to the movement, which tends to create friction between fixed and moving plate (figure 5b). The balance must be restored $\sum\vec{F} = 0 \quad (\vec{F_1} + \vec{F_2} + \vec{F} = 0)$. The moving plate must move towards the stator opposite the direction of application of force F in order to restore the balance. This is because the smaller the air gap, the higher the attractive force. By decreasing the air gap on one side and thus increasing it on the other, the equilibrium of forces is achieved within a certain limit. This limit is conditioned by the size of the air gap as well as the normal stiffness constant. The magnetic balance of the moving plate is very unstable. The phenomenon described above has caused many failures in the design of linear electrical machines with a multi-air gap structure with guided or friction plates. Operation is affected by high wear of the friction interfaces (friction).

In order to fully understand how magnetic solutions work; they must be compared to a mechanical system. When the stiffness constant is positive, it is assimilated to a spring which will oppose the displacement. Conversely, when the stiffness constant is negative, the solution favors deviation from the original position.

IV. Calculation of Normal Force

The air gap is very important in the electromagnetic parameterization of a linear electric machine with a multi-air gap structure with guided or friction plates. This normal force which depends on the air gap is strictly related to the mutual position of all permanent magnets and stators [9], [10].

a) Analytical calculation of force

As the magnetic circuit changes its shape during operation (displacement of the moving plate), the force is calculated analytically using the virtual working principle and Maxwell's torsor methods. Here we use the principle of virtual work.

Faraday's Law of Induction presents the voltage induced in the winding, which creates a current that tends to resist flux changes. The voltage equation for the winding is written as follows:

$$u = Ri + \frac{d\Psi}{dt} = Ri + \frac{dLi}{dt} \tag{1}$$

u: voltage; R: winding resistance; Ψ: induced flux and L: inductance.

Let's calculate the power in the winding by introducing N the number of bars and the flux Φ.

$$\mathrm{ui} = \mathrm{Ri}^2 + \mathrm{Ni}\frac{d\Phi}{dt} \quad (2)$$

The transformed energy is given by the equation:

$$dW = \mathrm{uidt} = \mathrm{Ri}^2\mathrm{dt} + \mathrm{Nid}\Phi \quad (3)$$

$(\mathrm{Ri}^2\mathrm{dt})$ is energy transformed into heat and $\mathrm{Nid}\Phi$ is reversible energy.

The virtual displacement principle allows the driving force to be calculated analytically. The calculation is carried out at maximum displacement.

$$F = \frac{\partial w(x)}{\partial x} = \frac{\partial}{\partial x}\left[\int_v \left(\int HdB\right)dV\right] \quad (4)$$

x is the displacement of the mobile (m); W: the magnetic energy (J);

B: magnetic induction (T); H: magnetic field (A/m) and V: volume (m^3).

b) Calculation by the finite element method

The finite element method uses the same principle; it is applied over the entire pattern of the linear electric machine. The table below gives all the dimensions of the prototype.

Table 1: Magnetic structure, three-phase linear machine

Element	Symbol	Value (mm)
Slot opening height	-	1.0
Slot wedge height	-	0.0
Slot body height	-	5.0
Slot opening width	-	0.5
Slot wedge width	-	2.5
Slot body bottom width	-	2.5
Slot pitch	-	5.0
Pole pitch	τ	5.0
PM length	-	5.0
PM thickness	hm	3.0
Air gap	g	0.3
Generator length		230
Generator width		50
Stroke	Ls	20
PM mass	0.25875 kg	
Generator power	1 kW	

Figure 6 shows the field lines of the ANSYS model when the moving plate is centered. It represents the path of the equal-flux lines within the machine. The teeth channel a large part of the flux flowing through the magnetic circuit. As the flux flow is almost constant, the teeth are subject to a high magnetic induction.

