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Piezoelectric Film Fabrication by Stencil Printing Method
ステンシル印刷法による圧電薄膜の作製に関する研究

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1. Introduction

Ultrasonic non-destructive testing is widely used in various industrial fields because of the simmplicity and cost effectiveness. Ultrasonic transducers made by sol-gel spray technique could be useful due to curved surface suitability, high tempearature durability, relatively low center frequency such as 2-20MHz, reasonable signal strength, and high signal-to-noise ratio (SNR).[1-2] However, in order to achieve desired frequency, it requires multipul spray coating and thermal treatments, and in some case, it could be a concerned issue, especially for on-site fabrication under controlled area.

Stencil printing is fast and simple method and it could be possible to fabricate thick film by one coating process.[3-4] Basic idea of stencil printing process is illustrated in **Fig. 1**. First, a stencil mask should be prepared in the negative form of the desired pattern. Then the stencil mask is placed on a substrate and covered with paint material by a squeegee. The materials used for sol-gel spray technique could be applied to stencil printing, though it requires modification since suitable viscosity for spray coating and stencil printing is different. Therefore, 3 kinds of paint materials were investigated for piezoelectric film fabrication by stencil printing method.

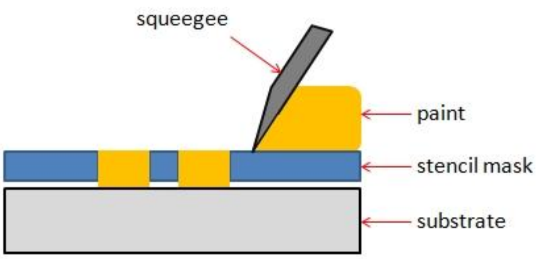

Fig.1 Image of stencil printing process.

2. Experimental materials and procedures

The three kinds of paint were prepared for this experiment; (a) piezoelectric powder and organic binder (b) piezoelectric powder, organic binder and sol-gel solution (c) piezoelectric powder and sol-gel solution. Plastic stencil masks with 100μm thick were used for patterning facility, curved surface suitability and low cost. Mask pattern was 2×2 25mm^2 squares with 1mm pitch. Mask pattern was made by laser cutting. Steel substrates with dimensions of 4.2mm thickness, ~50mm length, and ~50mm width were used, since steel is common material for industrial structures. As piezoelectric powder and sol-gel solution, lead zirconate titanate (PZT) was chosen, because PZT was one of the most popular piezoelectric materials for ultrasonic NDT application due to high piezoelectricity, relatively high Curie point, and low cost. As an organic binder, some commerically available product was used.

After stencil printing process, for some samples, simmilar thermal treatments with sol-gel technique, such as drying process at 150°C by a hot plate, annealing process at 650°C by a furnace, were followed, whereas the lest of the samples did not have any thermal process. Poling and top electrode fabrication process were operated for all samples. Film thickness was measured by a micrometer. Capacitance was measured by a LCR meter in order to calculate dielectric constant. Ultrasonic responses were attempted to be measured for performance comparison purpose.

3. Results and Discussions

3.1 PZT powder and organic binder

First, organic binder was added into PZT powders until suitable viscosity was obtained for stencil printing process. The sample became solidified at room temperature. An optical image of the sample after solidification was shown in **Fig. 2**. Film thickness was ~200-250μm. It is noted that the film surface was not uniform. However, film was melt with organic solution of silver conductive pen, and film adhesion was vanished after 650°C annealing process.

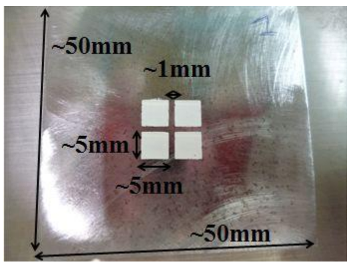

Fig.2 Film Optical image made by PZT powder and organic binder.

