

ACST

59th

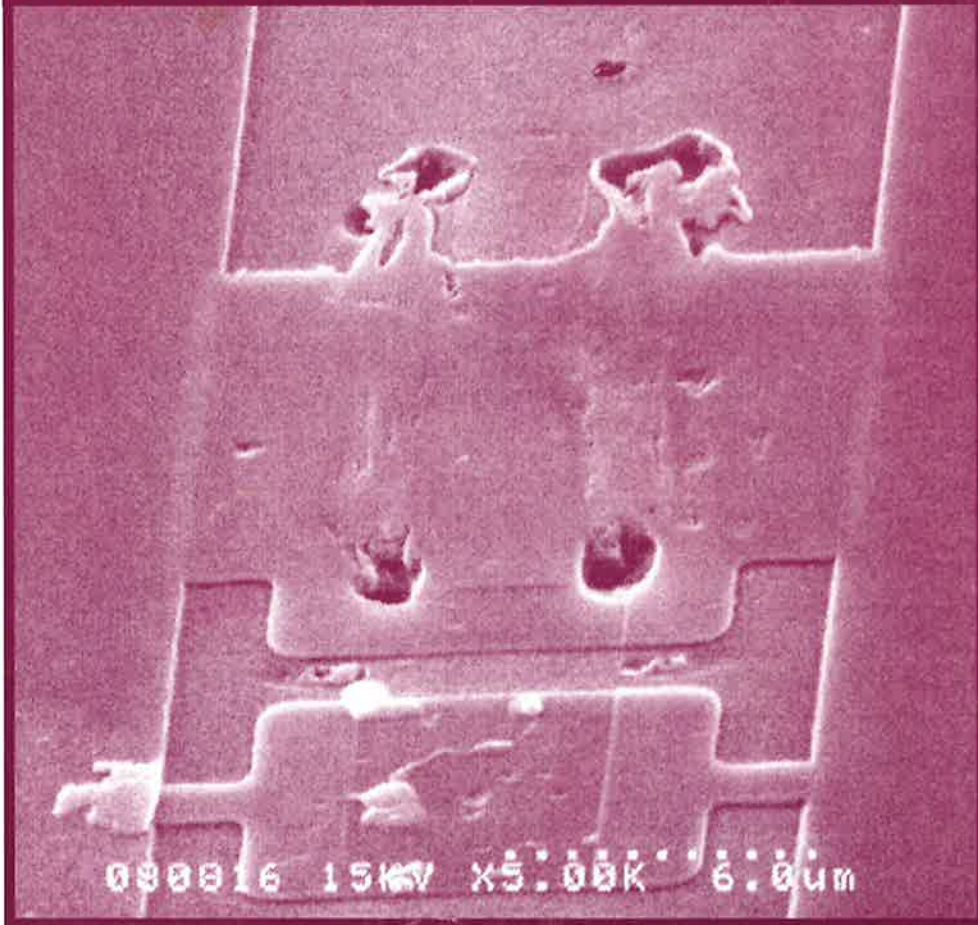


JUNE 25-27, 2001
UNIVERSITY OF NOTRE DAME
NOTRE DAME, INDIANA



DEVICE RESEARCH CONFERENCE

CONFERENCE DIGEST



Amorphous Si TFTs on Plastically-Deformed Substrates with 3-D Shapes

P.I. Hsu, H. Gleskova, Z. Suo, S. Wagner, and J.C. Sturm
Center for Photonics and Optoelectronic Materials (POEM), Princeton University,
Princeton, NJ 08544 USA
609-258-6624, irishsu@ee.princeton.edu

Current generations of electronic and optoelectronic products are fabricated on the surface of flat, rigid semiconductor or glass substrates. For large-area electronics applications such as displays, large-area sensor arrays (e.g. X-ray imaging plates), and eventually intelligent furniture, clothes, etc, it is highly desirable that they be lightweight and deformable. Previous work [1,2] has demonstrated that transistors on thin metal or plastic foil substrates can be rolled into cylindrical shapes down to a 0.5mm radius of curvature with no adverse effects. With such cylindrical shapes, the strain on the surfaces (where the devices are) can be kept low by using thin substrates. However, to form arbitrary 3-D electronic surfaces, there is no way to avoid a large strain in the substrate. In this paper we report the first transistors fabricated on a substrate that is then plastically deformed. Using amorphous silicon (α -Si) device islands on a polyimide substrate, TFTs can withstand an average substrate strain of 6%, as the substrate is deformed into a spherical cap shape subtending angles as large as 66° (1 steradian solid angle).

