

# EMI Issues in Semiconductor Manufacturing Environment

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**Abstract**—This paper discusses impact of EMI in semiconductor manufacturing environment, EMI origins, propagation and susceptibility of equipment to EMI. An ongoing effort to update SEMI E.33 EMC Standard is discussed as well.

- Erratic response
- Parametric errors
- Sensor misreading
- Component damage

Keywords – EMI, ESD, EMC, Electromagnetic, lock-up, immunity.

All of that causes equipment downtime, loss of productivity and product defects.

Proper management of electromagnetic environment is a complex task consisting of management of electromagnetic emission sources, propagation path and equipment's immunity to electromagnetic radiation. This paper will consider each of these tasks.

## 1. BACKGROUND

Electromagnetic environment in today's semiconductor FABs presents serious challenge to normal operation of equipment. Electromagnetic interference causes equipment malfunction, parametric errors and downtime. As the sensitivity of semiconductor equipment increases with smaller geometry, its susceptibility to EMI increases accordingly. High-energy tools and co-location of them with sensitive equipment influence productivity of the FABs and associated downtime.

The nature of electromagnetic interference in the FAB environment is discussed in details.

## 3. EMI GENERATION

There are several types of generators of electromagnetic emission that can eventually cause interference (thereafter called EMI):

- ESD Events (discharges)
- Parasitic emission from equipment
- Intentional emission from equipment that uses electromagnetic fields as a part of the process

## 2. NATURE OF ELECTROMAGNETIC INTERFERENCE

Every tool or instrument that uses electricity generates associated electromagnetic fields. Voltage causes electric fields, and currents cause magnetic fields. It is normal to expect presence of electromagnetic fields in any environment. Not all electromagnetic fields are a problem. Wireless communication is possible solely due to electromagnetic fields, for instance. Electromagnetic fields generate voltages and currents in any conductive object just like they do in antennae of mobile phones and radio and TV antennae. Similarly, electromagnetic fields in the FABs generate voltages and currents in electric circuits of semiconductor process equipment which act just like antennae. When these induced voltages and currents reach the level that can cause undesirable operation of equipment, it is called EMI, or electromagnetic interference.

EMI can manifest itself in the following forms:

- Outright equipment lock-up
- Tools do things they weren't supposed to do
- Software errors

### 3.1. ESD Events

ESD Event is characterized by very rapid drop in static voltage and by equally rapid surge of discharge current. The resulting electromagnetic field is similarly characterized by a very sharp transient nature. The effect on the equipment is determined not only on the voltage that was discharged by the ESD Event, but also by the charge that was dissipated during the event and the properties of contact. Another important parameter in assessing EMI impact of ESD Events is the antenna properties of the discharging parts. More effective antenna leads to higher magnitude of electromagnetic field.

### 3.2. Parasitic Emission from Equipment

This is type of emission that is a side product of normal operation of equipment. Though FCC, CE or similar regulations tightly control parasitic emission, in actual installations it is often higher than a manufacturer foresaw. This is mainly due to extra long cabling that may also have partially-engaged connectors and often-open covers that are supposed, among other things, attenuate electromagnetic emission coming generated inside.

Parasitic emission may have any characteristics, which is unpredictable and varies from one type of

equipment to another.

### 3.3. Intentional Radiation

Some types of tools generate substantial EMI as a part of their normal operation. Examples of it include CVD, ion implanters, etc. Special precautions shall be taken to isolate such equipment from other tools, including separate power and ground, for example.

Controlling EMI generation is a key component in EMI management.

## 4. EMI PROPAGATION

In order for electromagnetic emission to reach its target, it must have a propagation path. Electromagnetic emission propagation paths include:

### Radiated

- Electromagnetic field composed of electric and magnetic fields propagates via air path just as emission from a mobile phone would reach the base station
- This field would create voltages and currents in any metal object, i.e. wire, PCB trace, etc.