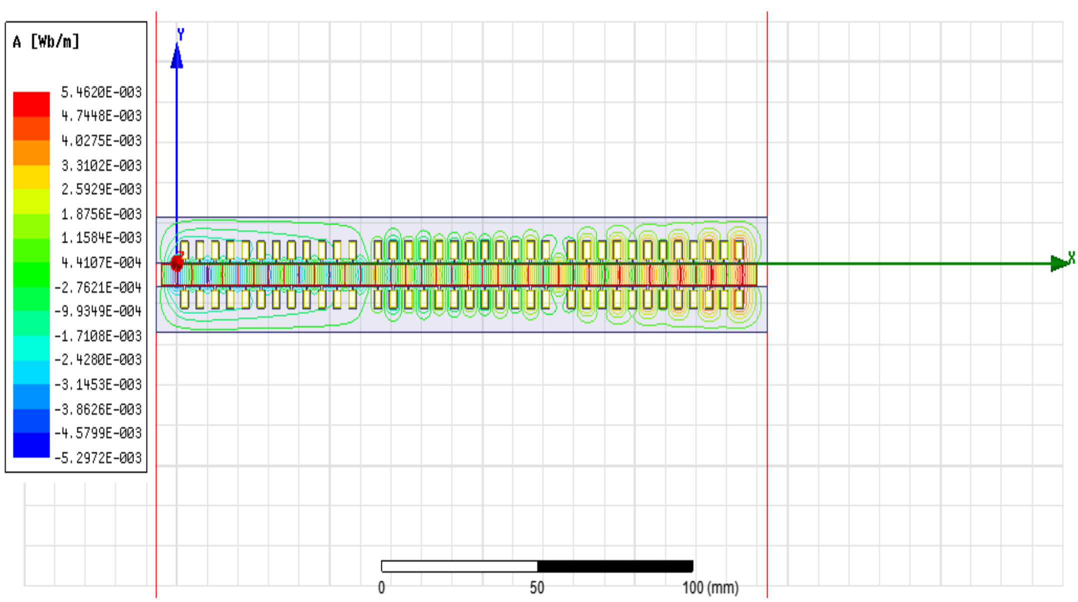

Fig. 6: Field lines of the centered model

Figure 7 shows the normal force as a function of the mechanical air gap simulated with the ANSYS MAXWELL software centered on e = 0.3 mm.

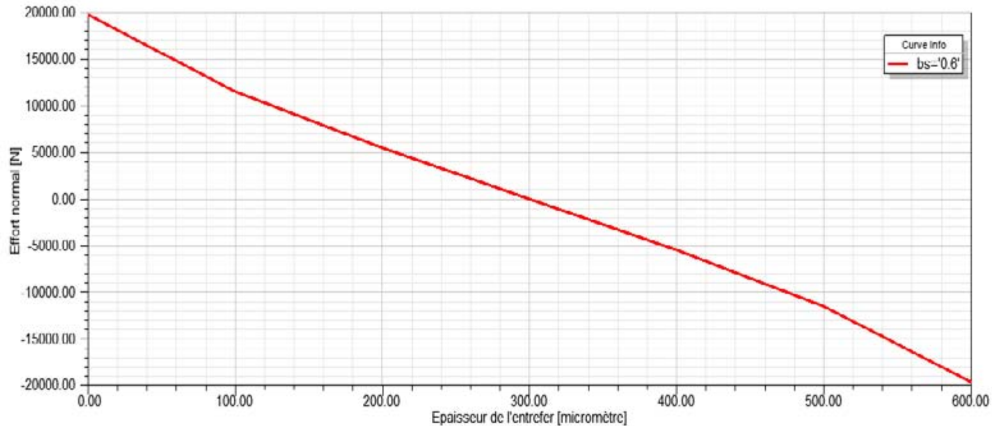

Fig. 7: Normal force as a function of air gap thickness: bs = 0.60

The suspension consists of NdFeB (neodymium-iron-boron) permanent magnets and the two stationary stators are made of metal sheet grade M300-35A, where on the side of stator 1 there is an air gap of 0.2 mm, on the side of stator 2 there is an air gap of 0.4 mm (figure 8).

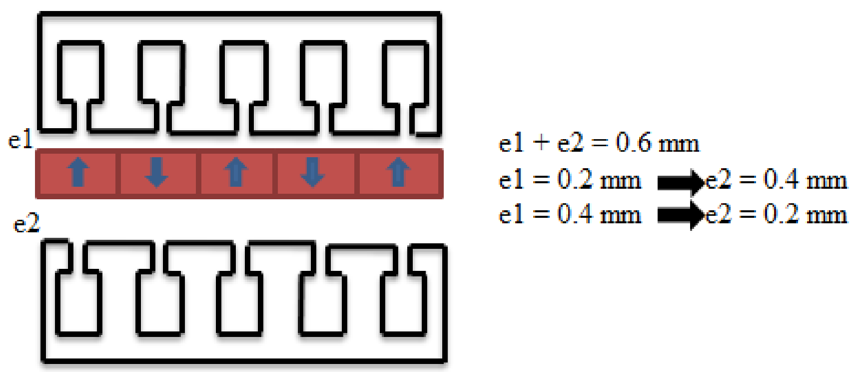

Fig. 8: Cross-section of the linear machine

From Figure 7, we can estimate that linearity is important enough to consider normal stiffness to be constant. We can deduce the following characteristics:

The normal stiffness (N/m) is equal to the variation of the normal stress on the variation of the air gap.

The current stiffness (N/A/mm²) is equal to the variation of the total force on the variation of the current density.

These calculated parameters are used to dimension the analytical model.

The simple model established around an operating point makes it possible to control the suspension, in Laplace's formalism, by placing oneself around any point to be enslaved.