In this work, the α -Si TFTs are made on patterned silicon nitride islands on a polyimide (Kapton®) substrate (Fig. 2, 3). To achieve a spherical cap subtending 1 steradian ($\sim 66^\circ$ field of view), the average strain in the substrate can be shown by geometrical considerations [3] to be $\sim 6\%$ (Fig. 1). This leads to permanent plastic deformation of the plastic or metal substrates, and cracks uniform inorganic device films (, which can withstand $\sim 1\%$ strain at most). Previous results [3] have shown that by patterning hard (and brittle) silicon and silicon nitride layers (without devices) into isolated islands on soft polyimide substrates, the semiconductor islands can remain crack-free despite average strain in the substrate in excess of 5%. Most of the deformation takes place in the inter-island region and the substrate flows underneath the hard islands. The strain in the semiconductor island is therefore reduced. In this work, the maximum amorphous silicon island size is about $100\ \mu\text{m}$. To create electronics on a deformed curved substrate, we first fabricate α -Si TFTs on a silicon nitride buffer on a flat plastic or metal foil. The maximum process temperature is 150° . The foil is then plastically deformed into the final desired shape after the nitride and α -Si are patterned.

Fig. 4 shows TFTs' characteristic curves before and after the substrate was deformed into a 1 steradian spherical dome. After fabrication, the curves are well behaved with $\mu_{n, \text{linear}} = 0.2\ \text{cm}^2/\text{V}\cdot\text{s}$, $V_T = 1.8\ \text{V}$, and $I_{\text{ON}}/I_{\text{OFF}} \sim 10^6$. After deformation, devices are still well behaved, with mobility and threshold voltage nominally unchanged (within device to device variations). The leakage current increase is thought to be due to heating to $\sim 150^\circ\text{C}$ during deformation (to soften the polyimide substrate) as opposed to the deformation itself. Further work is underway to complete circuits and increase island sizes with novel geometries.

This work was supported by ONR/DARPA N60001-98-1-8916.

- [1] E. Y. Ma, S. D. Theiss, M. H. Lu, C. C. Wu, J. C. Sturm, and S. Wagner, Thin Film Transistors For Foldable Displays, *Tech. Dig. Int. Electron Devices Meet.*, p. 535-538 (1997).
- [2] H. Gleskova and S. Wagner, Failure Resistance of Amorphous Silicon Transistors Under Extreme In-plane Strain, *Appl. Phys. Lett.*, **75**, 3011 (1999).
- [3] P-H .I. Hsu, M. Huang, S. Wagner, Z. Suo, and J.C. Sturm, Plastic Deformation of Thin Foil Substrates with Amorphous Silicon Islands into Spherical Shapes, *Proc. Symp. Mat. Res. Soc.*, 621, Q8.6, 2000.

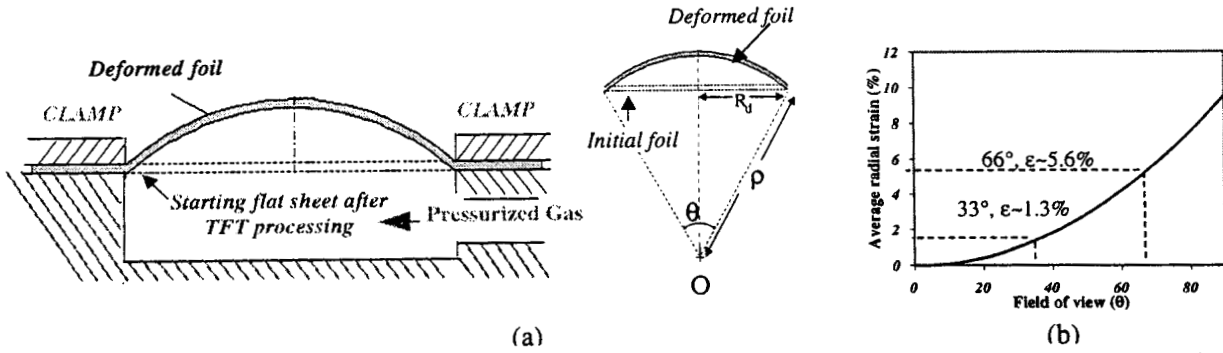


Figure 1. (a) Schematic diagram indicating apparatus for deforming substrates, and definition of subtended angle θ after deformation. (b) Average radial strain across the foil after deformation as a function of θ .

