Diamond high speed and high power MEMS switches

J. Kusterer, E. Kohn, A. Lüker, P. Kirby, M.F. O'Keefe

(matthew.okeefe@filcs.com)

[1]Institut of Electron Devices and Circuits, University of Ulm, Germany

[2]School of Applied Science (SAS), Cranfield University, UK

[3]Filtronic Compound Semiconductors Ltd., Newton Aycliffe, UK.

OBJECTIVE

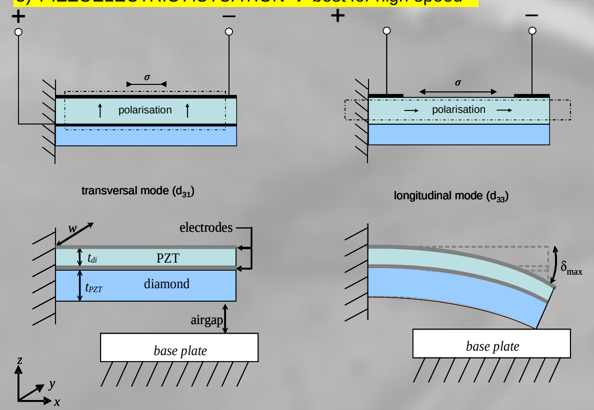
The main objective of this study was the evaluation of nanocrystalline diamond as MEMS material for high-speed switch technologies. Diamond is an excellent materials basis for microsystems technologies, because of its outstanding properties.
In switches this translates into a high power handling capability and high switching speeds.

	diamond	nano-diamond	Si (intr.)	(3c)SiC	Ni	Si_3N_4	PZT
Hardness [GPa]	100	100	13	29.6	0.7	~40	~15
Young's modulus [GPa]	1143	≥ 1000	170	450	210	300	80
density [g/cm³]	3.52	3.52	2.33	3.21	8.90	3.18	7.50
breakdown field [10^6 V/cm]	10	10	0.5	3	-	~10	10
electrical Resistivity [Ωcm]	10^{12}-10^{16}	10^8	10^4	10^2-10^6	$7\cdot10^{-6}$	$>10^{14}$	$>10^{14}$

Physical properties of various MEMS materials

ACTUATION PRINCIPLES

1) ELECTROSTATIC ACTUATION → high volaltage, limited forces
2) THERMOELECTRIC ACTUATION → depending on heat removal
3) PIEZOELECTRIC ACTUATION → best for high speed



Schematic view of unimorph showing crystal deformation and induced stress in piezoelectric layer. Unimorph actuator displacement in switch application

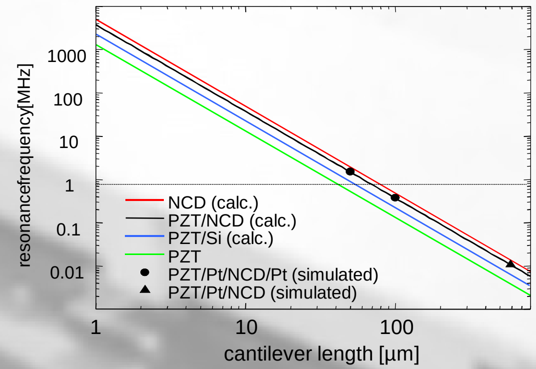
CHOICE OF PIEZO MATERIAL

In this study two piezoelectric materials have been considered in combination with nanocrystalline diamond, namely PZT and AlN.

	Young's modulus [GPa]	Transversal piezoelectric coefficient [pm/V]	Longitudinal piezoelectric coefficient [pm/V]	Density of mass [g/cm3]	Curie temperature [°C]
PZT	80	250	500	7.5	350 - 450
AlN	350	2	7	3.2	> 1000

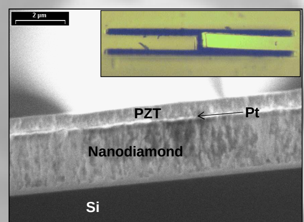
Salient properties of piezo-materials

SIMULATION



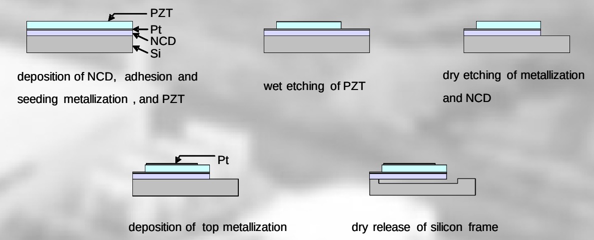
Comparison of simulated and calculated resonance frequencies of a PZT-NCD unimorph.

CHOICE OF STRUCTURE



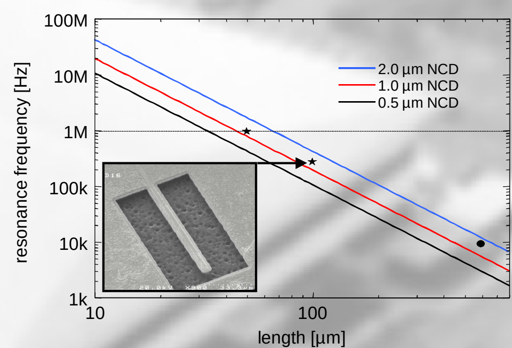
Cleaved cross section of the NCD/Pt/PZT unimorph layer stack deposited by Cranfield University

CHOICE OF TECHNOLOGY



Surface machining processing steps for the fabrication of free standing single ended cantilever structures. In this case the top metallization is Pt

RESULTS



Measured resonance frequencies of unimorphs compared to theoretical data. Dimensions for calculations were: t_{PZT} = 0.5 µm; $t_{diamond}$ = 0.5, 1.0, and 2.0 µm. Dimensions for measured devices were:
t_{PZT} = 0.5 µm; $t_{diamond}$ = 1.8 µm; $t_{Pt,bottom}$ = 0.1 µm; $t_{Pt,top}$ = 0.05 µm; (stars)
t_{PZT} = 0.5 µm; $t_{diamond}$ = 1.8 µm; $t_{Pt,bottom}$ = 0.1 µm; (dot)

CONCLUSIONS

resonance frequency [MHz]	1	10
cantilever length [µm]	60	19
diamond thickness [µm]	1.8	1.8
PZT thickness [µm]	0.5	0.5

A rough classification for geometrical windows, which are needed for resonances in the range of 1 MHz and 10 MHz.

EM REMOTE SENSING
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