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# Contemporary constructions of inhomogeneous piezo-active dielectric structures

***Abstract**. Non-uniform dielectric structures, made of dielectric materials with different elasticity coefficients with a charge deposited in their interface exhibit significant piezoelectric properties. Evolution of the piezo-active dielectric structures from the simplest 3-layer model to charged tube model is presented, as well as the equations describing $d_{33}$ parameter characterizing properties of the particular model. Application of the tube model for the textile technology (textronics) was also discussed.*

**Keywords:** electrets, dielectric films, piezoelectricity, piezoelectric transducer, polymers

## Introduction

One of the mechanisms leading to piezo-activity of dielectric materials is non-uniformity of their mechanical strain in the presence of a built-in space charge [1]. The phenomenon can be used in a construction of layered dielectric structures containing “soft” and “hard” layers with the charge deposited on the interface between the layers [2, 3]. The piezoelectric effect can be characterized by a piezo-coefficient $d$. Analysis of the piezoelectric phenomenon for two- [e.g. 2, 3] and multi-layer (sandwich) models e.g. [4] and stress applied normally to the sample surface leads to a general relation which can be written in the form:

$$d_{33} \cong K \frac{q_s}{Y_1}, \qquad (1)$$

where $K$ is a constant depending on the electric permittivity of particular dielectric layers and their thicknesses, $Y_1$ is an elasticity coefficient of the “soft” dielectric layer and $q_s$ is a density of the charge deposited on the interface. It should be noted that according to the relation (1), the most important factors limiting the piezo-coefficient $d_{33}$ value in case of layered structures are charge density $q_s$ and elasticity modulus of the "soft" layer $Y_1$.

The problem of the maximum achievable charge density value is a basic problem of physics and technology of electrets [e.g. 5]. Thus, the basic problem in a construction of sandwich-type structures was associated with the lack of “soft” dielectrics, exhibiting sufficiently good electret properties. To solve the problem, some dielectric “composites”, which mechanical and electrical properties could satisfy the mentioned requirements, were applied.

## Soft dielectric layers and structures

High elasticity dielectric elastomers exhibit a relatively short Maxwell-time constant and it is why they cannot be applied in the construction of layered electret structures. Thus, the “soft” layers of piezo-active dielectric structures were made of “dispersed dielectrics” – gas-polymer composites like foamed layers [e.g. 6] or fibrous layers e.g. [7]. It was also shown that the tube-like structure, made of electret polymer (PTFE), with bipolar charge distributed along its inner surface, can be treated as the 3-layer non-uniform piezo-active structure, with $d_{33}$ coefficient determined by the relation [8, 9]:

$$d_{33} \cong \frac{K}{K_m} \cdot \frac{q_s}{Y_T}, \qquad (2)$$

where $K_m$ and $K$ are mechanical and electrical factors depending on the type of the particular composite structure and $Y_T$ – elasticity (Young) modulus of the basic polymer (PTFE). The $d_{33}$ coefficient measured for the freshly prepared structures was found to be on the level of 20-30 pC/N, it is – two times lower in comparison to the values determined on the basis of equation (2). It was also shown that the obtained piezo-tubes can be processed into the piezo-active fabric using well-known textile technologies. It should be noted, that the different mechanisms determining the strain of the "soft dielectric" layer determine the dependence of the $d_{33}$ coefficient on the applied pressure $p$. It allows to adapt the $d_{33}(p)$ characteristics for the whole structure according to the requirements of a particular application.

## Conclusions

The main advantage of the presented piezo-active polymeric structures is their universality. The non-uniform dielectric structures particularly allow for:

- obtaining high $d_{33}$ coefficient value (over 1000 pC/N) structures with $d_{33}$ stability on the level of that like for PVDF piezo-active layers,
- obtaining both, the micro as well as the large-dimension structures,
- tailoring the $d_{33}(p)$ characteristics according to the requirements of the particular transducer.

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