Accommodation of Characterization Tools: Understanding Vibration, Stray Electromagnetic Fields and Acoustics to Avoid Catastrophic Interferences in New Building Construction or Building Renovation

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ABSTRACT

Characterization tools are the cornerstone to nanoscale research including microscopy (TEM, SEM, AFM and Aberration Corrected Electron Microscopy), spectroscopy/spectrometry (NMR, FTIR, Acoustic), and advanced nano mechanical (nano scale manipulations) tools. External disturbances such as stray magnetic field, mechanical vibration, noise etc… can cause image distortion, jagged edge lines and difficulty with image capture for electron microscopy (EM). It is vital to understand the installation requirements of your specific EM and to identify and/or create adequate noise free space for these highly sensitive, and often costly, characterization tools. This accommodation will ensure they will function properly to support current and future research efforts.

Keywords: vibration, acoustic, stray electromagnetic fields, EMI, microscope criteria

1 INTRODUCTION

External disturbances such as stray magnetic field, mechanical vibration, noise etc… can cause difficulty with imaging for electron microscopy. Often these disturbances in SEM images are caused by structural, mechanical designs/installation conditions or other influences such as:

1) DC EMI disturbances (the disturbances in earth's magnetic field from ferromagnetic moving objects) such as the movement of metals chairs, doors, hand trucks, elevators or perhaps, disturbances from autos, buses and rail traffic.
2) AC EMI disturbances from alternating current sources such as power distribution lines, improper grounding, electrical distribution boards, nearby conduits, florescent lights; cathode ray tubes (CRT) or monitors;
3) Vibration due to low floor strength and propagation of ground induced vibration from external vehicular/rail traffic, internal pedestrian foot traffic or building systems such as HVAC or pumps.
4) Acoustic disturbances due to high airflow HVAC systems (designed to maintain the temperature or temperature stability requirements) or pumps.

AGI has used real world examples from recent metrology center designs at Duke University Fitzgerald Center for Interdisciplinary Engineering and Medical Applied Sciences (Characterization Labs), Harvard University Laboratory for Interface Science and Engineering (Imaging/Metrology Center), Arizona State University (Biodesign Institute Labs and Light Rail) and University of Arizona (Existing tool set and a future Modern Street Car) to identify these challenges and to highlight best methods of accommodating characterization tools in state-of-the-art facilities.

2 CHARACTERIZATION TOOLS

For the purpose of this paper characterization tools include microscopy (TEM, SEM, AFM and Aberration Corrected Electron Microscopy), spectroscopy /spectrometry (NMR, FTIR, Acoustic), and advanced nano mechanical (nano scale manipulations) tools as well as semiconductor support tools for high end E Beam writing/lithography.

3 IMAGE DISTURBANCE

Examples of the impact of stray electromagnetic fields and vibration on images are provided below in figure 1 and figure 2:

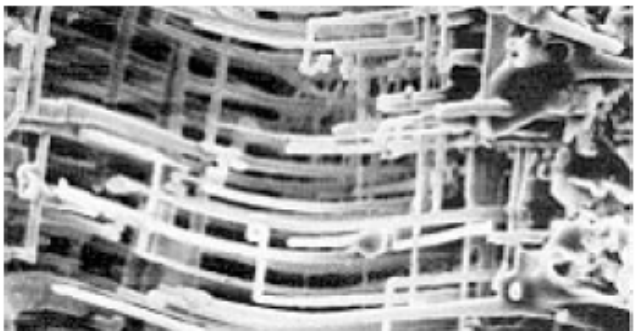

Figure 1(a): Influences of external magnetic field disturbance [1]

Figure 1(b): No external magnetic field disturbance [1]

