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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for piezoelectric constant d_{33} of piezoelectric ceramics by direct quasi-static method

Céramiques techniques (céramiques avancées, céramiques techniques avancées) — Méthode d'essai pour déterminer la constante piézoélectrique d_{33} *des céramiques piézoélectriques par méthode quasi-statique directe*

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Contents

Page

Foreword ..... **iv**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **1**

4 Measurement principle **2**

5 Equipment and instruments **3**
5.1 Test equipment 3
5.2 Probes 3

6 Specimens **4**
6.1 Standard specimens 4
6.2 Shape and size of specimens 4

7 Test method **4**
7.1 Test environment 4
7.2 Test conditions 4

8 Calculation **5**

9 Report of test results **5**

Bibliography **6**

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Foreword

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This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for piezoelectric constant d_{33} of piezoelectric ceramics by direct quasi-static method

1 Scope

This document specifies how to measure the piezoelectric constant d_{33} of piezoelectric ceramics using a direct quasi-static method (d33 meter method, Berlincourt method).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20507, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Vocabulary*

IEC 60483, *Guide to dynamic measurements of piezoelectric ceramics with high electromechanical coupling*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20507 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
piezoelectric constant
d_{33}
part of the piezoelectric fundamental equation (d-form):

$$S = s^{E}T + dE \text{ (inverse piezoelectric effect)} \quad (1)$$

$$D = dT + \varepsilon^{T}E \text{ (direct piezoelectric effect)} \quad (2)$$

where

S is strain;

T is stress, in N/m^2;

E is electric field (strength), in V/m;

D is electric flux density, in C/m^2;

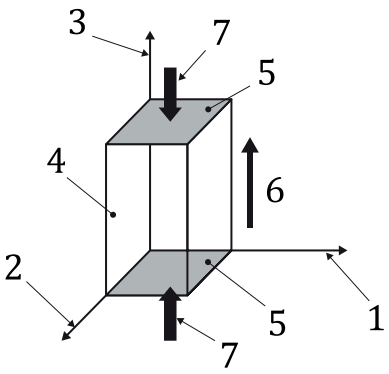
ε^{T} is free permittivity (assuming constant T), in F/m;

s^{E} is elastic compliance (assuming constant E), in m^2/N.

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The piezoelectric constant d in Formula (1) expresses the inverse piezoelectric effect, while d in Formula (2) expresses the direct piezoelectric effect. The unit of d in each equation is [m/V] and [C/N], respectively, and they are equivalent. The subscript 33 in the symbol d_{33} indicates the vibration mode; the two digits indicate electric axis (first) and mechanical axis (second), respectively. Figure 1 shows a schematic diagram of poling (polarization) direction and the axes of piezoelectric specimen. Since descriptions of piezoelectric ceramics typically use the polarization axis direction as axis 3, in this case, the polarization axis direction (axis 3) indicates electric flux density D_3 along axis 3 when stress T_3 is added. Now, assuming electric field E is constant (for example, 0) in Formula (2) that expresses the direct piezoelectric effect, d_{33} can be found using Formula (3):

$$d_{33} = [\delta D_3 / \delta T_3]_E \tag{3}$$



Key

1 axis 1
2 axis 2
3 axis 3
4 specimen
5 electrodes
6 polarization direction
7 stress, T_3

Figure 1 — Schematic diagram of poling (polarization) direction and the axes of piezoelectric specimen

4 Measurement principle

Figure 2 shows a conceptual diagram. Specimen (1), which is a piezoelectric ceramic plate, is coated with electrode (3) on both the upper and lower surfaces, and polarization treatment is applied in the third axis direction (from bottom to top or top to bottom). The specimen is held fixed by contact probes (2), which are loaded with a dead load (specimen gripping force). Denoting the electrode area (i.e. the area of the surface to which stress is applied) by A [m^2], the surface charge by Q [C], and the applied alternating force by F [N], the electric flux density D becomes $D = Q/A$ and the stress T is expressed as $T = F/A$, which implies that Formula (3) can be rewritten as Formula (4):

$$d_{33} = (Q/A)/(F/A) = Q/F \tag{4}$$

Now, if an alternating force F is applied to the specimen from the bottom (or top) of the probe, an alternating charge Q is generated on the upper and lower electrodes of the specimen. As a consequence, by applying an alternating force F with known amplitude, the d_{33} value can be obtained from Formula (4) by measuring the generated charge Q. The generated charge Q is calculated by measuring the AC current in a circuit with virtual ground or AC voltage of a standard capacitor with a sufficiently larger capacity than the specimen. In principle, the d_{33} value can then be obtained by using Formula (4),

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