Handheld Total Chemical and Biological Analysis Systems

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Bridging NMR, Digital Microfluidics, and Semiconductors

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Preface

This book investigates the handheld total chemical and biological analysis system implemented with complementary metal–oxide–semiconductor (CMOS) based on nuclear magnetic resonance (NMR) technique. The global market for in vitro diagnosis is expanding in both developed and developing countries ascribed to the growing population and longer life expectancy. Conventional benchtop tools for disease diagnosis such as PCR (DNA amplification) are costly, bulky, and time-consuming and require trained technicians for operation, which confound their usages in the centralized laboratory.

CMOS is a promising alternative solution for rapid and quantitative diagnosis at a low cost. It overcomes the miniaturization of healthcare diagnostic tools, allowing low-cost and rapid detection of specific targets in tiny fluid samples. Among numerous possible solutions to POC sensing mechanism, NMR stands out as a trailblazing option since it is versatile and low-cost as it requires little processing on both the samples and interfacing hardware, i.e., the transducers. However, the reported NMR systems in literature encounter some issues such as bulky hardware, sample managements, and magnetic field shifting. So herein the materials presented in this book are focused on optimizing CMOS NMR platform for enhancing their applicability by bridging NMR, semiconductor chips, and microfluidic technique and promoting the application of NMR outside standard centralized laboratory with the aid of CMOS chips. The proposed miniaturized NMR systems in this project achieve (1) accurate and sensitive chemical/biological detection from microliter samples by the CMOS integrated circuits; (2) electronic-automated sample management scheme inside the space-limiting portable magnet, which significantly reduces the labors and turnaround time of the assay; and (3) robust operation against environmental

variation such as temperature or displacement of the sample. The platforms show promise as robust and portable diagnostic devices for a wide variety of biological analyses and screening applications.

We hope the readers will enjoy the contents of this book.

Macao, China
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Contents

List of Abbreviations

1/f noise	Flicker noise
AC	Alternating current
ADC	Analog-to-digital converter
AIDS	Acquired immune deficiency syndrome
B_0-field	Static magnetic field
B_1-field	Radio-frequency magnetic field
BJT	Bipolar junction transistor
BW	Bandwidth
CMOS	Complementary metal–oxide–semiconductor
CPMG	Carr–Purcell–Meiboom–Gill
DAC	Digital-to-analog converter
DC	Direct current
DMF	Digital microfluidic
DNA	Deoxyribonucleic acid
EC	Eddy current
EIS	Electrochemical impedance spectroscopy
ELISA	Enzyme-linked immunosorbent assay
EWOD	Electrowetting-on-dielectric
FoM	Figure of merit
FPGA	Field-programmable gate array
GBW	Gain–bandwidth product
hCG	Human chorionic gonadotropin
HIV	Human immunodeficiency virus
hMAM	Human mammaglobin
IC	Integrated circuit
IDT	Interdigital transducer
IF	Intermediate frequency
IgG	Immunoglobulin G
IgY	Immunoglobulin Y
IIP3	Third-order intercept point
IRN	Input-referred noise

ISFET	Ion-sensitive field-effect transistor
ITO	Indium tin oxide
IVD	In vitro diagnostic
LNA	Low-noise amplifier
LO	Local oscillator
LOC	Lab-on-a-chip
LoD	Limit of detection
LPF	Low-pass filter
LSB	Least significant bit
MNP	Magnetic nanoparticle
MOSFET	Metal–oxide–semiconductor field-effect transistor
MP	Magnetic particle
MUX	Multiplexer
NMOS	N-channel MOSFET
NMR	Nuclear magnetic resonance
NW	Nanowire
PA	Power amplifier
PBS	Phosphate-buffered saline
PC	Personal computer
PCB	Printed circuit board
PLL	Phase-locked loop
PM	Phase margin
PMOS	P-channel MOSFET
PNIPAM	Poly(N-isopropylacrylamide)
PoC	Point of care
PoU	Point of use
PSS	Pulse sequence synthesizer
qPCR	Quantitative polymerase chain reaction
RBC	Red blood cell
RF	Radio-frequency
RX	Receiver
SAL	Supercritical angle luminescence
SAW	Surface acoustic wave
SNR	Signal-to-noise ratio
SPAD	Single-photon avalanche diode
TAT	Turnaround time
THD	Total harmonic distortion
TIA	Transimpedance amplifier
TRX	Transceiver
TX	Transmitter
UART	Universal asynchronous receiver/transmitter
VHS	Vertical Hall sensor
WHO	World Health Organization
XO	Crystal oscillator
β-LG	β-Lactoglobulin

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