Project III. 4: THIN FILM DEVICES for LARGE AREA ELECTRONICS

Project leader: D. N. Kouvatsos

PhD candidates: M. Exarchos, L. Michalas (University of Athens)

Projects Running:

- Research grant from Sharp Laboratories of America. 2003-2005
- Greece-Serbia 2004-2006 bilateral research project.

Goals:

This research aims at the optimization of the active layer of polysilicon films obtained using advanced excimer laser crystallization methods and of the resulting performance parameters of thin film transistors fabricated in such films. Specifically, the targets are:

- Evaluation of device parameter (a) hot carrier and (b) irradiation stress-induced degradation and identification of ageing mechanisms in TFTs fabricated in advanced excimer laser annealed (ELA) polysilicon films. Investigation of polysilicon active layer defects using transient drain current analysis in ELA TFTs.
- Investigation of the influence of film thickness and crystallization technique on defects and on device degradation for ELA technology optimization.
- Evaluation of bias stress-induced instabilities in solid phase crystallized (SPC) TFTs.

Main results:

The results obtained to date can be summarized as follows:

a) Hot carrier stress degradation

Superior hot carrier stress endurance has been demonstrated for ultra-thin film ELA TFTs as compared to ones in typical 50 - 100 nm films. Two ageing mechanisms have been identified (corresponding to ΔV_{th} power law exponents of ~0.2 and ~0.5, respectively): hot-carrier injection in the gate insulator and deep-state generation in the active device "body". The relative dominance of degradation mechanisms has been ascribed to charged defect field and partial depletion effects.The trap densities N_t and D_{ts}, extracted from a Levinson analysis and from the subthreshold swing ***s***, respectively, are insensitive to stress for TFTs in ultra-thin SLS ELA polysilicon films. A vertical channel orientation relative to the direction of the elongated grains results in a suppressed interfacial (expressed in ***s*** and g_m) degradation rate, as compared to a parallel one. *Fig. III.3.1* shows***:*** degradation **Δs** vs. stressing time for TFTs parallel oriented in 30, 50 or 100 nm films, or vertically oriented in 100 nm films.

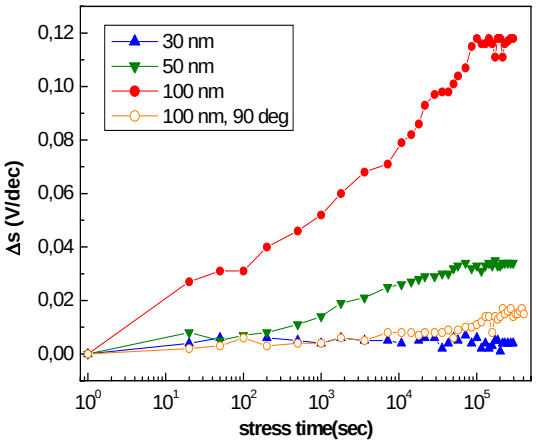

Fig. III.3.1: *Degradation Δ**s** vs. stressing time for TFTs parallel oriented in 30, 50 or 100 nm films, or vertically oriented in 100 nm films.*

b) Transient drain current analysis

The observed, after the application of a gate bias pulse, drain current transients in SLS (sequential lateral solidification) ELA TFTs are of the same order of magnitude at dark as well as under illumination. Moreover, the DLTS signals $\Delta I_{DS}/I_{DS}$ fall sharply at low temperatures, indicating a carrier generation freezeout. From these characteristics, a low density of generation-recombination centers and a corresponding high crystalline quality of ELA polysilicon films crystallized by the SLS technique are inferred.

