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Slender piezoelectric cantilevers of high quality AlN layers sputtered on Ti thin film for MEMS actuators

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ABSTRACT

Very good crystallinity and highly *c*-axis-oriented aluminum nitride (AlN) thin films are sputtered on titanium (Ti) to fabricate thin piezoelectric cantilevers. Raman spectroscopy measurements and X-ray diffraction (XRD) indicate the high quality of these AlN films. A fabrication process, fully CMOS compatible, is developed to realize slender piezoelectric microcantilevers. Actuation enhancement for the AlN piezoelectric cantilevers is achieved by coating the slender beams with a thin PECVD silicon nitride (SiN) layer. Very good linearity and high displacement, up to 19.5 nm for 200 μm long cantilevers and 4.25 nm for 100 μm long cantilevers for 1 V actuation at quasi-static mode, are obtained with a 500 nm SiN top layer. These displacement values are three times larger than our previously reported values for cantilevers without SiN layer coating. This makes these cantilevers, without the need of employing nonstandard metals such as platinum (Pt), very promising for micro/nanoactuators.

1. Introduction

Cantilevers have been widely employed for sensors and actuators targeting advanced bio-medical technology applications [1]. Piezoelectric actuators, compared to capacitive and magnetomotive actuators, present the considerable advantage of miniaturization and low power consumption. Thin films of piezoelectric layers are very interesting for actuation devices, in particular for NanoElectroMechanical Systems (NEMS) [2,3]. Piezoelectric cantilevers based on thick (5–30 μm) silicon beams (Fig. 1a) have been investigated [4–6]. However, controlling the final thickness of these beams is difficult unless expensive SOI substrates are employed. Furthermore, the miniaturization of these cantilevers, as required by nanoscale applications, is rather challenging. Due to its CMOS compatibility, aluminum nitride (AlN) has been considered as an attractive piezoelectric material for nanoscale actuation devices [3]. Nevertheless, AlN piezoelectric devices are normally fabricated using AlN deposited on nonstandard metals (such as Pt, Mo) [2,3]. Recently, Ti electrodes have been utilized to preserve CMOS compatibility, but so far these attempts resulted in a lower quality of the AlN thin-films than the one obtained with other conventional electrode materials [4].

In this paper we report on a process to obtain good crystallinity and highly *c*-axis-oriented AlN layers sputtered on Ti electrodes. Furthermore, we have recently realized slender cantilevers based on Ti/AlN/Ti [7] suitable for micro/nanoscale device fabrication. Here we present a new configuration (Fig. 1b), consisting of AlN slender piezoelectric cantilevers coated by a thin PECVD layer of SiN. This additional high stiffness, but thin, layer results in high performance piezoelectric devices as predicted by the analytical model of the quasi-static mechanical behavior of piezoelectric cantilever reported in [8]. Due to its availability in CMOS technology and well-known properties, SiN is actually preferred to other candidates, such as diamond. This SiN layer can be also deposited prior to the sputtering of the AlN and the metal electrode [9]. However, we noticed that the quality of the AlN/Ti sputtered films is better by direct deposition on a bare silicon substrate. Moreover, when releasing the cantilever by dry etching of the silicon substrate, the selectivity between SiN and Si is rather poor, making AlN preferred as etch stop material. The improvement of the cantilevers performance was investigated by quasi-static vibrometer measurements. The performance of these cantilevers, fabricated in a CMOS compatible process and without the need of nonstandard metals such as platinum (Pt), indicates that they are very promising candidates for micro/nanoactuators.

2. Thin film depositions and characterizations

Titanium thin films have recently presented as potential bottom electrodes for AlN growth due to its good etch selectivity [4] and small lattice mismatch to AlN [10]. Ti electrodes were previously optimized for both surface roughness and crystallinity

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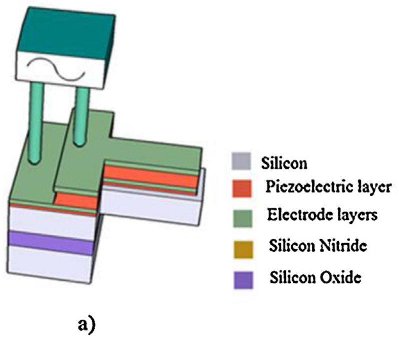


Fig. 1. Schematic drawing of (a) AlN piezoelectric cantilever with a thick supporting layer of silicon and (b) AlN piezoelectric cantilever with a top SiN layer.

by tuning the sputtering pressure during deposition [7]. For a good piezoelectric response, a high (0 0 2) orientation of the AlN thin-films is required [11]. This was achieved by pulsed DC sputtering technique using an SPTS Sigma 204 DC magnetron PVD system [12]. In this study, we have implemented the deposition at lower N_2/Ar gas mixture (66%) with constant substrate temperature (300 °C) to obtain a lower residual stress (∼500 MPa for 500 nm thick AlN) of the films. The sputtering power was adjusted to optimize the quality of AlN thin films.

