Metrological properties of PZT-26 ceramics SPM scanners in XY-plane and comparison between PZT-26 and PZT-19.

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When choosing a particular sort of ceramics for SPM scanners it is important to know that several critical characteristics of piezoceramics, of course depending from conditions of use, exists. As concerns to commercial SPM, it is common thing that producers use bipolar voltage to increase scanner range. In such conditions coercivity of ceramics becomes significant, because it sets the maximum value of electric field which can be applied antiparallel to polarization. So using ceramics with larger values of coercive force gives opportunity to apply higher voltages to scanner and have larger scanner ranges. Furthermore, it is very possible that ceramics with bigger coercivity will be more stable in long time periods demonstrating a low level of piezoscanner degradation with time.

PZT-26 ceramics as against to PZT-19 belongs to group of hard ferroelectric materials. This group demonstrates substantial thermal stability and large values of coercivity, so PZT-26 ceramics probably can be more appropriate for producing SPM scanners than PZT-19.

We already had investigated some metrological properties of PZT-19 ceramics scanners in XY-plane, main results of investigations is in the work (1). The goal of our new investigations, which this work devoted to, was to find the metrological properties PZT-26 ceramics scanners (as more appropriate for bigger scanner ranges, time and thermal stability) in XY-plane and the ways of software correction of these properties. Besides, in this work we make a comparison between two sorts of piezoceramics.

First we become with the range of a scanners. We found that for PZT-19 ceramics average value of scanners range (special type of scanner for NT-MDT SMENA Solver) is about 60 microns. Using TDG (one dimension grating with 278 nm step) on a small scan voltage we found, that d_{31} coefficient for new material scanner is 1.2 times bigger then commonly for PZT-19. So we were expecting approximately 70 microns scan range for new material. But it turned out that the range of scanner prepared from PZT-26 is about 90 microns. This discrepancy pointed to us on substantial difference between inner properties of two sorts of ceramics. Next our step was to determine nonlinearity of scanner with PZT-26.

In our measurements we were using TGG grating (one dimension grating with 3 microns step) provided by NT-MDT. This grating is much more convenient for large scan ranges (more the 50 microns) than TDG which we use earlier (1). We use peaks of the grating as points for measuring distance; additional fitting was executed for correct considering of the beginning and the end of grating section. With such conditions of measurements repeatability of nonlinearity value less the 0.5% was achieved (it is in the case when measuring initial scanner nonlinearity; when software correction is performed residual scanner nonlinearity can be measured several times more precisely).

On the Figures below (Fig. 1, Fig. 2) presented curves X/Xmax-U/Umax (U/Umax) for two sorts of ceramics. Here X – displacement, and U – voltage (to see the value of nonlinearity and difference between curves it is better to presented X(U) in such a manner). The curves are for trace and retrace scanner movements, slow and fast axes of scanning. At first you can see that nonlinearity for PZT-26 ceramics for fast axis is about 12% while for PZT-19 it is about 10%. For slow axes we have 13% and 11.5%. Second important moment is difference between tracing and retracing scanner movement. While for PZT-19 for fast scan axis this difference is commonly less than 0.5% and for slow scanning axis about 1% or better, for PZT-26 fast axis – 1% difference, slow axis – 2% difference.

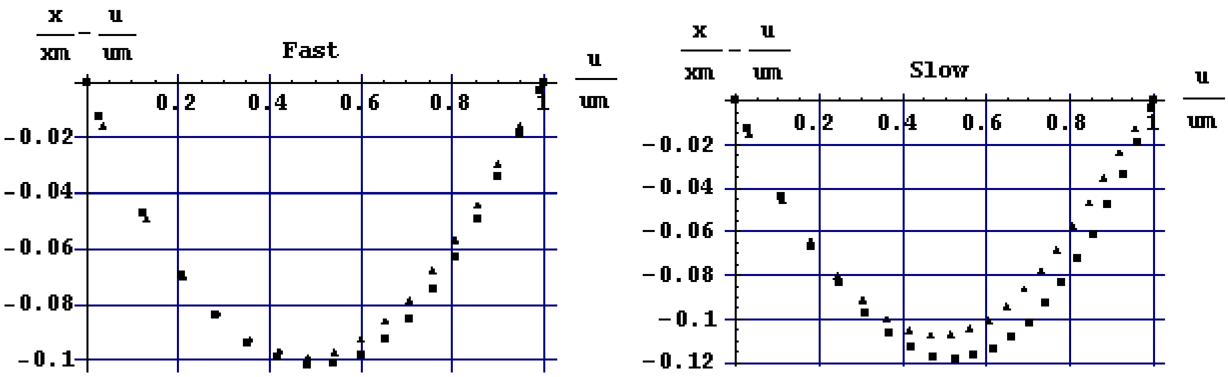


Fig .1 Curves X/Xmax-U/Umax (U/Umax) for PZT-19 ceramics scanner. Left-fast axis of scanning, right-slow axis of scanning. Boxes – trace, triangles – retrace.

