
Preface

Strain is an old concept in semiconductor physics. However, strain applied in Si logic technology is a relatively new response to the diminishing returns of pure geometric scaling. Process-induced strain was the first additive feature enhancement introduced into planar Si MOSFET transistors by Intel in 2002 which heralded a new age of feature enhanced CMOS scaling. Prior to strain in logic technologies, Si and Ge piezoresistive strain sensors were initiated much earlier, circa 1957, to respond to variable strain. Strain has also been used to enhance optoelectronic devices such as quantum well lasers incorporated via lattice-mismatched heterostructures. Before the advent of strain enhanced MOSFETs, there were already many, though scattered, research reports on strain effects in semiconductors. However, there had not been a strong driving force for strain studies in semiconductors until it began to play a major role in the mainstream VLSI semiconductor industry. Now in almost every semiconductor workshop, strain is induced by various means to boost device performance. Device and process engineers apply advantageous strain to improve electronic product performance and power at low additive cost to meet the demand of consumers.

There are excellent books on strain physics, such as *Symmetry and Strain-induced Effects in Semiconductor* by Pikus and Bir, and also many books on device physics, such as *Fundamentals of Solid-State Electronics* by Sah and *Physics of Semiconductor Devices* by Sze, as well as numerous papers published on the topic of strained Si, Ge, and other semiconductors, but there is a lack of a single text that combines both strain and device physics. Therefore, drawing from our experience both in the semiconductor industry and in the academic field, we have attempted to summarize in this book some of the latest efforts to reveal the physics underlying the advantages that strain has brought forth as well as its applications in devices, and perhaps help guide the development of strained semiconductor devices. Thus in this book, we have included much of our own research, and have collected many valuable achievements and ideas by the research community. However, due to space

constraints, we note that unfortunately only representative papers and not all key papers have been cited in this work.

This book is designed for two levels of readers. For readers such as students and applications engineers who seek a qualitative discussion, we provide a qualitative overview at the beginning of every chapter. For advanced graduate students and research and development engineers with a background in semiconductor physics who wish to dig deeper, the second part of each chapter provides a more systematic and mathematically involved treatment of the subject. We hope this book provides useful insight into the common physics of strain effects in semiconductors that serve as the foundation for the varied strained semiconductor device applications for both sets of readers.

Strain Effect in Semiconductors

Theory and Device Applications

Sun, Y.; Thompson, S.E.; Nishida, T.

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