2.1. Crystallinity and orientation

Raman spectroscopy has been utilized for the investigation of the AlN crystallinity and orientation [13,14]. The Raman spectra measured by a Renisshaw Raman microscope with Argon 514.5 nm laser excitation are reported in Fig. 2. The 500 nm AlN films on 170 nm thick Ti electrodes were prepared by tuning the sputtering power (0.5, 1 and 1.5 kW). All samples display two major peaks around 655 cm^{-1} and a minor peak at approximately 610 cm^{-1} corresponding to the E_2 (high) mode and the A_1 (TO) mode, respectively. Furthermore, two other modes consisting of the E_2 (low) and the A_1 (LO) with very low intensity were also observed. It is well known that the crystallinity of AlN films can be detected by the FWHM of the rocking curve of the E_2 (high) mode that is related to interfaces, small grains and point defects [14]. Kuball et al. reported a value of 3 cm^{-1} for extremely high quality AlN bulk crystals [15] and a value of 50 cm^{-1} was reported by Perlin et al. for fully deteriorated crystals [16]. The low FWHM value of the E_2 high mode (around 11 cm^{-1}) we observe in our films, denotes the high crystallinity obtained [14]. Sputtering power has an obvious influence on the crystallinity of the films (see Fig. 2b). By increasing the sputtering power, the crystallinity of AlN films was slightly improved due to the higher energy provided. In addition, the *c*-axis orientation of AlN films can be deduced by the ratio of the integrated areas of the E_2 (high) mode and that of the A_1 (TO) mode ($R_{E2/A1}$) obtained by Lorentzian function fitting, where the higher ratio indicates a higher *c*-axis orientation [13]. Fig. 2b also shows that the AlN films sputtered at 1 kW have the highest $R_{E2/A1}$ value and thus the best *c*-axis orientation. We chose this sputtering parameter for further investigations because the high *c*-axis orientation is the most important parameter for a good piezoelectric response of the AlN films [11].

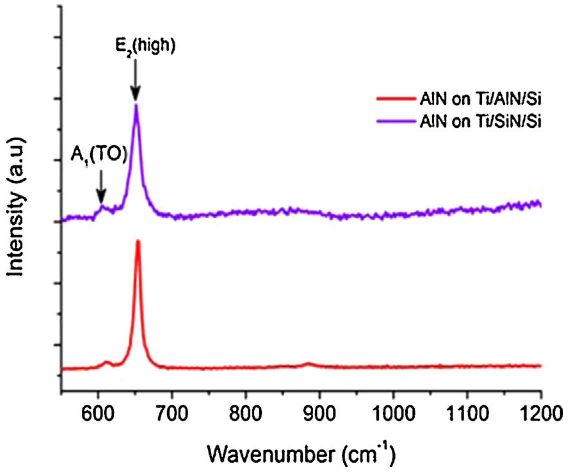


Fig. 3. Raman spectroscopy of AlN thin films sputtered on Ti/SiN/Si and Ti/AlN/Si. The sharper peaks in the sample on bare Si indicate the improvement in crystallinity and orientation of the AlN layer.

To compare the quality of the AlN layers in different configurations, two samples consisting of AlN/Ti/AlN/Si (sample A) and AlN/Ti/SiN/Si (sample B) were prepared using optimized sputtering parameters. In sample A, a 100 nm AlN interlayer below the bottom Titanium electrode was utilized to enhance the quality of the upper AlN layer [4,17], and to act as a protection layer during the etching of the bulk silicon from the wafer backside for the cantilever fabrication. For the sample B, a 500 nm LPCVD SiN was used instead. Raman parameters of the two sample stacks (see Fig. 3) are compared to the ones of the AlN/Ti as shown in Table 1. A slightly higher crystallinity in the AlN layer on sample A is observed, while a significantly lower quality of the AlN layer in sample B can be noticed. This can be explained by the poorer quality of Ti deposited

