Chapter 9

Microelectronics toward 2010

T. Yanagawa1, S. Bampi2, G. Wirth3

1 General Secretary - The Information Processing Society of Japan Shibaura-Maekawa Bldg. 7th Floor 3-16-20 Shibaura, Minato-ku, Tokyo 108-0023, JAPAN; Tel: +81-3-5484-3535, Fax: +81-3-5484-3534 E-mail: yanagawa@ipsj.or.jp

2 Prof. at the Informatics Institute and Electrical Engineering Department UFRGS – Federal Univ. of Rio Grande do Sul; P.O. Box 15064 – 91501-970 Porto Alegre, BRAZIL; Tel: +55-51-316-6812, Fax: +55-51-319-1576; E-mail: bampi@inf.ufrgs.br

3 Prof. at the Electrical Engineering Department and Informatics Institute UFRGS – Federal Univ. of Rio Grande do Sul; P.O. Box 15064 – 91501-970 Porto Alegre, BRAZIL; Tel: +55-51-316-6828, Fax: +55-51-319-1576; E-mail: wirth@inf.ufrgs.br

Key words: Microelectronics, Moore's law, roadmap, limitations, breakthroughs

Abstract: Middle-term perspectives of process-device technology of semiconductor integrated circuits are described. Even though Moore's law is generally considered to hold good for 10-15 years more, many of the current technologies are foreseen to face growth limitations and thus undergo innovative changes. Problems and possible breakthroughs are discussed for lithography, transistor size, interconnections and power dissipation as the principal factors of such limitations. Future directions to expand functionality and performance of integrated circuits are also described.

1. INTRODUCTION

Microelectronics is one of the most marvelous technologies developed in this century. It has been playing a prominent role in raising the electronic industry to the leading position and will continue to be a keystone to accelerate the development and integration of computers, communications
and consumers which are the three core constituents for the emerging advanced information society. The key components here are semiconductor integrated circuits. They came into being as a result of the effort to assemble smaller and lighter circuits. However their benefits to electronic equipment are not confined to this original aim but extend to wider aspects such as low cost, high performance and high quality. These miraculous effects are of character that is enhanced as the number of components on a semiconductor chip increases. Therefore this number or, in other words, the integration level is the universal index to show the progress of integrated circuit technology.

Integrated circuits integrate components by virtue of relying on various technologies and methodologies ranging from semiconductor physics, materials science, electronics, computer science, to system architectures. Specifically process-device technology and design technology are center pieces without which the integrated circuit business cannot exist. The former technology defines the upper bound of realizable performance and functions while the latter gives specific functionality to products. Process-device technology (expressed as semiconductor technology or just technology hereafter) is important since it is the engine for pushing forward the integration level. It is the core competence for semiconductor manufacturers even in the market driven circumstances.

In this chapter a middle term outlook for semiconductor technology is presented, targeting at 2010. An accurate prediction is not easy because of the rapid technology progress in this area but this is a challenging task since the progress of integrated circuits is closely correlated with that of information society. In the following sections, general trends of technology progress are overviewed at first and then problems and solutions to follow the trends are discussed for major elementary technologies. Lastly some directions to further advance the performance and functionality of future integrated circuits are described.

2. TRENDS OF SEMICONDUCTOR TECHNOLOGY

When discussing the prediction of semiconductor technology, there are two guidelines which should be taken into account: Moore's law (Schaller, 1997) and the SIA semiconductor roadmap (ITRS, 1999). Moore's law was publicized originally in 1965 by Gordon E. Moore, one of the founders of Intel Corporation (Moore, 1965). He projected that the integration level would grow at the rate of 1000 times per decade. Later in 1975 the growth rate was mitigated to 100 times per decade or 2 times in 18 months (Moore, 1975). As shown in Figure 1, this law has guessed right for almost a quarter