### Conducted

- The most neglected type of propagation
- High-frequency currents move via power, ground and data cables and inject undesirable signals into equipment

### Mixed

- Radiated emission generates signals in wires and cables. These signals are then injected into equipment via conductive path.

Poorly done grounding and power distribution networks provide a venue for EMI to propagate from one tool to another. It is not uncommon to witness EMI generated in one corner of a cleanroom to manifest itself in another corner.

Controlling propagation path is another key component in EMI management.

## 5. EMI SUSCEPTIBILITY

Three basic types of failures can be observed in equipment due to EMI:

### Fatal failure due to overstress

- direct ESD discharge
- very high EMI-induced signals (EOS)

### Latch-Up

- induced voltages are outside of supply rails
- often recoverable after power-cycling
- sometimes causes overheating and failure

### Injection of false signals

Induced signal is comparable to legitimate signals.

### 5.1. Equipment Malfunction

The first two types of failures described above are

self-evident when occur – equipment simply locks up. However, the most problematic is the third type – injection of false signals.

Figure 1 shows how EMI can cause false signal in the tool.

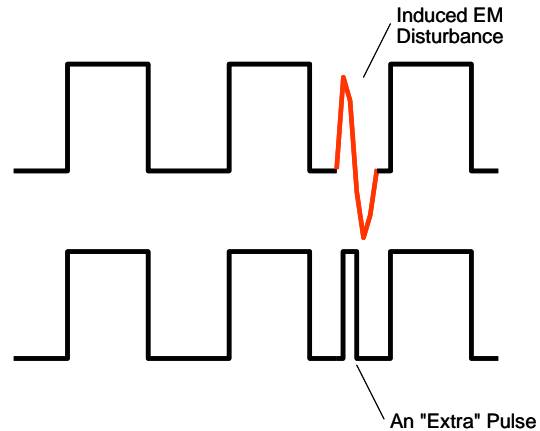


Figure 1. “Extra” Pulse Due to EMI

The top waveform of Fig. 1 shows how electromagnetic field creates a signal in a wire or in a trace of a circuit board of a tool. When such signal passes through the logic gate, it transforms into a pulse which is nearly impossible for the tool to separate from a legitimate signal. This “extra” pulse can cause equipment to perform operation which it wasn’t supposed to perform potentially causing serious damage. This type of malfunction is very difficult to diagnose. Often, the electronics circuit does not suspect that it was affected by EMI. Today’s high-speed circuits are much more susceptible to ESD-induced high-speed transients. Such equipment malfunctions are frequently blamed on the tool’s software while the root of the problem can be entirely different. One of the clear indications that the problem is EMI-caused is difficulty of reproducing the malfunction due to randomness of EMI occurrence.

### 5.2. Sensor Misreading

Sensors in the tools may transmit signals of very low levels. EMI can impose sufficient noise on cables and wires to the sensors to alter the signal from the sensors to the degree where the sensors seem to indicate different values of the parameters than they really are. In fully-automated process without safeguards this may lead to random change in recipes and product defects.

Some systems can detect abnormal status of their signals and indicate alarm. Figure 2 below shows situation where a mobile phone induced sufficient

signal into sensitive electronics so that the tester recognized the problem and indicated alarm.

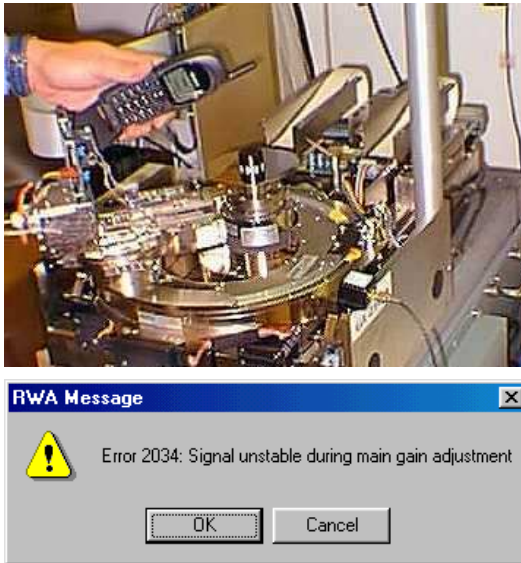


Figure 2. Magnetic Head Tester under Influence of EMI

## 6. EMI AND GROUND

As technological and process requirements change, the demands for the quality of grounding change, too. Simply complying with the safety standards and conventional ESD grounding standards no longer is enough. We need to examine ground from a different perspective—electromagnetic interference.

