Devlopment of a Stress-Free Polysilicon Deposition and Annealing Process

Richard Brown
Cornell NanoScale Facility
August 13, 2009

Deposition Conditions

Uniform film thickness with low surface roughness has been achieved by depositing undoped Si at 570°C and 590°C and 100 mTorr. A thick film ~ 3-4 microns of poly grown at 610°C was very rough when viewed by eye – Indicating either

570°C – 2.85 nm/min
590°C – 4.76nm/min
580°C – Coming soon...
610°C – Film too rough to measure

Film roughness and nonuniformity seemed to increase as the deposition temperature increased due to the more polycrystalline nature of the deposition at higher temperatures. For thicker films however, it may be a trade-off worth making to cut down deposition times.

Annealing Conditions

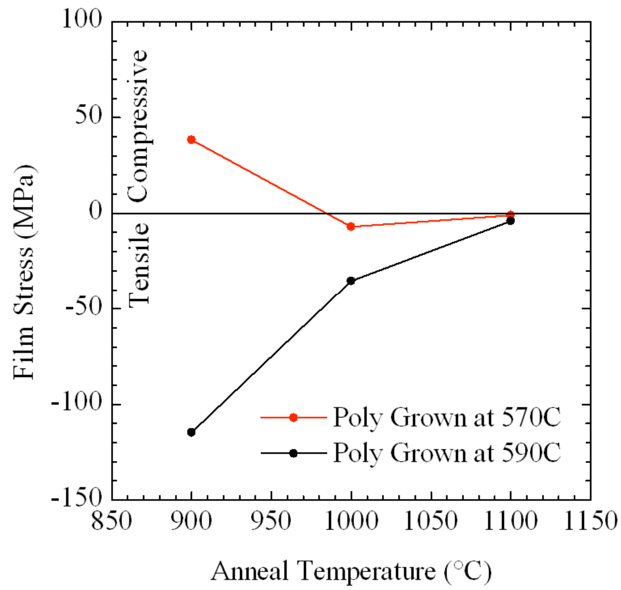
The amorphous films were annealed in Nitrogen at 900°C, 1000°C, and 1100°C for 5 hours. Film smoothness was maintained after the anneal with no noticeable roughness. To dope the film a ~75nm thick 2% PSG (Phosphosilicate glass) film was deposited on top of the poly via the GSI PECVD (2% PSG recipe, 20 seconds in the deposit step). Using PSG with higher doping concentrations resulted in the P segregating out of the film. Films with high P content also have a much lower melting temperature, which is not compatible with the high annealing temperatures we are using.

Substrate Preparation

To remove the PSG, a 30 second dip in HF was performed followed by a DI water rinse.

Film Stress Characterization (In-Plane)

In-plane film stress characterization was done by measuring the wafer curvature before and after the back-side poly was etched in 7 minutes of SF_6. It can be noted that the 570°C grown films were grown initially in compressive stress, while the 590°C films were deposited in tensile stress. Both films however reached a near zero level of in-plane stress with an anneal of 1100°C for 5 hours.



Stress gradient measurments:

Structures were patterned in the polysilicon by SF_6/O_2 RIE etching. The structures were then released in a HF solution followed by a supercritcal Carbon Dioxide drying. Below are some images of released MEMS structures taken with the Veeco optical profilometer .

Small (155 micron) clamp-open cantilevers were used to estimate the stress gradient in the grown film by the following equation:

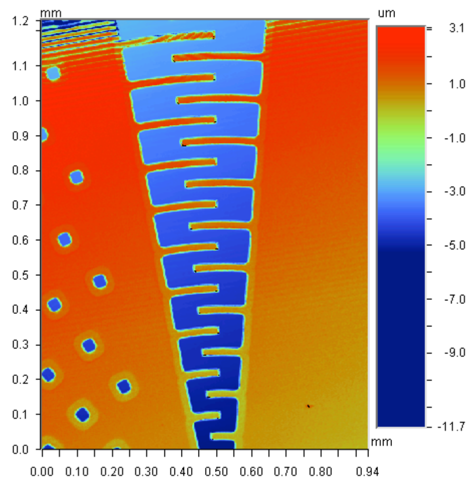
$$\frac{ds}{dt} = \frac{2yE}{(1-v)l^2}$$