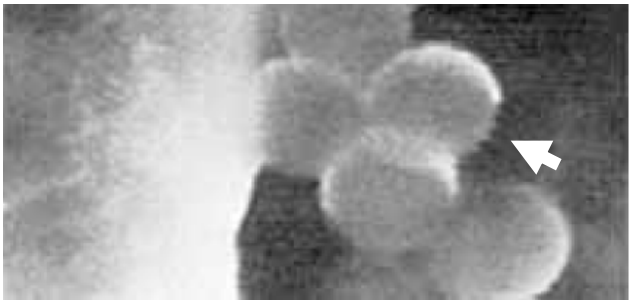

Figure 2(a): Micrograph (x 50,000) shows jagged edge lines due to external mechanical vibration [1]

Figure 2(b): Micrograph (x 50,000) shows image with no jagged edges and no mechanical vibration. [1]

4 UNDERSTANDING INSTALLATION REQUIREMENTS

Manufacturers Installation Guides or Facilities Manuals must be obtained and examined to understanding the requirements (ambient conditions for the site as well as the facilities services) for accommodation of the EM tool.

Most microscope manufacturers provide very tool-specific criteria. Unfortunately, at this time, there is no standardization and confusion can arise due to the forms of data representation used as well as the required calibrated measurement equipment and recommended measurement methods which shall be used to measure ambient acoustic, vibration and stray fields. Criteria may be communicated in velocity, displacement or acceleration for vibration. Stray field requirements may be measured in tesla or milligauss.

The criteria are communicated in the technical guides; often called Facilities Manuals or Pre Installation Requirements, Figure 3. It is essential that the potential tool owners gain these technical guides BEFORE the tool is purchased to ensure a fit for the research and for the proposed tool location (including service support equipment or specialty requirements such as a preference for an anechoic room).

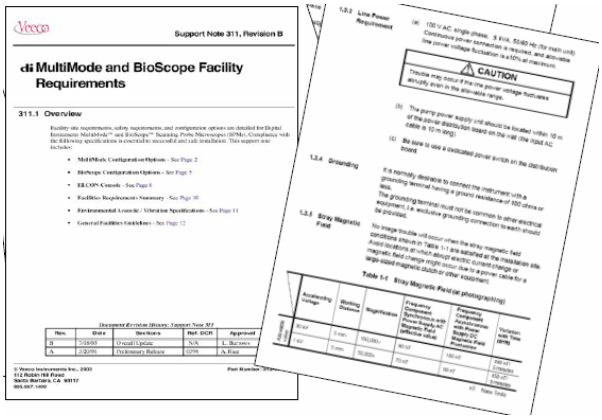

Figure 3: EM Installation Guides are the key to identifying the tool specific room conditions requirements.

It is also important to note that tool sensitivities vary significantly and a less sensitive tool may be capable of accomplishing the desired research (the less sensitive tool being easier and less costly to accommodate) OR a more sensitive tool may be a better choice to sustain future, more demanding research, Figure 4.

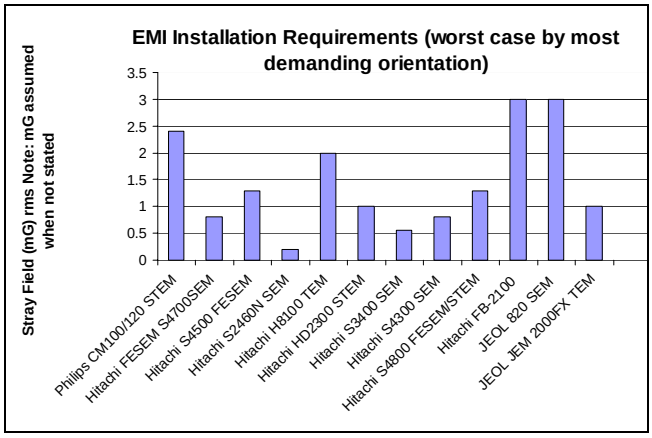

Figure 4: Stray Field EMI room conditions requirements can vary from 0.2 mG rms to greater than 3.0 mG rms.