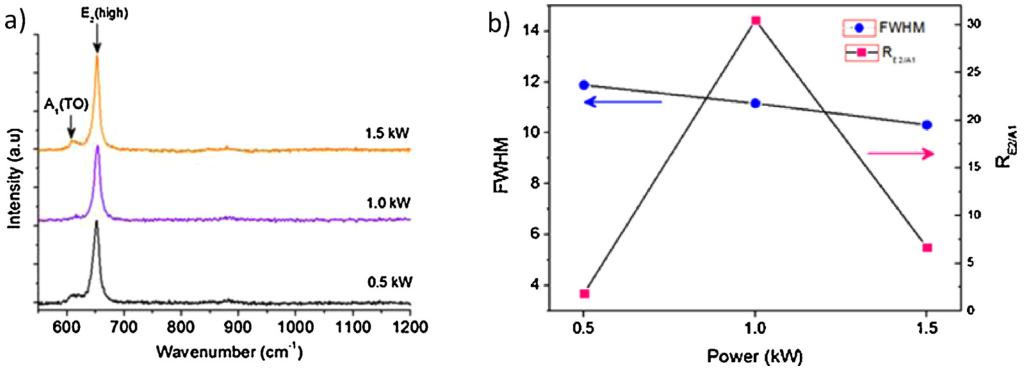


Fig. 2. Effect of sputtering power on AlN film quality: (a) Raman spectroscopy of AlN thin films deposited with different sputtering power; (b) FWHM of E_2 (high) mode and ratio of integrated areas of the E_2 (high) mode and that of the A_1 (TO) mode ($R_{E2/A1}$).

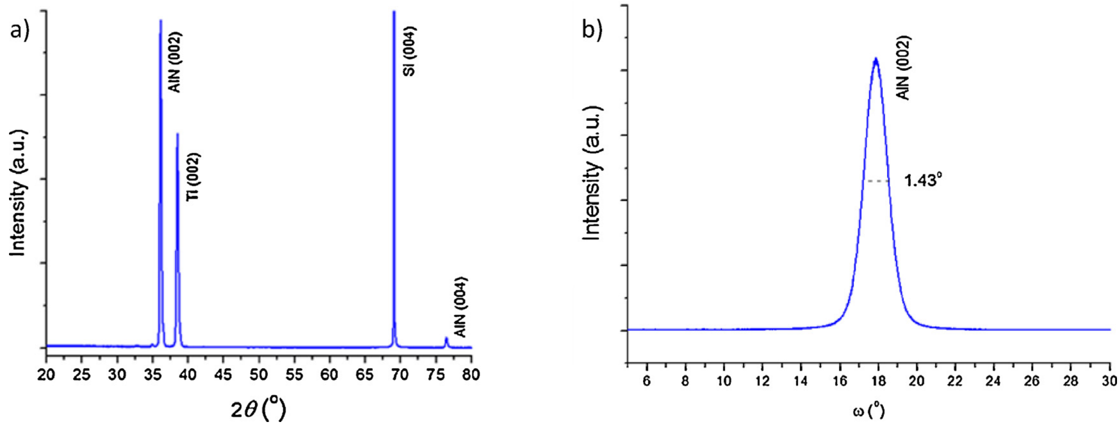


Fig. 4. X-ray diffraction of AlN on Ti/AlN/Si indicating the high (0 0 2) orientation of the top AlN layer (a) and the very narrow FWHM of (0 0 2) rocking curve of 1.43° underlying the very high crystallinity of the layer (b).

Table 1
Parameters of Raman spectroscopy of AlN films sputtered on different substrates.

Sample	FWHM	$R_{E2/A1}$
AlN on Ti/Si	11.0	30.1
AlN on Ti/AlN/Si (this work)	9.6	18.0
AlN on Ti/SiN/Si	15.0	14.1

on amorphous SiN leading to poorer quality of the above AlN layer. These results indicate that the structure of AlN and Ti sputtered directly on Si is preferred to deposition on Si wafer coated with SiN layers.

Further evidence of the high quality of the AlN thin films was provided by XRD pattern measurements of sample A (Fig. 4). This result shows that the top 500 nm AlN has a full c-axis orientation (no peaks related to other grains beside (0 0 2) grain are present). Such orientation is similar to the one of AlN on Ti deposited on bare (1 0 0) silicon [7]. The FWHM of (0 0 2) rocking curve of this AlN sputtered film is 1.43°. This value is smaller than the values recently reported for AlN deposited on Ti layers [4,17].