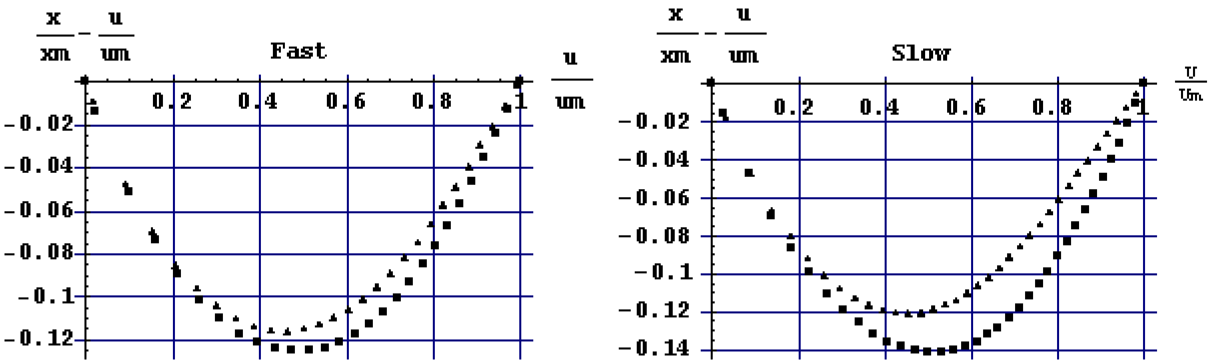


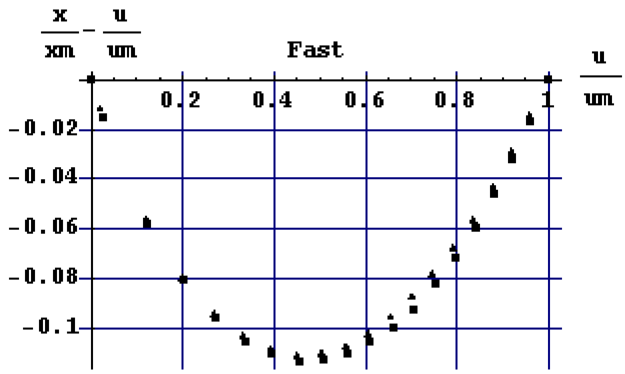
Fig. 2 Curves X/Xmax-U/Umax (U/Umax) for PZT-26 ceramics scanner. Left-fast axis of scanning, right-slow axis of scanning. Boxes – trace, triangles – retrace.

It is necessary to touch on a question about scanning velocities. For PZT-26 ceramics it was found that nonlinearity is increasing in 1% when velocity is diminishing in 30 times. In this work we does not consider this dependence, assuming that for use of SPM in practice it is rather rare case to work on such big velocities range for full scan area. When the area of scanning is diminishing the dependence is diminishing too, as example, for 60 microns scanner when scanning area along slow direction is about 6 microns or smaller X(U) dependence is much more close to “fast velocity curve” than to “slow velocity curve”.

Earlier (1) developing software method of correction based upon in assumption that the shape of curve X(U) is not depending upon absolute displacement of scanning area (if not maximum scan range). Difference between tracing and retracing movement is evidence that such assumption has restrictions (if we suppose that we just have two different curves for movements from left to right and from right to left then we will find that for scan voltages smaller than maximum trace and retrace scans have different sizes – this is unobserved phenomenon for periodical scanner movements when no creep). In spite of this using for computation of nonlinear correction coefficients the "average" curve, which runs between trace and retrace, for PZT-19 ceramics we usually achieve nonlinearity 1% or better and dependence upon the place of scanning result in error in measurement of image size less then 5%.

As for PZT-26 ceramics standard procedure of nonlinear correction steel gives error in measurement of image size less then 5% but nonlinearity for slow axis of scanning is not better than 1.5%.

Nevertheless we can carry out comparison between two sorts of ceramics in another way. If we use PZT -26 ceramics only on reduced scan voltage about 76% from maximum, scan range will be about 60 microns, as it is for PZT-19. On fig. 3 corresponding x-u(u) curves are presented. One can see that difference between trace and retrace curves is even less than for PZT-19.



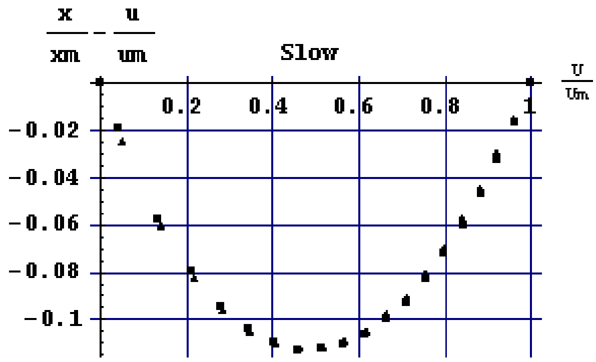


Fig. 3 Curves X/xmax-U/Umax (U/Umax) for PZT-26 ceramics scanner when applying reduced voltages. Left-fast axis of scanning, right-slow axis of scanning. Boxes – trace, triangles – retrace.

Thus we can conclude that when high electric fields (up to 600 V/mm) applied PZT-26 ceramics gives 50% bigger scan range than PZT-19. So PZT-26 utilizing is more preferable if first of all it is necessary to have large scan ranges for given voltages and at the same time low level of scanner degradation. At the same time use of PZT-26 ceramics with reduced voltages allows more precise measurements with software nonlinear correction while maximum scan range remains the same as when utilizing PZT-19.

1. Bykov V.A., Saunin S.A., Belyaev A.V., Zhizhimontov V.V., Evplov D.A., Malyk S.G., Metrological properties of PZT-19 ceramics SPM scanners in XY-plane and abilities of its correction. Proceedings of Scanning ProbeMicroscopy-2001. Nizhny Novgorod. February 26.-March 1. 2001.