

# Abbreviations, Symbols, and Definitions

## Abbreviations

ADC	Analog to digital converter
BDC	Ball diameter at capillary imprint
BGA	Ball grid array
BH	Ball height
CERDIP	Ceramic dual-in-line package
CONT	Contact (removal of contact oxide)
CMOS	Complementary metal oxide semiconductor
DAC	Digital to analog converter
DIFF	Diffusion
EFO	Electrical flame-off
FAB	Free air ball (gold ball before impact)
FC	Flip-chip
FEM	Finite element method
FFT	Fast Fourier transform
FIR	Finite impulse response
FOX	Field oxide
FR4	Epoxy glass fibre laminate
FPGA	Field Programmable Gate Array
FSR	Full scale range
H	Capillary hole diameter
IIR	Infinite impulse response
KOH	Potassium hydroxide
LED	Light emitting diode
LIM	Laser vibrometer measurement
LSL	Lower specification limit
MEMS	Micro electro mechanical system
MOSFET	Metal oxide semiconductor field effect transistor
NEF	Noise equivalent force
PCB	Printed circuit board
PE PSG	Plasma enhanced phosphorus silica glass
PSD	Position sensitive detector

PTAT	Proportional to absolute temperature
QFN	Quad-flat non-leaded
QFP	Quad-flat package
RMS	Root mean square
SEM	Scanning electron microscope
S/N ratio	Signal to noise ratio
SF	Shear force
SS	Shear strength (SF normalized by ball contact area)
SOI	Silicon on insulator
TC	Temperature coefficient
TCE	Thermal expansion coefficient
TCO	Temperature coefficient of sensor offset
TCS	Temperature coefficient of sensor sensitivity
TCR	Temperature coefficient of resistivity
$T_g$	Glass transition temperature
UBM	Under bump metallization
UPH	Units per hour
US	Ultrasound
USL	Upper specification limit
VDD	Positive supply voltage
VSS	Negative supply voltage

## Symbols

$A_H$	Ultrasound amplitude at horn	[m]
$A_T$	Ultrasound amplitude at freely vibrating capillary tip	[m]
$E$	E-modulus	[Pa]
$\Phi$	Electrostatic potential	[V]
$F_j$	Force applied in direction $j$	[N]
$F_N$	Bond force measured by m/c sensor	[N]
$F_I$	Impact force measured by m/c sensor	[N]
$g_{ij}$	Transductance tensor	[V/V/N]
$I$	Cross-sectional-area moment of inertia	[m <sup>4</sup> ]
$I_{US}$	Ultrasound current amplitude	[A]
$\kappa$	Timoshenko shear coefficient	[ ]
$\Lambda_{ij}$	Conductivity tensor	[A V <sup>-1</sup> m <sup>-1</sup> ]
$\mu$	Dynamic friction coefficient	[ ]
$\mu_0$	Static friction coefficient	[ ]
$\nu$	Poisson-ratio	[ ]
$\pi_{ijkl}$	Piezoresistive tensor	[Pa <sup>-1</sup> ]
$r_c$	Contact radius	[m]

$S_i$	Sensor signal of sensor $i$	[V]
$s_i$	Normalized sensor signal of sensor $i$	[V/V]
$\tilde{s}_i$	$s_i$ of linearized Wheatstone bridge	[V/V]
$\sigma_{ij}$	Stress field tensor	[Pa]
$\sigma_{\text{yield}}$	Yield stress	[Pa]
$T_s$	Substrate temperature	[°C]
$t_{\text{US}}$	Ultrasound bonding time	[ms]
$U$	Voltage across the Wheatstone bridge	[V]
$E_{\text{cap}}$	E-modulus of capillary	[Pa]
$c_{\text{cap}}$	Viscous damping constant of capillary	[kg m <sup>-1</sup> s <sup>-1</sup> ]
$\rho_{\text{cap}}$	Density of capillary	[kg m <sup>-3</sup> ]
$\nu_{\text{cap}}$	Poisson-ratio of capillary	[ ]
$K_{\text{TH}}$	Rotational spring constant transducer horn	[N m rad <sup>-1</sup> ]
$c_{\text{cz}}$	Damping constant contact zone	[kg s <sup>-1</sup> ]
$K_{\text{Tcz}}$	Rotational spring constant contact zone	[N m rad <sup>-1</sup> ]
$K_{\text{cz}}$	Spring constant contact zone	[N m <sup>-1</sup> ]
$m_{\text{cz}}$	Lumped mass of contact zone	[kg]
$c_{\text{Tcz}}$	Rotational damping constant contact zone	[N m s rad <sup>-1</sup> ]

## Definitions

$$\partial_z^2 \equiv \frac{\partial^2}{\partial z^2} \quad \text{Partial derivative}$$

$$i \equiv \sqrt{-1}$$

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