2.2. Electrical properties

Leakage current and breakdown properties of the 500 nm thick AlN films were measured using a capacitance test structure with area of 0.0048 cm^2 fabricated by deposition of Ti/AlN/Ti/AlN/Si layers. A typical I-V characteristic of the AlN films, analyzed using a HP 4146C parameter analyzer, is reported in Fig. 5. It shows very low leakage current (4.63 nA/cm^2 at 1 V, 259.6 nA/cm^2 at 10 V and 10 μA/cm^2 at 30 V). The breakdown voltage, indicated by the rapid increasing of leakage current, is approximately 40 V (corresponding to 80 MV/m). In comparison to the value reported in [2], the breakdown field of our AlN films is slightly lower. This difference might be due to different conditions of the breakdown measurement and the larger surface roughness of the Ti layer used as electrode (~4.56 nm) [7] leading to more defects. The measured low leakage current and high breakdown voltage basically indicate the potentially low power consumption and high voltage operation of our sputtered AlN films.

3. Device fabrication

The process to fabricate Ti/AlN/Ti slender cantilevers with a PECVD SiN top layer is schematically depicted in Fig. 6. The Ti(200 nm)/AlN(500 nm)/Ti(170 nm)/AlN(100 nm) stack was sequentially sputtered on a (1 0 0) silicon substrate (Fig. 6a). To contact the bottom Ti electrode, the top two layers were anisotropically etched using HBr/Cl$_2$ inductive coupled plasma (ICP) with a photoresist layer as mask. The AlN layer residues were subsequently removed by wet etching in MF322 developer at 35 °C (Ti top electrode layer used as a mask). As shown in Fig. 6a, a PECVD SiO layer (to act as masking layer for the DRIE of the Si) was deposited on the wafer backside and patterned by C$_2$F$_6$/CHF$_3$ dry etch. In the next step, a PECVD SiN layer with various thicknesses (0.5, 1.5 and 3.0 μm) is deposited on top of the AlN/Ti stack. The SiN was removed by CHF$_3$ dry etch on the contact pad area (Fig. 6b). Then, a 200 nm thick Al layer is sputtered, followed by a 500 nm thick PECVD silicon oxide deposition. The SiO layer is here utilized as a hard mask to pattern the stack of Ti/AlN/Ti/AlN in a single lithographic step so to prevent misalignment of the SiN to the other layers. This SiO layer is later stripped by plasma, where the thin Al layer between SiO and SiN is used to protect SiN in C$_2$F$_6$/CHF$_3$ gas. The Al and SiN were sequentially patterned in HBr/Cl$_2$ mixture and C$_2$F$_6$ gas after etching of the oxide mask in C$_2$F$_6$/CHF$_3$ mixture using a 3 μm thick photoresist layer mask (Fig. 6c). The whole stack of AlN and Ti layers, defined by HBr/Cl$_2$ dry etch, is shown in Fig. 6d. Next, the device is released by DRIE in SF$_6$ (Bosch process) after openings are created in the oxide mask in C$_2$F$_6$/CHF$_3$ gas. The top Al layer and bottom AlN layer were finally stripped in Al etchant solution and MF322 developer, respectively. The layers stack as illustrated by the SEM sample side view image in Fig. 7a, is well defined by the single lithography step used. Furthermore, top view scanning electron micrograph (SEM) of an array of

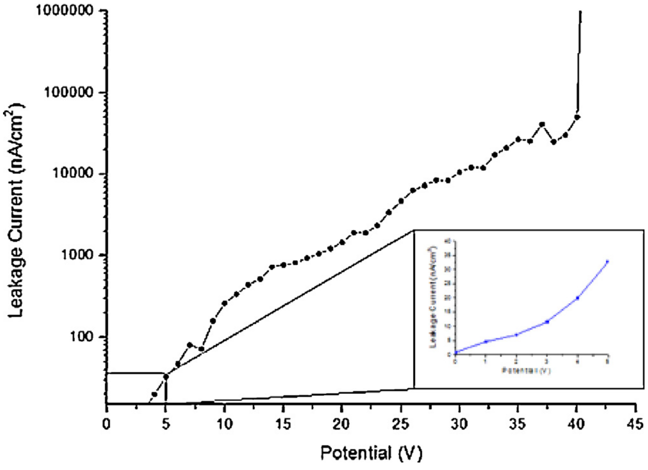


Fig. 5. *I–V* characteristic of AlN thin-film, the breakdown voltage is around 40 V.

