Microsc. Microanal. 8 (Suppl. 2), 2002
DOI 10.1017.S1431927602106672

Thin Film Thickness and Grain Structure Determination of Ferroelectric $SrBi_2Ta_2O_9$ with Cross-Sectional Atomic Force Microscopy

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Ferroelectric (FE) thin film samples (~200nm) on silicon (Si) substrates were prepared for detailed cross-sectional microscopy study via adaptation of the tripod polishing technique [1]. $SrBi_2Ta_2O_9$ (SBT) films on Si substrates were imaged with contact atomic force (c-AFM) and non-contact AFM (nc-AFM) microscopy with data indicating film thickness and grain structure as a function of post processing conditions. Cross-sectional transmission electron microscopy (TEM), plan-view nc-AFM, plan-view scanning electron microscopy (SEM), and electrical measurements were additionally collected. Samples were prepared by metal organic deposition (MOD) onto silicon nitride (Si_3N_4) coated Si substrates. Si_3N_4 was deposited with jet vapor deposition (JVD) and acted as a buffer between the Si substrate and the SBT preventing the intermixing of materials [2]. After SBT deposition, samples were annealed at temperatures ranging from 800˚C – 950˚C. In order to provide stability, strength and protection to the SBT samples during the polishing process, three pieces of bare Si wafer were attached to the sample with M-Bond 610. The Si-SBT sandwich was then polished with a South Bay Technology tripod polisher with various diamond abrasive films (30μ, 15μ, 3μ, 1 μ, & 0.5μ) and colloidal silica [3].

During AFM imaging, the SBT was differentiated from the Si substrate because of differences in material polishing. The cross-sectional AFM data revealed the SBT's thickness and grain structure and are represented in Table 1 & Figures 1, 2. When this data was correlated with other microscopy techniques (Table 1 & Figures 3,4) and the electrical measurements, it was determined that the film thickness, grain structure and electrical properties are dependent on the post annealing temperature with 915˚C being the optimum temperature.

For this study AFM was successfully applied as a complementary technique to TEM and SEM for measuring thin film thickness and internal structure of thin films in cross-section. AFM provided a quicker, more efficient and practical way to collect data. Data collection efficiency was greatly improved with AFM vs. TEM and a greater length of interface was available for sampling. Additionally, AFM samples were more durable than TEM samples and AFM provided the ability to image insulating surfaces without charging effects. Yet another major advantage of the technique is that after the AFM scans are completed, the surface can be coated for SEM imaging, and the sample can be processed further for imaging with the TEM. [4]

References

[1] J. P. Benedict et al., Mat. Res. Soc. Symp. Proc. **199**, 189 (1990).
[2] T. P. Ma, IEEE Trans. Electron Devices **45**, 680 (Invited Paper) (1998).
[3] South Bay Technology, Inc., San Clemente, CA
[4] This research was supported by the Microscopy Society of America (*Undergraduate Research Scholarship*) and the Connecticut Microelectronics and Optoelectronics Consortium (TranSwitch Prize).

Cross-Sectional Data

	TEM Thickness Measurements			AFM Thickness Measurements		
Annealing Temp	SBT Thickness	Std Dev	Std Dev	SBT Thickness	Std Dev	Std Dev
˚C	nm	nm	%	nm	nm	%
850	220	14	6.4	246.38	2.1463	0.9
900	290	9.6	3.3	302.16	5.6115	1.9
950	290	20	6.9	282.98	5.503	1.9

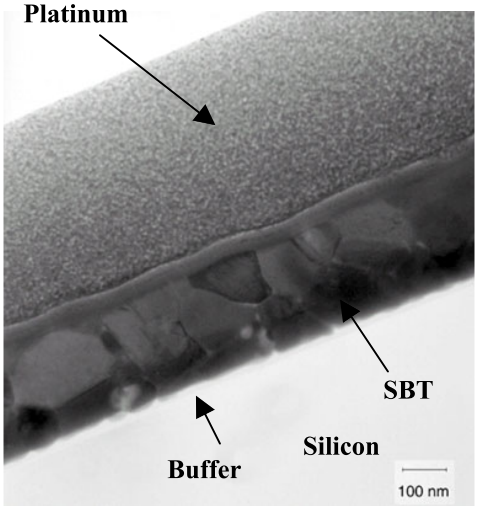

Figure 1: TEM image of SBT annealed at 900°C (prepared with FIB).

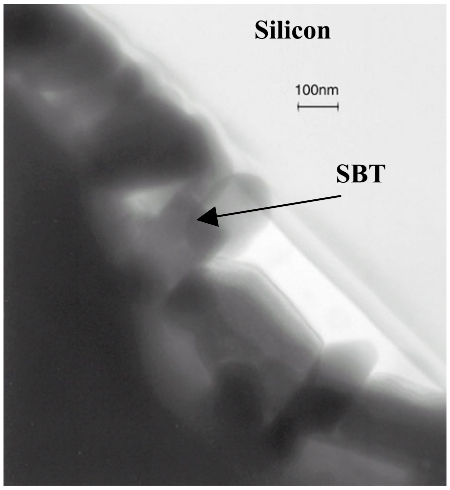

Figure 2: TEM image of SBT annealed at 950°C (prepared with FIB)

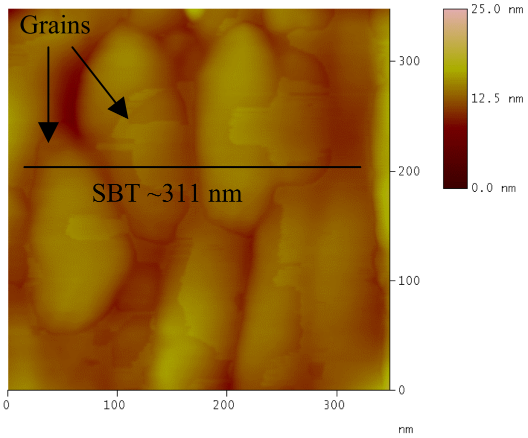

Figure 3: AFM image of SBT annealed at 900 °C.

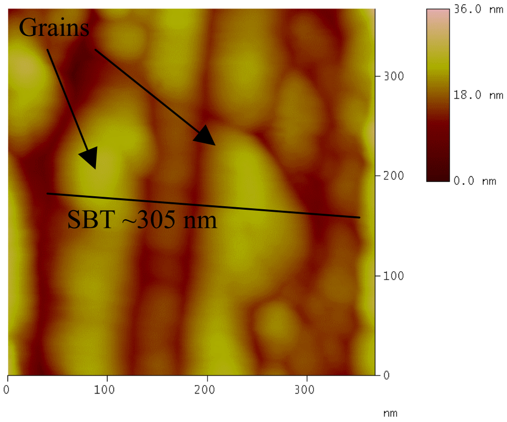

Figure 4: AFM image of SBT annealed at 950 °C.