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VIBRATION AS A PARAMETER IN THE DESIGN OF MICROELECTRONIC FACILITIES

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The rapid advances in microelectronic chip technology over the past several years have led to increased interest in the sources, mechanisms, and control of vibration in building structures. Vibration can interfere in a critical and destructive way with the process of "wafer fabrication", in which the microelectronic circuitry is imprinted in stages on a wafer of silicon, or some other substrate material, and with the operation of electron microscopes, E-Beam systems, and other equipment used in technology development.

It is important therefore in designing a new wafer fabrication facility, or in retrofitting an existing facility for a higher technology product, that vibration be considered as one of the design parameters. Vibration in fact may be regarded as one of the several "contaminants" that can adversely affect the yield in a production facility.

Vibration Criteria: What constitutes an acceptable vibration environment for the equipment and processes used in wafer fabrication? The answer to this question is not easily come by for at least two reasons. Firstly, unlike the engineering science of acoustics, there are virtually no standards which define or advise methods of measurement and quantification of building vibration. Secondly, it is the rare manufacturer of vibration sensitive equipment who is able to provide any guidance or specifications regarding the vibration sensitivity of his equipment.

Over the past several years we have developed measurement techniques and evaluation standards which seem to do well. We measure the root-mean-square floor vibration in one-third octave bands of frequency over the band center frequency range 5 Hz to 50 of 100 Hz. The definition of measurement bandwidth is important since in a well-defined facility much of the vibrational energy is broadband in character. Almost invariably the vertical component of floor vibration lies 10 to 20 dB above the horizontal components. Horizontal vibration may therefore be neglected in most instances.

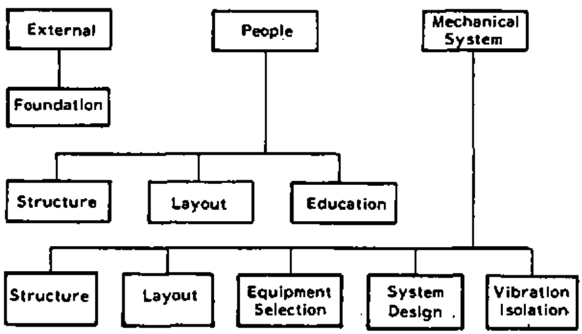
And over the years with this method of measurement the appropriate criteria for wafer fabs have emerged. These criteria take into account the measured or deduced sensitivities of some of the most sensitive process equipment currently in use. More importantly they take into account the experience of wafer fab operators. The criterion sets a limit on the rms vibration velocity within any frequency band. Currently the limit is 1000 µin/sec or lower, depending upon the type of process that will be accommodated, and the desires of the user as regards future flexibility etc. 1000 µin/sec lies a factor of five below the human threshold of vibration detectability as defined by ISO.

Design Characteristics: The wafer fabrication process occurs within ultra clean spaces which are supplied with large volumes of highly filtered and highly conditioned air. Typically the airflow in a modern high-tech facility may approach 100 cfm per square foot of floor area. And typically the installed mechanical equipment horsepower to support a wafer fab may exceed 0.1 hp/square foot of clean room floor.

A typical wafer fabrication plant consumes one hundred times the mechanical power of a conventional commercial building. This clearly poses a challenge to the vibration design consultant.

A further challenge is posed by the fact that many wafer fab users prefer to have something approaching a full basement beneath the production clean room floor. There are a number of reasons for this preference which we need not go into here.

Vibration Sources and Control: The major sources of building vibration, and the elements of vibration control are illustrated below:



External Sources. A vibration survey should form part of the site selection process for a new building. And generally the site should exhibit ambient vibration characteristics substantially below the design criterion. Techniques that can protect a building against a "noisy" site can be quite expensive.

People Sources. The major definable vibration input from plant personnel is that of direct walker excitation of the fab floor.

We can predict the level of walker vibration velocities quite accurately - thanks to past work by Ungar, White, and others. It is necessary to assume a certain average walker weight and an appropriate walk rate (paces per minute). And the peak velocity takes the form

$$V = K/kf_o$$

where k and f_o are the floor stiffness and fundamental resonance frequency, respectively. K is a constant defined by the walker characteristics.

The control requirement for walker excitation is a stiff floor with concomitant high resonance frequency. The layout of the facility is also important in reducing the effects of walker excitation. One should certainly avoid having heavily traveled corridors closely adjacent to vibration sensitive equipment unless the structural design makes provision for this. And, of course, personnel education can help in minimizing walker-related problems in the clean rooms themselves.

Mechanical Systems. The mechanical equipment and systems which supply the clean rooms, condition the air, and which serve the many other functions required, represent the major source of environmental vibration within a production wafer fabrication facility. Almost every aspect of the building design is important in determining the final outcome: the layout of the building - especially in regard to the location of the air handling units, the chillers and major pumps; the structural design - in defining the stiffness characteristics of critical floors, support foundations for major equipment and the provision of distance and/or structural breaks between source and receiver areas; the mechanical design insofar as it applies to the type of equipment that is selected and the configuration and flow velocities that are allowed in ducting and piping systems; and finally, the specification and installation of the mechanical isolation hardware.

In a recent study we analyzed the ambient vibration condition measured in thirteen operating wafer fabs; in each of which a good level of vibration isolation had been achieved by careful design and specification. We found that in all instances the broadband spectrum peaked in the one-third octave band containing the fundamental resonance frequency of the operating floor at mid-span. And we found the level in this band to be well-correlated with the mid-span stiffness of the floor.

<u>**In Conclusion**</u>: There are many parameters to be taken into account in designing a building which will house vibration-sensitive equipment and processes. Techniques have been developed which now allow good building designs to be developed with a good degree of confidence and in a cost-effective manner.