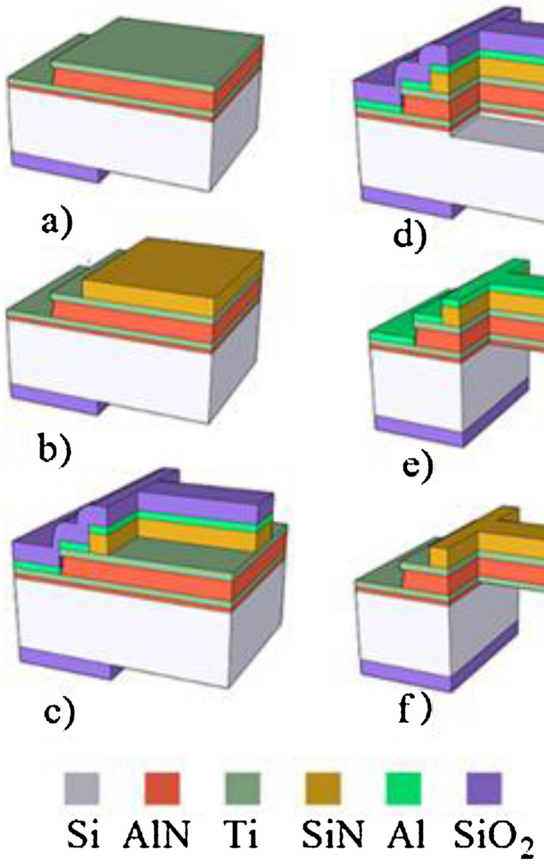


Fig. 6. Process flow for AlN piezoelectric cantilever fabrication with a top SiN structural layer. (a) Deposition of the Ti/AlN/Ti/AlN stack by sputtering and contact opening to the bottom Ti electrode followed by deposition and patterning of the oxide mask layer at the backside; (b) deposition of PECVD SiN and patterning of the SiN at contact areas; (c) deposition of a double mask layer of Al and SiO and patterning of the SiO, Al and SiN layers; (d) patterning the AlN/Ti stack by dry etching using the SiO mask; (e) DRIE etching of the Si substrate from the backside and removal of the oxide mask on the front side; (f) removal of the AlN bottom layer and removal of the Al top layer to open contact areas to both electrodes.

50 µm wide released cantilevers (Fig. 7b) exhibit no cracking and deformations.

4. Device actuation

To measure the actuation of the cantilevers a laser Doppler vibrometer (Polytec OFV 5000) as schematically indicated in Fig. 8, was used. In this system, the light of a laser is pointed at the tip of the cantilever. A sinusoidal voltage is applied to the electrodes of the cantilever by a generator and an amplifier. The displacements in the z direction at the tip of the cantilevers cause a change in frequency and phase of the reflected light. The optical signals are modulated into electrical signal by an optical sensor. The velocity presented by the electrical signal is integrated and translated into a displacement value by a vibrometer controller. This set-up can detect the cantilever movement down to nanometer scale with a resolution of 1 nm. Mechanical vibrations are the largest source of noise, with amplitude of roughly 20 nm at a frequency of 50–70 Hz. The resonant frequency of the cantilevers is equal or higher than 19 kHz (the lowest measured resonant frequency is 19.332 kHz for 200 µm long Ti/AlN/Ti beams [7]). Therefore, to average out the noise, the cantilevers were actuated at a frequency of ~1 kHz, well below the resonance frequency for quasi-static mode.

