TCAD TFT AMLCD Pixel Simulation

1. Introduction

The main drawbacks of circuit level simulation are the many assumptions made of the device model. For example the a-Si:H TFT model assumes that the channel is uniform and ignores interface trap effects. For more accurate circuit level simulation, a device numerical modeling approach is attractive and predictive. Silvaco's ***ATLAS/MixedMode*** module enables users to predict device performance and also the circuit level behavior of transient switching characteristics in AMLCD pixel simulation. Figure 1 shows conventional equivalent circuit diagram of the unit pixel.

2. Liquid Crystal Capacitance Model

In order to simulate transient behavior of the unit pixel in ***MixedMode***, a time and voltage dependent liquid crystal capacitance model is to be used.

$$\varepsilon_{ps} = \varepsilon_{PL} + \delta \cdot \gamma \cdot \exp(D_{time}) \cdot \sqrt{\frac{V}{V_C} - 1}$$

The total amount of LC capacitance(C_{LC}) is calculated from above ε_{ps} and the geometry of the LC cell as follows:

$$C_{lc} = \frac{\varepsilon_0 \cdot \varepsilon_{ps} \cdot L \cdot W}{D}$$

here, L and W are total area of the LC cell which is connected to each TFT and D is the thickness of the LC cell(cell gap).

The parameters used in the simulation are listed in Table 1.

Liquid Crystal Parameters	
L	=152um
W	=148um
D	=10.02um
δ	=51.0 mm^2/s
γ	= 51.2 ms/mm^2
D_{time}	= 100ms
Vc	=1.887V
e_{PL}	=3.1

Table 1. LC parameters in *MixedMode* simulation.

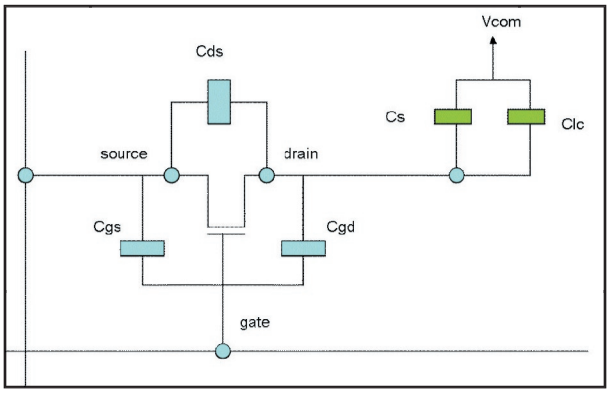

Figure 1. This figure shows AMLCD unit pixel.

3. *MixedMode* Circuit Description

In order to simulate liquid crystal capacitance with ***MixedMode***, a user-defined two terminal function with C-Interpreter is necessary.

Bxxx n+ n- infile="filename"
function="function_name"

Bxxx is a user-defined name and infile="filename" is the source file which includes the function name.

An example C-Interpreter source file is listed below.

```
#include <math.h>
#include <stdio.h>
double my_lc_rc(double v, double temp,
  double ktq, double time, double *curr,
  double *didv, double *cap, double
  *charge)
{

  double eps,e0;
  double epl,clc;
  double theta,gamma;
  double Dtime;
  double vc;
  double L,W,D;

  L=152;
  W=148;
  Dtime=100e-3;
  theta=51.0; /* sec */
```

```
  gamma=51.2e-3; /* sec */
  epl=3.1;
  vc=1.887;
  D=10.02;
  e0 = 8.854e-12;

  if(v > vc)
       eps = epl + theta*gamma*exp(Dtime)*
  sqrt(v/vc - 1.0);
  else if( v <= vc)
       eps =epl;

  clc= e0*eps*L*W*1e-6/D; /* F */

  *curr=v/10e9;
  *didv=1/10e9;
  *cap=clc;
  *charge=*cap*v;

  printf("clc = %e(F)\n", clc);
  printf("charge = %e\n", *charge);

  return(0);
}
```

In the calculation above, a user-defined two terminal current is defined by the following formula:

$$I=F1(V,t) + F2(V,t)*dF/dV$$

The 1st term is the DC current and the 2nd term is the capacitive current.

MixedMode performs capacitance and total charge calculation based on the user-defined C-Interpreter function. A typical voltage driven response of unit pixel is shown Figure 2.