While for 50/60Hz and for DC regular long and often coiled ground wires may be sufficient, for high frequency signals they present significant impedance resulting in significant levels of high-frequency voltage on ground of operating tools.



Figure 3. Grounding with High and Low Impedance Path

Figure 3 shows different ways to arrange grounding of the tools. The tool on the left has long coiled ground wire while the tool on the right has short braided straight cable.

But, are these two tools grounded equally well? Existing standards specify properties of grounding mostly at DC and 50/60 Hz. At high frequency

situation changes.

With 5 turns of 30 cm diameter, inductance of this coil will be  $12.2\mu\text{H}$  which at 100MHz will present impedance of 7.66kOhms. With only 1mA of current at this frequency the 100MHz voltage on ground of the tool will be 7.66V.

What if the ground wire is not coiled but simply too long? Inductance of a straight 10m wire at 100MHz will be  $17.36\mu\text{H}$  which with 1mA of current will produce ground bounce of 10.9V.

Such situations are prone to cause significant EMI problems for the tool.

## 7. PROPER EMI PRACTICES

### 7.1. Equipment EMC Compliance

In view of increasingly sensitive processes in semiconductor fabrication it is a prudent practice for the FAB owners to buy only the equipment that have met appropriate electromagnetic compliance standards, both for emission and for immunity

### 7.2. Installation

FAB owners must pay attention to co-location of equipment and not to place sensitive equipment near high-energy tools. It is also not advisable to place such tools on the same ground and power lines.

### 7.3. Maintenance

Do not leave tools after maintenance with disconnected grounds, open doors and covers – all of it greatly increases probability of EMI-related malfunctions.

### 7.4. EMI Audits

It is advisable to conduct EMI audits in a similar way as ESD Audits are conducted. It is outside of the scope of this paper to describe the specifics of such audits, however they are highly effective in understanding EMI environment in the FABs and they promote proactive rather than reactive approach to EMI issues.

## 8. SEMI E.33 DEVELOPMENTS

SEMI E.33 standard which specifies electromagnetic compliance of semiconductor equipment is in its revision phase. The original E.33 document was issued in 1994 – it has been 12 years since. Not only regulatory requirements have changed significantly, but also did the fabrication technology. Requirements for electromagnetic performance have significantly risen in the past years as well.

Fundamental changes to SEMI E.33 include:

- Updated references to existing EMC

- standards and regulation
- More specifically, compliance with the requirements of the EMC Directive meets the minimum requirements for conformance with SEMI E33
- Limits for such parameters as ELF are updated in accordance with current process requirements

The new item in SEMI E.33 draft is definition of responsibilities for EMI performance of equipment (see Table 1).

Table 1. EMI Equipment Responsibility Levels

Item	Responsibility
Equipment itself	Equipment manufacturer
Equipment in combination with other equipment if supplied (integrated) by one supplier	Equipment supplier (integrator)
Equipment in combination with other equipment if integrated by the end-user	End user
Equipment installation-related compliance and EMI-performance issues	Party responsible for installation
Equipment co-location issues	End user
Equipment after repair and/or maintenance	Party responsible for repair/maintenance
Post-sale additions or modifications made by the user that affect EMC compliance	End user

Items not covered by the current draft of SEMI E.33 are:

- Electromagnetic environment in the facility – only equipment is covered
- Semiconductor device manufacturing (i.e. back end)
- Frequencies above 1GHz
- Transient emission
- Safety issues

These and other items are expected to be addressed in future work on EMI-related standards within SEMI.

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