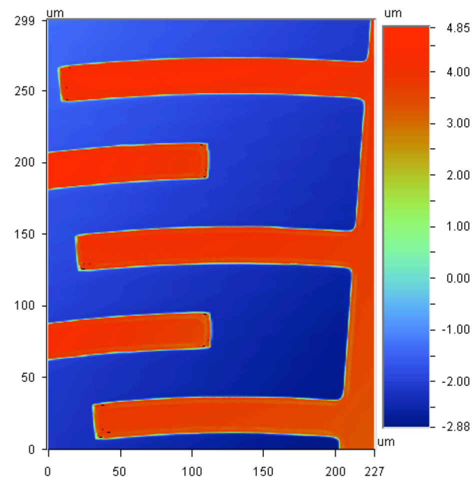
Where:

s = strain
t = thickness of polysilicon
E = Young's modulus of beam
v = Poisson's ratio for polysilicon
l = beam length

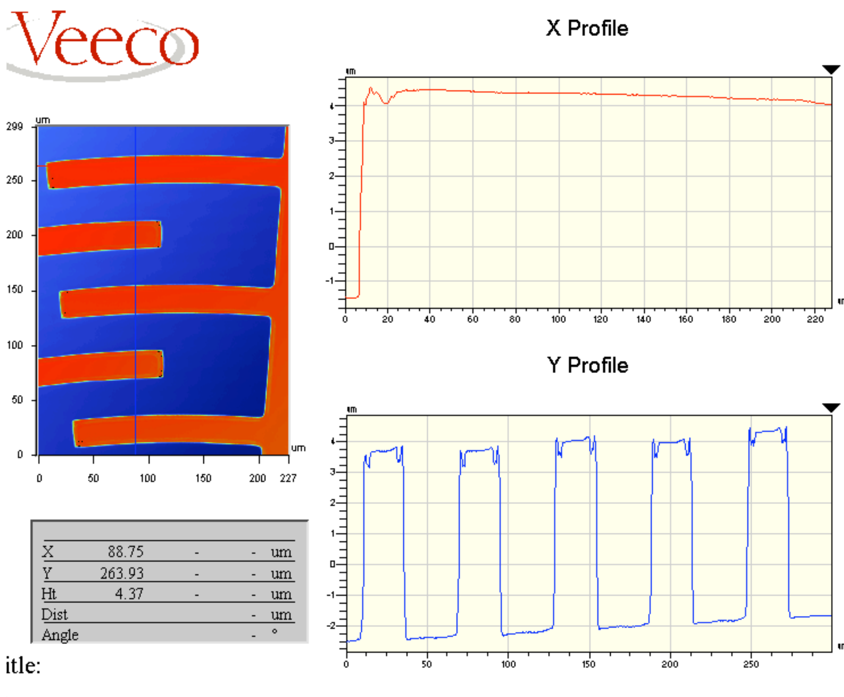
T (Growth)	T (Anneal)	Gradient (Mpa/um
570	900	8.8
570	1000	7.04
570	1100	8.8
590	900	17.61
590	1000	3.52
590	1100	5.28

As seen from the above data, 5-hour 1000 °C anneals seem to reduce the stress gradient to a minimum compared to the other temperatures attempted.



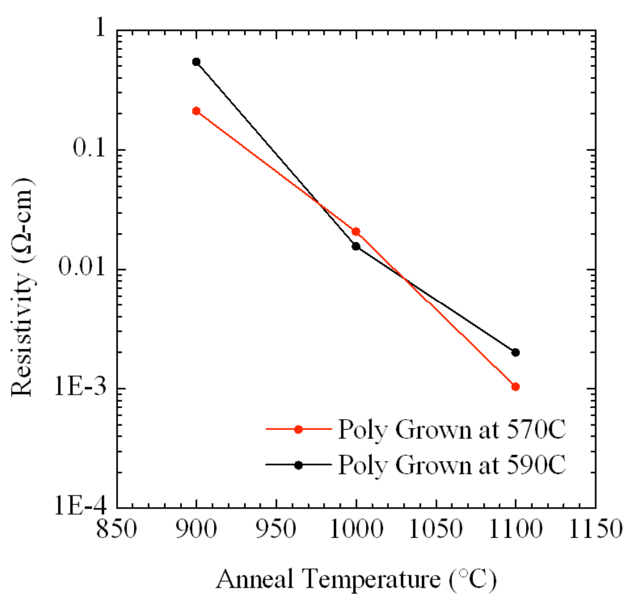


These height plots show MEMS structures with very small bending radii. Below is a cross sectional plot generated from the above height plots.



Film resistivity measurements:

4-point probe measurements were performed on the films, and with knowledge of their thicknesses, the following resistivity data was collected:



The lowest resistivity was obtained with the highest anneal temperature. This is expected as more dopant is driven in at high temperature, and the film recrystallizes to some extent, enhancing its mobility.