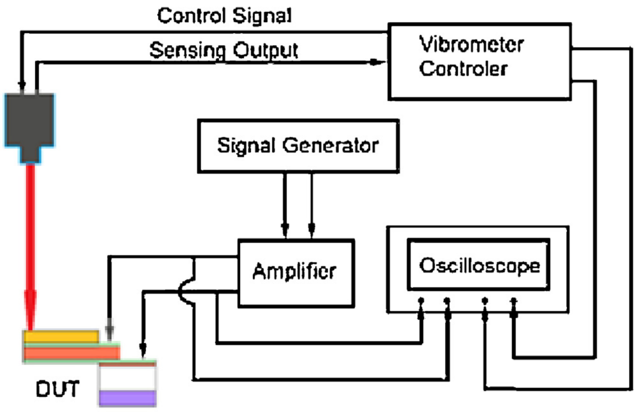
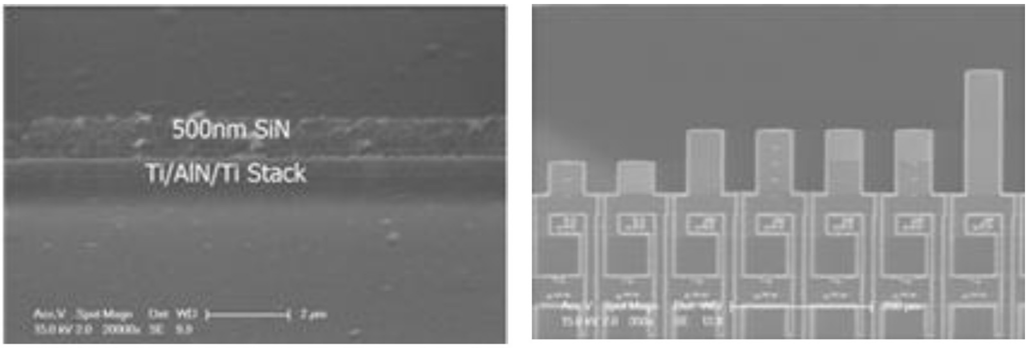


Fig. 8. Experimental set-up for the cantilever tip displacement measurement using a laser Doppler vibrometer.

The dependence of quasi-static displacement of the cantilevers with different thickness of SiN layer for varying input amplitude is displayed in Fig. 9a. High linearity and a large influence of the SiN layer thickness are observed. It can be clearly noticed that with the slender cantilever with the thinner SiN layer, a greater tip displacement is obtained. For the 200 µm long cantilevers, a value of 19 nm/V (tip displacement per input amplitude unit) is measured. This is a threefold increase with respect to the slender AlN cantilever without the top SiN layer presented in [7].

A displacement was observed in the AlN cantilever without the top SiN. Although a piezoelectric cantilever with a symmetrical layer stack around the neutral layer plane does not deflect when applying an actuation voltage, already small asymmetries can lead



a) b)

Fig. 7. SEM images of (a) 500 nm SiN layer on Ti/AlN/Ti stack and (b) top view of 50 µm wide cantilevers with a length of 50 µm (left), 100 µm (center) and 200 µm (right).

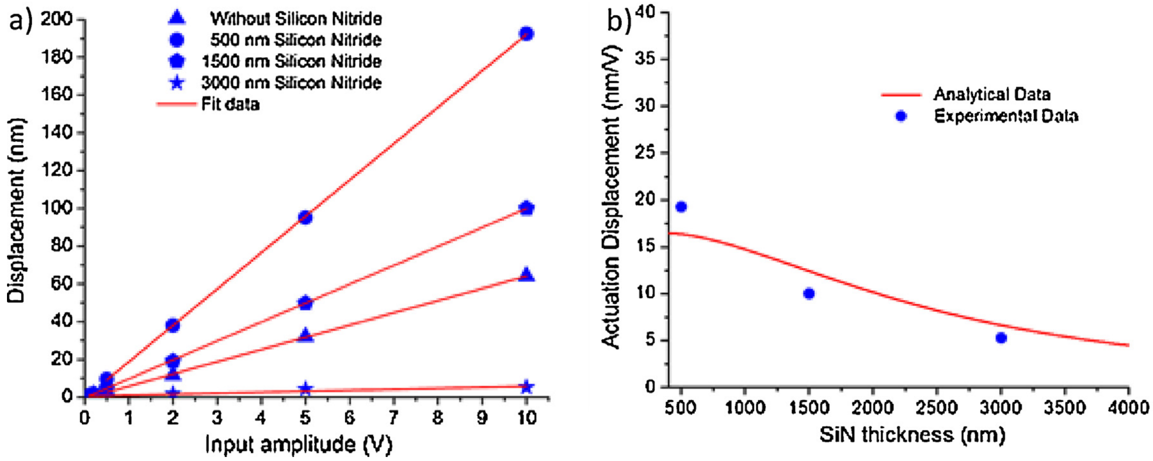


Fig. 9. The measured displacement of 200 μm long cantilevers coated with SiN of different thickness (a) and the comparison of measured data and analytical data (b).