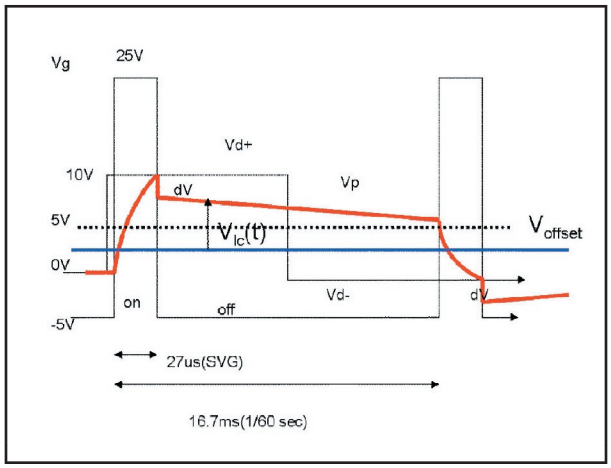

Figure 2. A typical TFT AMLCD unit pixel voltage driven response.

Before transient simulation in ***MixedMode***, the DC characteristics of the a-Si:H TFT is simulated to reproduce the experimental transfer curve and output curve.

Interface traps are specified for the bulk and front and back channel using continuous DEFECT and INTDEFECT statements. Interface fixed charge is also included.

In a TFT-LCD pixel simulation, the following a-Si:H TFT model and circuit behavior should be considered:

1. the charging state which is driven by the on-current of an a-Si:H TFT
2. the holding state which is affected by the off-current of an a-Si:H TFT
3. the voltage drop characteristics of an a-Si:H TFT and LC capacitance

The ***MixedMode*** circuit description input deck is listed below:

```
.begin

vcom 6 0 5
vg 1 0 0 pulse 0 20 0 1e-6 1e-6 40us
  180us
vd 3 0 0 pulse 0 10 0 1e-6 1e-6 160us
  320us
atft 2=source 1=gate 3=drain infile=a-Si-
  TFT.str width=41
re 2 4 1.28k
co 4 5 317f
rlc 5 6 10g
cst 2 6 1.06p
#clc 4 0 125f
bLC 5 6 infile=lc_cap.lib function=my_lc_
  rc


.numeric vchange=0.5 dtmin=1e-9 imaxtr=50
.options print
.load infile=tft_dc
.log outfile=tft
.tran 0.1us 320us

.end
```

In Figure 3, the AMLCD pixel dynamics are correctly reproduced, accordingly the source voltage shape shows pixel charging, holding, and voltage drop.

5. Conclusion

ATLAS/TFT/MixedMode is a useful tool for TFT AMLCD unit pixel simulation and predicts transient pixel characteristics with trap density of a-Si:H TFT and liquid crystal modeling through a user-defined two terminal device.

TCAD approach to pixel design and combined device level capacitance characteristics is necessary for both circuit and device performance.

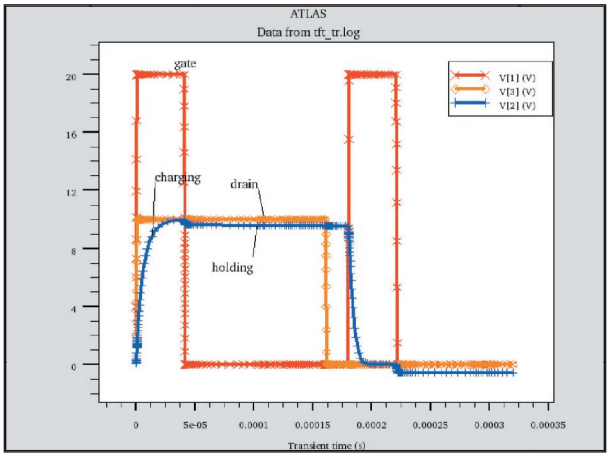

Figure 3. TFT AMLCD pixel voltage.

References:

1. "Dynamic Characterization of a-Si TFT-LCD pixels", Hitoshi Akoi,ULSI Research Laboratory, HP Labs, Hewlett-Packard Company, 3500 Deer Creek Rd., Palo Alto, CA 94304
2. "*ATLAS User's Manual*", Silvaco, Santa Clara, California, USA.