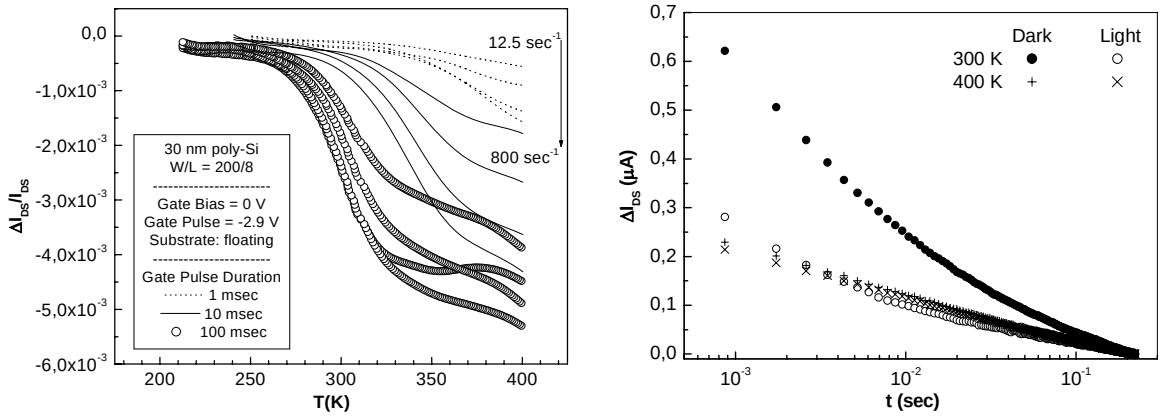

Fig. III.3.3: ***(Right)*** *Drain current transients $\Delta I_{DS}(t)$ against time after end of the gate pulse.* ***(Left)*** *Normalized ΔI_{DS} against temperature (DLTS spectra), exhibiting freezeout.*

From the observed shift, for various pulse durations, of the generation freezeout point a thermally activated generation process via a hole trap at 0.49 eV above E_V is inferred. Dislocation and RTA-related traps have been identified for TFTs fabricated with various SLS ELA techniques.

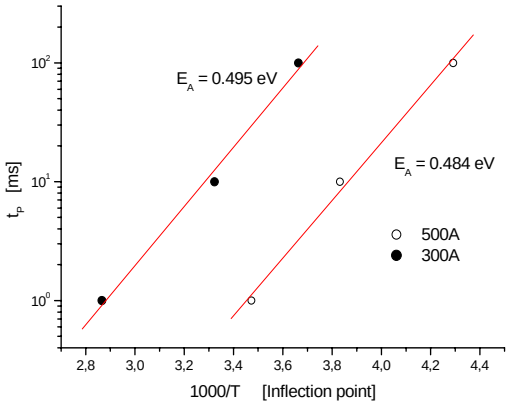

Fig. III.3.4: *Arrhenius plot for the freezeout inflection point.*

c) γ-irradiation induced degradation

TFTs in ultra-thin SLS ELA polysilicon films were found to exhibit significantly less pronounced γ-irradiation-induced degradation, as compared to TFTs in thicker films: less oxide/interface charge trapping (ΔN_{ot} and ΔN_{it}) and smaller subthreshold slope ***s*** degradation. Furthermore, significantly better threshold voltage stability was exhibited by TFTs in ultra-thin polysilicon films, while the mobility degradation was similar. The γ-irradiation-induced degradation was enhanced in the presence of a gate field.

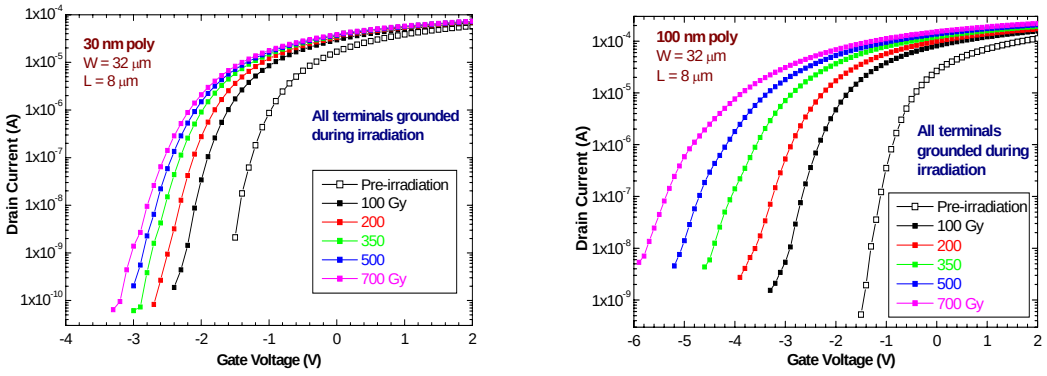

Fig. III.3.5: *Transfer characteristics for γ-irradiated 30 nm (left) or 100 nm (right) TFTs.*