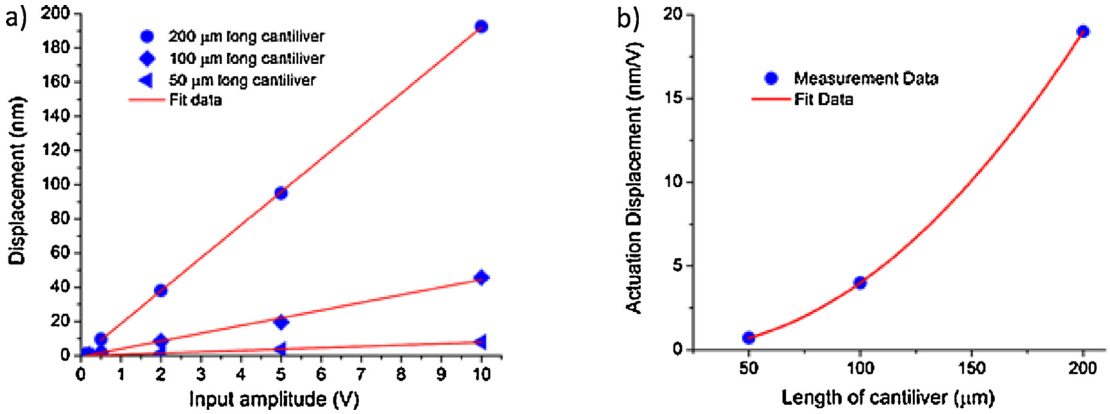


Fig. 10. The displacement of cantilevers of different lengths coated with 500 nm thick SiN layer (a) and generated actuation as a function of cantilever length (b).

to small deflections [8]. In our case, the top and bottom electrodes have different thicknesses. This can partially explain the measured deflection. Other possible causes of this displacement are gradients in the material properties of the layers.

By using the model in [8], the piezoelectric coefficient d_{31} can be estimated from the displacement of the cantilever. In spite of the very narrow rocking curve detected by XRD, the obtained d_{31} value of −0.45 pm/V for our AlN layers is an order of magnitude lower than the single crystal value. This lower value is probably caused by the high surface roughness of the Ti layer [18] and by the mono-oxide layer on the surface of Ti which occurs even in a high vacuum environment, leading to a more random distribution of polarity of the AlN films. In Fig. 9b the measured data and analytical data for varying SiN layer thickness are compared. For the analytical data, the model presented in Ref. [19] and the material properties collected from Ref. [4] are used. The discrepancy of the analytical data and the measured data observed is related to the difference in physical properties of our layers (densities, Young module, etc.) and the collected data. Furthermore, undercut of cantilevers caused by a slight misalignment during the bulk silicon etching from the wafer backside also contributes to these deviations.

The higher actuation obtained in AlN/SiN cantilevers is due to the large asymmetry of the piezoelectric structure that demonstrates the performance enhancement of these cantilevers. Furthermore, the displacement actuation of AlN/SiN cantilevers of different lengths was investigated (Fig. 10). The highly linear behavior in Fig. 10a is preserved also for the shorter (100 μm and 50 μm long) cantilevers. The bending of the cantilevers depends quadratically on the cantilever length (Fig. 10b). This indicates that the AlN piezoelectric layer is uniform throughout the length of the cantilever in agreement with [2]. The undercut of the cantilevers is accountable for the small error observed in the bending quadratic relationship.

5. Conclusions

In this paper, good crystallinity and high c-axis orientation AlN thin films sputtered on Ti have been used to fabricate piezoelectric cantilevers with very good linearity and high displacement at quasi-static mode. The addition of a top SiN layer results in a significant increase in displacement (up to three times for the 200 μm long cantilevers). Moreover, the SiN layer provides a useful coating which can be interesting for applications with liquids or aggressive substances. The realized structures are very thin (~1.4 μm with 500 nm SiN) as desirable for nanoscale device fabrication. The high static actuation displacement (19 nm/V for 200 μm long cantilevers and 4.25 nm/V for 100 μm long cantilevers) demonstrates the great performance enhancement achieved by the combination of high quality AlN layers with the high stiffness SiN, while CMOS compatibility is preserved.

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References

[1] K.S. Hwang, S.M. Lee, S.K. Kim, J.H. Lee, T.S. Kim, Micro-, Nanocantilever devices systems for biomolecule detection, Annual Review of Analytical Chemistry 2 (2009) 77–98.

[2] N. Sinha, G.E. Wabiszewski, R. Mahameed, V.V. Felmetsger, S.M. Tanner, R.W. Carpick, et al., Piezoelectric aluminum nitride nanoelectromechanical actuators, Applied Physics Letters 95 (2009) 053106.