5 UNDERSTANDING THE AMBIENT CONDITIONS OF THE PROPOSED TOOL LOCATION: SITE SURVEY

Once the manufacturers required minimally compliant criteria for ambient vibration/EMI/acoustic criterion have

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been comprehended, it is essential that the data is collected using the recommended calibrated test equipment and test methods. These ambient conditions are compared to the manufacturer's requirements and non compliances can be identified; the difficult task of identifying the disturbances can begin and abatement/mitigation alternatives can be developed and evaluated.

Figure 5 shows the manufacturer's requirement (Vertical Region I and II) and measured data for two potential locations (Location 1 and Location 2). Both locations are non compliant in the lower frequency requirements for walker induced vibration.

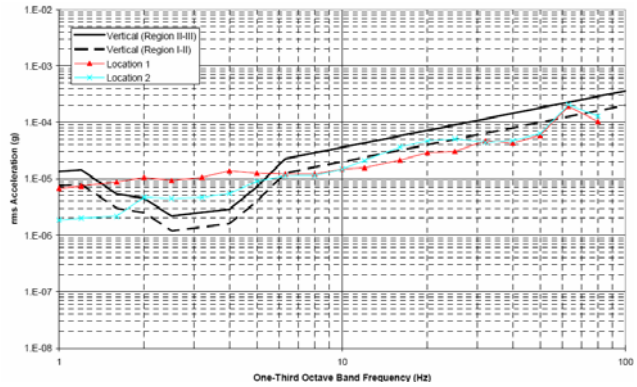

Figure 5: Walker Induced vibration exceeds the manufacturer's requirements. [2]

Figure 6 shows the manufacturer's requirement (Vertical Region I and II) and measured data for four potential locations (Locations 1-4). All locations are non compliant in the lower frequency requirements for acoustic noise.

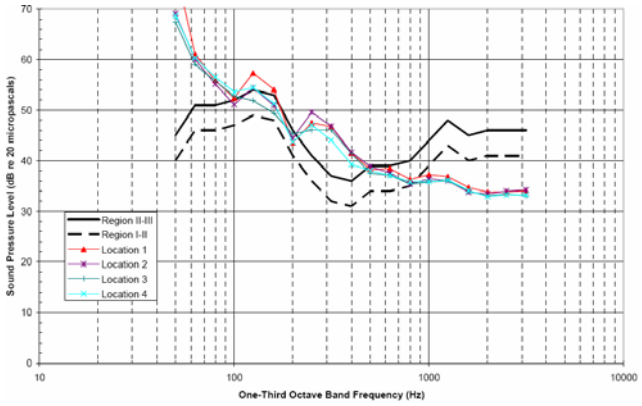

Figure 6: Acoustic noise exceeds the manufacturer's requirements. [2]

5.1 Site Survey: Light Rail and Modern Street Car Alignments

The arrival of light rail and modern street cars on research campuses provides convenient transit solutions but these rail systems are sources of many vibration, EMI and acoustic disturbances. The challenge for most facilities is to provide convenient access to transit but it is vital to maintain an adequate distance from the EM to avoid costly abatement or possible failure of the EM to perform adequately.

Figure 7 shows that it is highly likely that the proposed Modern Street car alignment will violate the manufacturer's stray field requirements for an existing EM on the north side of the research building. In this case the decision is to relocate the EM.

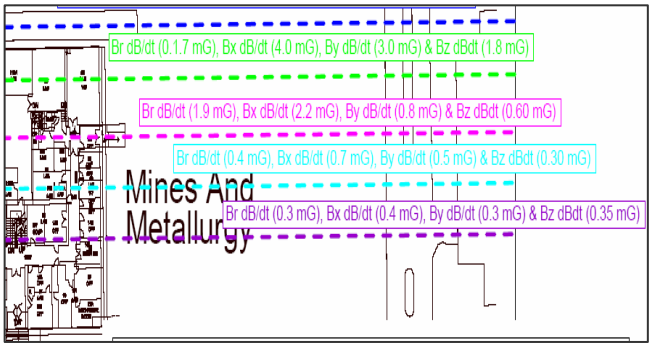

Figure 7: EMI from proposed Modern Street car system are overlaid on an existing microscopy center. [3]