The mechanics allows us to link the normal force $F_N(p)$ with the acceleration $\delta_N(p)$ and the mass of the moving plate (M).

$$\delta_N(p) = \frac{1}{M} F_N(p) \quad (5)$$

By integrating the acceleration, we obtain the velocity $V_N(p)$, and by integrating again, the position y(p).

$$V_N(p) = \frac{1}{p}\delta_N(p) \text{ and } y(p) = \frac{1}{p} V_N(p) \quad (6)$$

The normal force is proportional to the square of the induction (B_2), thus the square of the flux (φ^2).

$$F_N = \frac{B^2}{2\mu_0 S} = \frac{\phi^2}{2\mu_0 S} \quad (7)$$

V. Control/Command Mode

a) Spring compensation

The principle is to take up exactly the force of attraction between the moving plate and the two stationary stators by means of an adjustable spreading force between the two stationary stators, see figure 4.Adjusting the gap between the two stators to cancel friction. Flatness is obtained from the dial gauge by manipulating the eight screws of the guide device.

b) Compensation by coupling tangential and normal forces

The coupling of forces to compensate for frictional forces is a path to be explored. The variation in spring stiffness creates a damping effect to compensate for friction forces.

The principle consists in modifying the spring stiffness during the operation of the linear parallelepipedic electric machine (displacement of the moving plate) in order to compensate the friction forces.

- In the centered position (moving plate), the sound pressure at the output of the sound line delivers a sound power to the moving plate. It moves with a speed V.
- 0<t<td, the compensating force created by the springs provides a reaction force to keep the moving plate centred during operation of the linear parallelepipedic electric machine, where td is the time taken to cover the half stroke.

The coupling between two forces to transfer energy to a servo force, allows the recovery of vibration energy from the moving plate, as shown in figure 9.

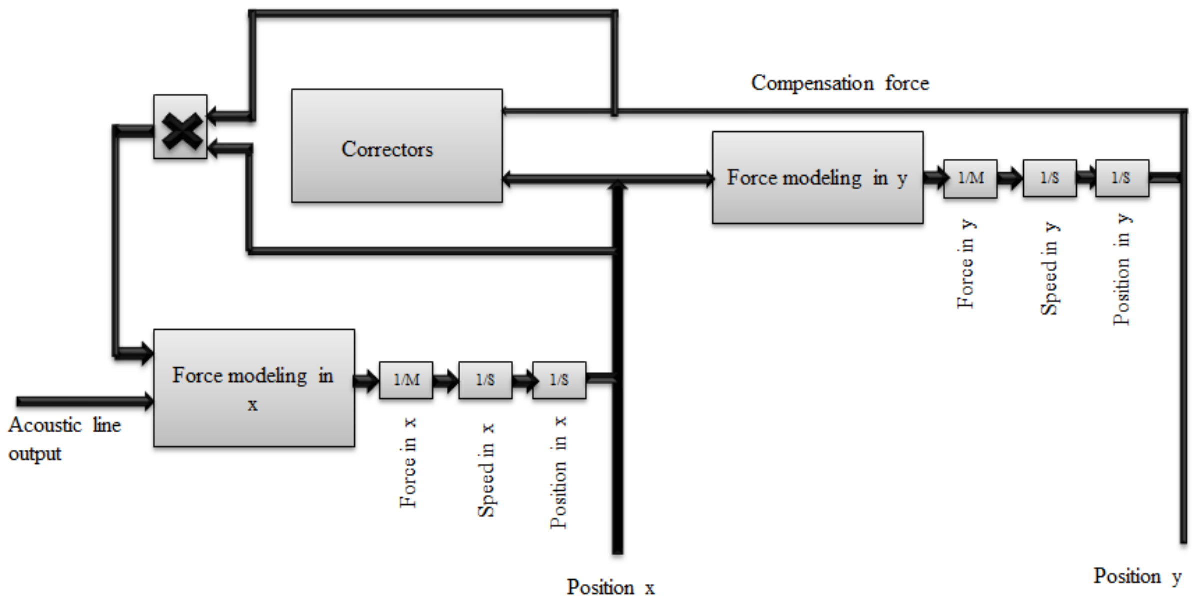

Fig. 9: Coupling of tangential and normal forces

At the level of the correctors, the normal force (in y) can be controlled by a conventional corrector. The addition of another proportional corrector will allow to control the current according to the following displacement x.

- Modeling of the tangential force (in x).

The centered position is changed by the control current when a disturbance occurs. The reaction force is obtained by multiplying the compensation force in x by the following displacement x.

- Modeling of the normal force (in y).

We add a link between the tangential and normal forces. The link constant is calculated by the finite element method. The reaction force is obtained by multiplying the compensation force in y by the following displacement y. The model of the normal force is identical to that of the tangential force: the force (in y) and the position (in y) are governed by the same equation.

VI. Conclusion

This paper focused on the magnetic suspension systems and the control systems using permanent magnets.The determination of the normal stress, stiffness's as a function of the mechanical air gap and current density was done by the finite element method using the ANSYS MAXWELL software. The air gap is quite small and very important in the electromagnetic parameterization of a linear parallelepipedic electric machine with guided or friction moving parts. The normal force depends on the air gap and is strictly related to the mutual position of all permanent magnets and stators.

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Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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