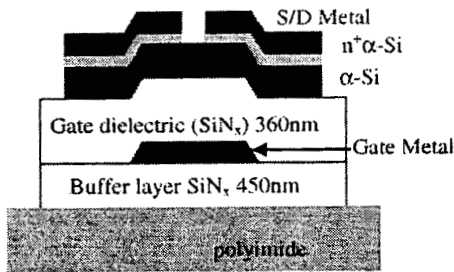


Figure 2. TFT structures

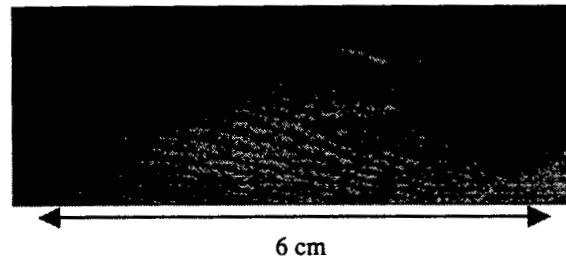


Figure 3. Polyme foil with a-Si/Si₃N₄ islands after deformation to a spherical cap shape with a $\sim 66^\circ$ field of view (~ 1 steradian).

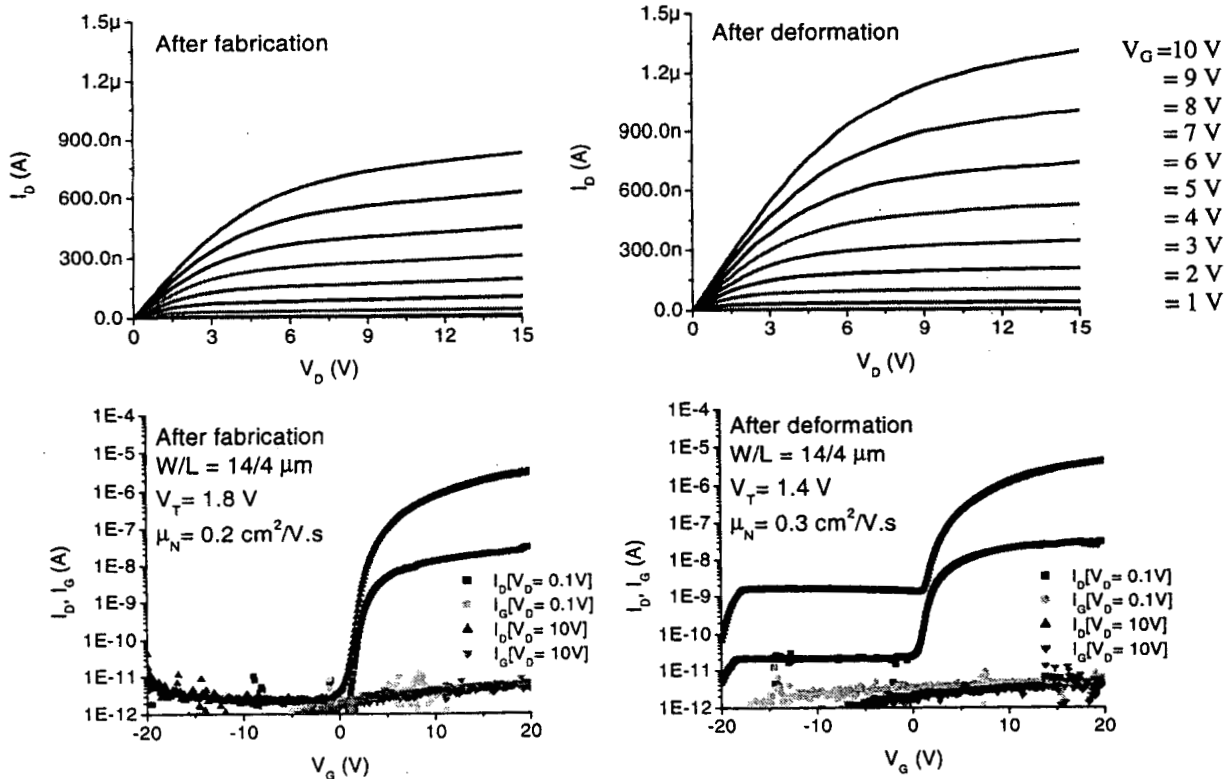


Fig. 4 TFT characteristics