5.2 Construction Documentation: Mitigation and Certification and Acceptance of Imaging areas

Vibration, EMI and acoustic abatement can be communicated and accomplished through the publication of construction methods and materials documentations that identify specialty materials and methods to minimize disturbances. In addition, certification and acceptance documents can define the recommended calibrated test equipment and test methods to ensure the environment meets the tool and researcher criteria once constructed and prior to tool installation.

5.3 Renovation: Control Center is remote from tool to reduce user disturbances

A "mini-environment" or separate room can be constructed to house the sensitive column of the tool. The mini environment reduces the space (and the cost) that must be shielded for EMI, acoustically abated or facilitized to achieve temperature control, temperature stability or other tight requirements. The layout in Figure 8 shows a construction layout that was used to achieve a compliant environment for the GB-300 Leica E Beam Nano Lithography tool. This nano-lithography tool is capable of exposing features as small as 30 nm and requires a very quiet operational environment. The product/samples are placed in the tool column which is located in a room separated from the operators control room.

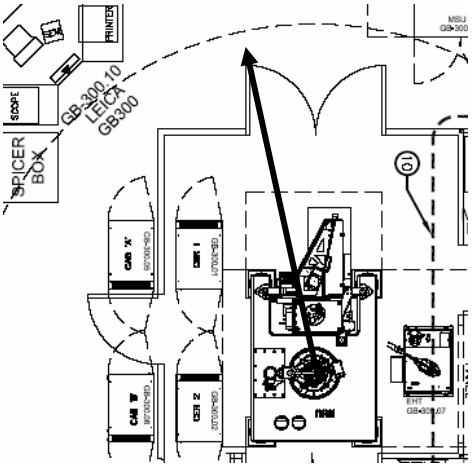

Figure 8: The column of the tool is isolated in a separate room with EMI, vibration and acoustic abatement.

6 ABATEMENT AND MITIGATION

It should be noted that distance from the disturbance/source is always the best solution for the EM tool. However, this is often not possible.

Abatement and mitigation can be prohibitively costly.

6.1 Vibration Abatement

Depending on the structure and foundation design of a future building, the ground vibration may be reduced somewhat by design considerations such as: digging of a basement, implementation of close column spacing for the building and/or caisson anchoring.

6.2 Acoustic Abatement

Noise mitigation may be applied to the dominant sources of noise such as pumps and the HVAC system. In some instances the tool/EM may be housing in an anechoic chamber.

6.3 Stray Field Abatement

It is important to take into consideration the design of the building to minimize stray electric fields and to create a layout which places the sensitive tools away from generators, electrical panels, elevators, truck docks, bus and large truck routes, etc… and other sources of AC and DC EMI.

Many research facilities employ dedicated room shields for ultra sensitive tools when the ambient conditions exceed the tool requirement. It is also possible to individually shield an EMI source such as conductors or elevator shafts with ferromagnetic materials.

Figure 9: Six sided EM room shield installation at a University Microscopy Center. [4]

7 CONCLUSIONS

External disturbances such as stray magnetic field, mechanical vibration, noise etc… can cause image distortion, jagged edge lines and difficulty with image capture for electron microscopy. It is essential to achieve the manufacturers recommended room condition requirements for these highly sensitive characterization tools to function properly and to support research efforts. Design mitigation, abatement of systems or sources can be a costly and distance from the source is the best alternative.

8 ACKNOWLEDGEMENTS

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[3] L. Vitale and L. York, “Tucson Modern Street Car, AGI Project 0562”, Prepared for HDR, Inc. and University of Arizona, page 2, August 28, 2006.

[4] Photo: Duke University Fitzgerald Center for Interdisciplinary Engineering and Medical Applied Sciences (Characterization Labs), 2006.