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VIBRATION CRITERIA FOR MICROELECTRONICS MANUFACTURING EQUIPMENT

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INTRODUCTION

The trend toward integrated circuits consisting of smaller, more tightly packed, elements has led to the requirement for greater precision and stability in microelectronics manufacturing and inspection equipment. There exists the need for a better quantitative understanding of the effects of environmental vibrations on this type of equipment, in order to enable microelectronics facility designers to provide suitable environments without costly overdesign.

The critical steps in microelectronics manufacture are essentially photographic. The line width (image sharpness) and precision of registration of successive optical mask patterns that can be obtained determine the element size and packing density that can be achieved. Some limits are established by the wavelength of the radiation used for the photographic exposure and by the thicknesses of the photo-sensitive coatings, but others are due to the vibration-related wobbling of the optical image during the photographic exposure.

OPTICAL EQUIPMENT FROM STRUCTURAL DYNAMICS VIEWPOINT

Although optical equipment items designed for different uses may differ considerably in their operational details, they are reasonably similar from the viewpoint of structural dynamics, no matter whether they are used for observation or for photographic exposure. From this viewpoint, an item of optical equipment is much like a conventional microscope consisting of an optical column and an image stage which are held in precise position relative to each other by a manually or automatically adjustable support structure. The entire system typically is supported on a "table", usually via a system of resilient isolators.

FLOOR VIBRATION CRITERIA DERIVED FROM TRANSFER FUNCTIONS

One may develop floor vibration criteria for a given item of optical equipment - i.e., limits that the floor vibrations must not exceed if a prescribed image quality is to be maintained - if one knows the relation between the image motion on the image stage and the floor vibration. In view of the small motions of interest here, linearity generally applies so that one may describe the relation between image displacement (or displacement of the optical column relative to the image stage) and floor motions in terms of a series of "transfer functions" (amplitude ratios as a function of frequency).

Even if one can neglect the effects of purely rotational motions, as usually is the case, one still needs to consider nine different amplitude ratios in general: the image displacements along each of three mutually perpendicular directions that result from floor motions along three orthogonal axes. In many optical equipment items, however, changes in focus are relatively unimportant, and motions of the optical column perpendicular to the image stage then need not be considered. If, as is true in most buildings, the horizontal floor motions are much less significant than the vertical ones, and if the optical equipment may be expected to be roughly equally sensitive to floor motions in all directions, one may neglect the effects of horizontal floor motions. Thus, one may arrive at a single transfer function that indicates the magnitude of the image displacement (in any direction) on the surface of the image stage due to vertical vibration of the floor. Of course, where configurational changes of the equipment - e.g., due to traversing of the image stage - can affect the dynamic characteristics of the optical equipment, additional transfer functions are necessary to account for the effects of these changes.

The desired transfer functions can be obtained (1) by direct measurement of image displacements, made as the equipment is subjected to purposely imposed vibrations, or (2) from an analytical dynamical model of the optical equipment. Because typically only the lowest few vibrational modes of the equipment contribute significant image motions, an analytical model with only a small number of parameters tends to suffice. Fig.1 illustrates floor vibration criteria obtained by means of transfer functions for two different equipment items and indicates the good agreement between directly measured data and analysis based on a simple analytical model.

SUPPLIERS' CRITERIA

Floor vibration based on transfer functions are available for only a few equipment items. Unfortunately, for most items their suppliers have provided only very inadequate criteria, without any explanation or indication of ranges of applicability. As an example, the

acceleration limits implied by a number of electron microscope suppliers' criteria are shown in Fig.2. Many of these criteria require motions at low frequencies that are practically impossible to achieve and that are unnecessarily restrictive; below their fundamental resonance frequencies, the equipment items act nearly as rigid bodies, experiencing relatively little image-displacing deflection due to a given amount of floor motion.

CRITERIA FROM IN-SITU MEASUREMENTS

Because of the dearth of useful criterion information and the costs and time requirements associated with transfer function measurement or analysis, it is sometimes useful to develop approximate criteria by monitoring the operation of an item of optical equipment in a working facility under quiet ambient floor vibration conditions and also in the presence of purposely increased floor vibrations with different levels and spectra, so as to obtain floor vibration spectra corresponding to satisfactory and unsatisfactory equipment performance. However, two facts need to be considered: (1) Because all frequency components associated with a given test environment act simultaneously, one cannot judge which component limits the equipment's performance; thus, considerably higher levels than those observed may be acceptable for some frequency components. (2) The vibration levels that can be attained often are determined by the available excitation means and thus do not represent limits on the equipment performance.

SUMMARY AND CONCLUSIONS

It appears that simple floor vibration criteria usually are inadequate. Useful criteria usually can be deduced from relatively simple measurements made in the presence of artificially increased floor vibrations. However, precise general criteria probably can best be developed from transfer functions that relate image displacements to floor vibrations, as obtained either by direct measurement or from simple analytical models.

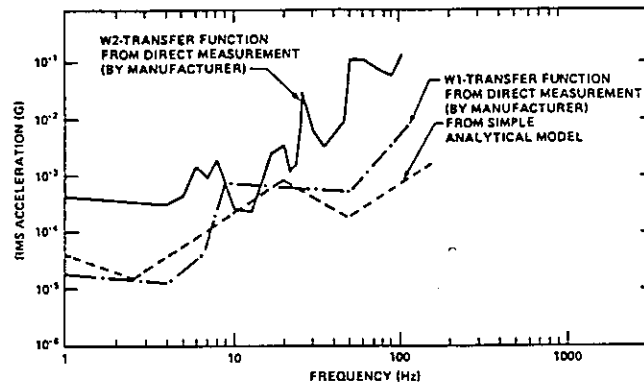


Fig.1. Floor acceleration criteria for two photolithography devices, developed from transfer functions.

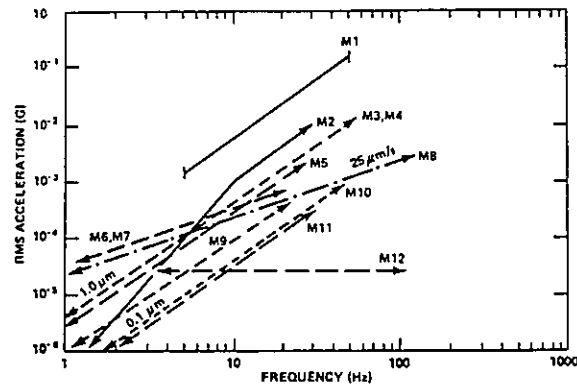


Fig.2. Suppliers' floor vibration criteria for twelve different electron microscopes. (Arrows at end of lines indicate criterion stated without frequency restriction.)