PUBLICATIONS in INTERNATIONAL JOURNALS

1. "Effects of hot carrier and irradiation stresses on advanced excimer laser annealed polycrystalline silicon thin film transistors", Kouvatsos, D. N., Davidovic V., Papaioannou G. J., Stojadinovic N., Michalas L., Exarchos M., Voutsas A. T. and Goustouridis D., *Microelectronics Reliability* 44 (9-11), 1631, (September 2004)
2. "Effect of silicon thickness on the degradation mechanisms of sequential-laterally-solidified polycrystalline silicon thin film transistors during hot-carrier stress", Voutsas, A. T., Kouvatsos D. N., Michalas L. and Papaioannou G. J., accepted to appear in *IEEE Electron Device Letters*
3. "The effect of Generation-Recombination mechanisms on the transient behavior of polycrystalline silicon transistors", Papaioannou, G.J., Voutsas A., Exarchos M. and Kouvatsos D., accepted to appear in *Thin Solid Films*

PUBLICATIONS in CONFERENCE PROCEEDINGS

1. "Characterization of Advanced Excimer Laser Crystallized Polysilicon Thin Film Transistors", Exarchos M., Kouvatsos D. N., Papaioannou G. J., Davidovic V., Stojadinovic N., Michalas L., and Voutsas A. T., *Proceedings of the 24th International IEEE Conference on Microelectronics (MIEL 2004)*, Nis, Yugoslavia, (May 2004)
2. "An investigation of the electrically active defects in poly-Si thin film transistors", Exarchos, M., Papaioannou G. J., Kouvatsos D. N. and Voutsas A. T., *Thin Film Transistor Technologies VII Symposium Proceedings*, 206th Meeting of the Electrochemical Society, Honolulu, Hawaii, (October 2004)

PRESENTATIONS in CONFERENCES

1. "The effect of Generation-Recombination mechanisms on the transient behavior of polycrystalline silicon transistors", Papaioannou G.J., Voutsas A., Exarchos M. and Kouvatsos D., *8th International Conference on Polycrystalline Semiconductors - Materials, Technologies and Device Applications*, Potsdam, Germany, (September 2004)
2. "Effects of hot carrier and irradiation stresses on advanced excimer laser annealed polycrystalline silicon thin film transistors", Kouvatsos, D.N., Davidovic V., Papaioannou G. J., Sojadinovic N., Michalas L., Exarchos M., Voutsas A.T. and Goustouridis D., *15th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2004)*, Zurich, Switzerland, (October 2004)
3. "Effects of DC gate and drain bias stresses on the degradation of excimer laser crystallized polysilicon thin film transistors", Kouvatsos, D. N., Michalas L., Voutsas A. T. and Papaioannou G. J., *2nd Conference on Microelectronics, Microsystems and Nanotechnology*, Athens, Greece, (November 2004)
4. "Investigation of drain current transient behavior in SLS TFTs with the DLTS technique", Exarchos M. A., Papaioannou G. J., Kouvatsos D. N. and Voutsas A. T., *2nd Conference on Microelectronics, Microsystems and Nanotechnology*, Athens, Greece, (November 2004)

MSc THESES

1. "Investigation of hot carrier effects in polycrystalline silicon TFTs", L. Michalas, Physics Department, University of Athens
2. "Fabrication of MOS devices utilizing W or W/Cu metallization and characterization of MOS capacitors and TFTs", T. Nikas, Informatics Department, University of Athens