DESIGN OF FGM BIMORPH PIEZO-ACTUATORS

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Fig. 1(a) and (b) are mono-morph and bimorph actuators, respectively. Despite large bending displacement, the bimorph piezo-actuator is known to suffer from large induced stress at the interface region. To overcome this, we designed two types of piezo-actuators, one-sided (Rainbow type) actuator with functionally graded microstructure (FGM), Fig. 1(c) where the electroelastic properties are graded smoothly along the thickness direction [3] and FGM bimorph actuator [1,2,4] where the top and bottom piezoelectric plates are composed of multilayers where the electroelastic properties are graded smoothly across the plate thickness, Fig. 1(d).

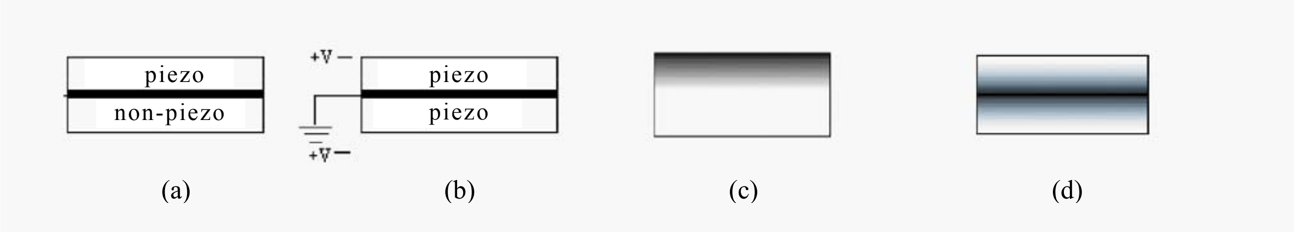

Fig. 1 Different types of piezoactuators, (a) monomorph, (b) bimorph, (c) one-sided FGM, and (d) FGM bimorph.

In this talk, I will introduce two types of FGM piezo-actuator designs, one is one-sided FGM, Fig. 1(c), the second is FGM bimorph, Fig. 1(d). Fig. 2 shows the cross section of one sided FGM piezo-actuator [3] and the results of curvature of the piezo actuator beam and applied electric field are shown in Fig. 3 indicating a good agreement between our model and the experimental data.

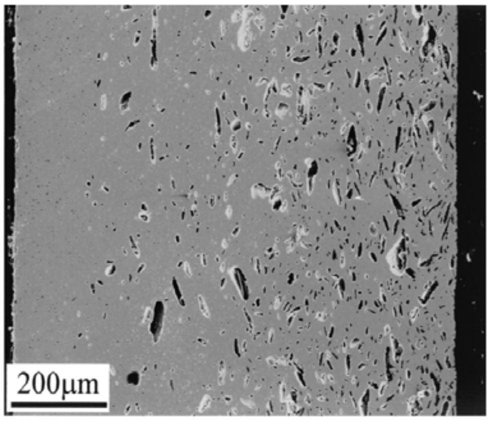

Fig. 2 SEM micrograph of the fabricated PZT sample with a linear porosity gradient.

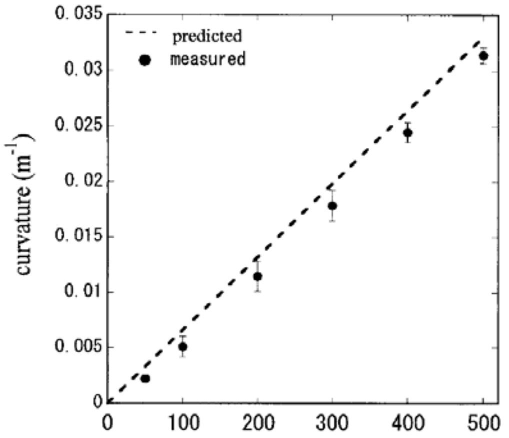

Fig. 3 Electric-field-induced curvature of the porosity-graded PZT beam-shaped as a function of applied voltage.

The requirements of bending actuators are large displacement and minimum stress induced in piezo-layers. In this respect, the Rainbow type piezo-actuators satisfy the second requirement, but not the first. In order to satisfy both requirements, we designed a set of FGM bimorph piezo-actuators, Fig. 1(d). The distribution of mechanical and piezoelectric properties are assumed to vary throughout the FGM plate thickness in a step wise manner as shown in Fig. 4 where two cases of stepwise linear distributions are considered, type A and type B. For each type, six layers of FGM are considered.

Fig. 4. Electroelastic properties distribution in FGM-bimorph

Bimorph System		Maximum Bending Displacement (μm)	σ_x Max. (MPa)	τ_{xz} Max. (MPa)
Standard Bimorph	Experimental	49.6	----	----
	CLT	47.5	3.08	----
	2D elasticity	47.8	3.07	1.48
	FEM	47.6	3.17	1.56
FGM Bimorph type-A	Experimental	43.8	----	----
	CLT	43.6	1.48	----
	2D elasticity	44.9	1.63	0.59
	FEM	44.8	1.65	0.63
FGM Bimorph type-B	Experimental	30.4	----	----
	CLT	29.2	3.38	----
	2D elasticity	29.5	3.69	1.82
	FEM	29.4	3.75	1.9

Table 1 Comparison of ANSYS FEM results with the analytical values for piezoactuators, standard bimoph EGM bimoph tapes A and B

We have processed two different types of FGM actuators (type A and B) and also standard bimorph[4]. A comparision between the experimental data and predictions by our models(classical lamination theory(CLT), 2D elasticity model and FEM) are summarized in Table 1. It is clear from Table 1 that the FGM bimorph type A exhibits the best performance, i.e large bending displacement, slightly less that that of the standard bimorph, while the induced stresses(σ_x and τ_{xy}) are smaller than those of the standard bimorph and the FGM bimorph type B. It is also noted in Table 1 that the 2D elasticity model[2] predicts reasonably accurate shear stress which could not be possible by CLT.

References

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