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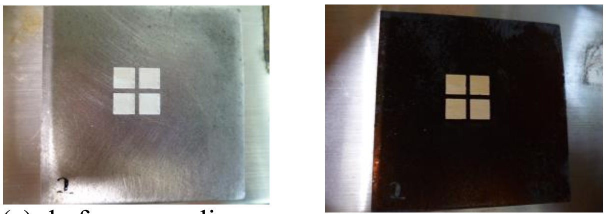
3.2 PZT powder, organic binder and PZT sol-gel

Then, the mixture of PZT sol-gel solution and organic binder was added into PZT powders until suitable viscosity was obtained for stencil printing process. The sample became solidified at room temperature as well, though this solidified sample did not react with organic solution of silver conductive pen. Optical images of the sample after room temperature solidification and after 650°C annealing process were shown in **Fig. 3**. Film thickness was ~200μm and ~150μm before and after annealing process, respectively.



(a) before annealing (b) after annealing

Fig.3 Film Optical images made by PZT powder, organic binder and PZT sol-gel solution.

Ultrasonic response of the films were attempted to be monitored, however the sample only before annealing showed some reflected echoes as shown in **Fig. 4**. The signal strength was very low due to low dielectric constant of organic binder and PZT sol-gel solution before annealing. The film becomes very fragile after annealing and it was considerable reason for no signal.

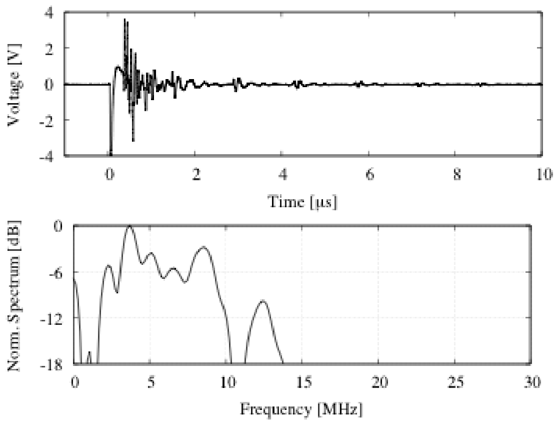


Fig.4 Ultrasonic response of the film made by PZT powder, organic binder and PZT sol-gel solution after room temperature solidification.

3.3 PZT powder and PZT sol-gel

PZT sol-gel solution was added into PZT powders until suitable viscosity was obtained for stencil printing process. It is noted that this PZT sol-gel solution was specially modified to increase viscosity. The sample became solidified at room temperature and this solidified sample did not react with organic solution of silver conductive pen. Optical images of the sample before and after 650°C annealing process were shown in **Fig. 5**. Film thickness was ~200μm and ~150μm before and after annealing process, respectively, and it was same as the samples in the previous section.

(a) before annealing (b) after annealing

Fig.5 Film Optical images made by PZT powder and PZT sol-gel solution.

Ultrasonic response of the films were attempted to be monitored, however the sample only after annealing showed clear reflected echoes as shown in **Fig. 6**. The signal strength might be sufficient for some industrial applications. Since the viscosity of PZT sol-gel solution was still much lower than organic binder and it could result in no signal for the sample before annealing due to too much volume of low dielectric constant component.

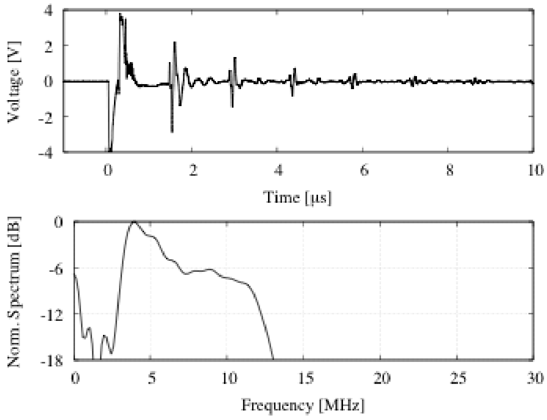


Fig.6 Ultrasonic response of the film made by PZT powder and PZT sol-gel solution after annealing.

4. Conclusions

Stencil printing of piezoelectric film was attempted and over 150μm thick films were successfully patterned. Ultrasonic responses were confirmed for some samples, and especially the sample made by PZT powder and PZT sol-gel showed reasonable signal strength and broadband characteristic.

References

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