[3] R.B. Karabalin, M.H. Matheny, X.L. Feng, E. Defay, G. Le Rhun, C. Marcoux, et al., Piezoelectric nanoelectromechanical resonators based on aluminum nitride thin films, Applied Physics Letters 95 (2009) 103111.

[4] J.C. Doll, B.C. Petzold, B. Ninan, R. Mullapudi, B.L. Pruitt, Aluminum nitride on titanium for CMOS compatible piezoelectric transducers, Journal of Micromechanics and Microengineering 20 (2010) 025008.

[5] M.D. Nguyen, H. Nazeer, K. Karakaya, S.V. Pham, R. Steenwelle, M. Dekkers, et al., Characterization of epitaxial Pb(Zr,Ti)O-3 thin films deposited by pulsed laser deposition on silicon cantilevers, Journal of Micromechanics and Microengineering 20 (2010) 085022.

[6] U. Sokmen, A. Stranz, A. Waag, A. Ababneh, H. Seidel, U. Schmid, et al., Evaluation of resonating Si cantilevers sputter-deposited with AlN piezoelectric thin films for mass sensing applications, Journal of Micromechanics and Microengineering 20 (2010) 064007.

[7] A.T. Tran, G. Pandraud, H. Schellevis, T. Alan, V. Aravindh, O. Wunnicke, et al., Fabrication of AlN slender piezoelectric cantilevers for high-speed MEMS actuations, Procedia Engineering 25 (2011) 673–676.

[8] O. Wunnicke, Analytical model of the quasistatic mechanical behavior of galvanic piezoelectric microelectromechanical system switches, Journal of Applied Physics 106 (2009) 104502.

[9] P. Ivaldi, J. Abergel, M.H. Matheny, L.G. Villanueva, R.B. Karabalin, M.L. Roukes, et al., 50 nm thick AlN film-based piezoelectric cantilevers for gravimetric detection, Journal of Micromechanics and Microengineering 21 (2011) 085023.

[10] J.S. Park, J.B. Lee, J.P. Jung, M.H. Lee, Effects of bottom electrodes on the orientation of AlN films and the frequency responses of resonators in AlN-based FBARs, Thin Solid Films 447 (2004) 610–614.

[11] A. Sanz-Hervas, M. Clement, E. Iborra, L. Vergara, J. Olivares, J. Sangrador, Degradation of the piezoelectric response of sputtered *c*-axis AlN thin films with traces of non-(0 0 0 2) X-ray diffraction peaks, Applied Physics Letters 88 (2006) 161915.

[12] A.T. Tran, H. Schellevis, H.T.M. Pham, C. Shen, P.M. Sarro, Influence of seed layer on crystallinity and orientation of pulsed—DC sputtered AlN thin-films for piezoelectric actuators, Procedia Engineer 5 (2010) 886–889.

[13] D. Chen, D. Xu, J.J. Wang, B. Zhao, Y.F. Zhang, Influence of the texture on Raman and X-ray diffraction characteristics of polycrystalline AlN films, Thin Solid Films 517 (2008) 986–989.

[14] V. Lughi, D.R. Clarke, Defect and stress characterization of AIN films by Raman spectroscopy, Applied Physics Letters 89 (2006) 241911.

[15] M. Kuball, J.M. Hayes, A.D. Prins, N.W.A. van Uden, D.J. Dunstan, Y. Shi, et al., Raman scattering studies on single-crystalline bulk AlN under high pressures, Applied Physics Letters 78 (2001) 724–726.

[16] P. Perlin, A. Polian, T. Suski, Raman-scattering studies of aluminum nitride at high-pressure, Physical Review B 47 (1993) 2874–2877.

[17] T. Kamohara, M. Akiyama, N. Ueno, K. Nonaka, N. Kuwano, Influence of aluminum nitride interlayers on crystal orientation and piezoelectric property of aluminum nitride thin films prepared on titanium electrodes, Thin Solid Films 515 (2007) 4565–4569.

[18] A. Ababneh, et al., c-axis orientation and piezoelectric coefficients of AlN thin films sputter-deposited on titanium bottom electrodes, Applied Surface Science 259 (2012) 59–65.

[19] A. Andrei, et al., AlN as an actuation material for MEMS applications: the case of AlN driven multilayered cantilevers, Sensors and Actuators A 141 (2008) 565–576.

Biographies

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