Electrolytic Etching Cell Fluid Dynamics

a

Finite Element Analysis (FEA)

using

flexPDE

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Partial Differential Equation Formulation for Fluid Dynamic Finite Element Analysis (FEA)

The Navier-Stokes equation for steady incompressible flow in two Cartesian dimensions is

dens*(dt(U) + U*dx(U) + V*dy(U)) = visc*del2(U) - dx(P) + dens*Fx

dens*(dt(V) + U*dx(V) + V*dy(V)) = visc*del2(V) - dy(P) + dens*Fy

together with the continuity equation

div[U,V] = 0

where U and V are the X- and Y- components of the flow velocity

P is the fluid pressure

dens is the fluid density

visc is the fluid viscosity

Fx and Fy are the X- and Y- components of the body force.

In order to derive a third equation for the Pressure variable, we differentiate the U-equation with respect to X and the V-equation with respect to Y. Using the continuity equation to eliminate terms, we get

del2(P) = 2*dens*[dx(U)*dy(V) - dy(U)*dx(V)]

Although this equation is consistent with the continuity equation, it does not enforce it. However, since div[U,V] = 0, we are free to add it at wil to the pressure equation. A negative value of div[U,V] implies the destruction of material, so we need a positive pressure to oppose the flow. This implies a modified pressure equation

del2(P) = 2*dens*[dx(U)*dy(V) - dy(U)*dx(V)] + L*(dx(U)+dy(V))

where L is a "large" number chosen to enforce "sufficient" compliance with the material conservation equation.

Setting U and V equal to zero in the U and V equations to reflect the conditions on a no-slip boundary, we get

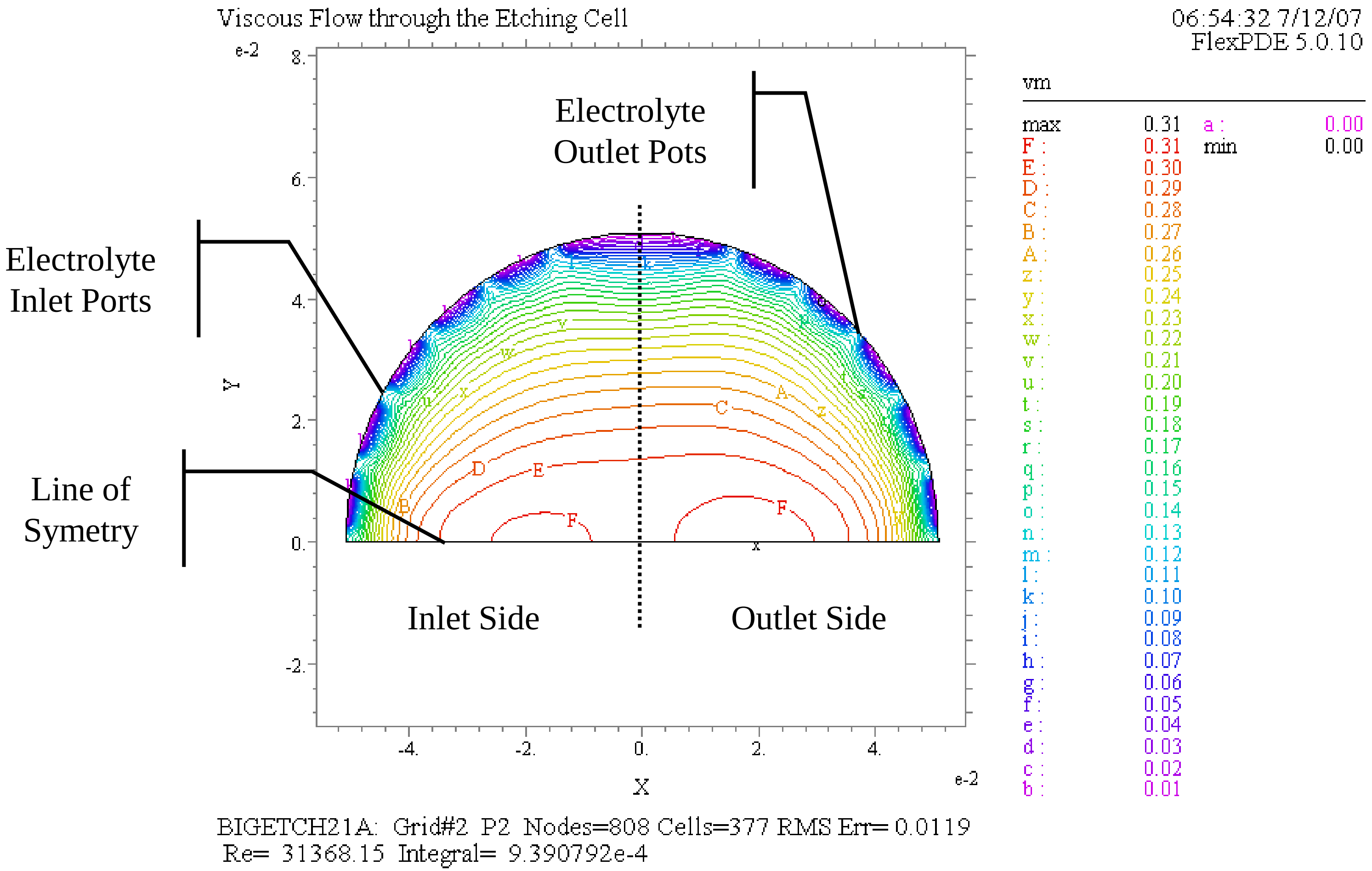
dx(P) = visc*del2(U)

dy(P) = visc*del2(V)

These relations can be used to specify the natural boundary condition for the pressure equation. The normal component of the gradient of P is

n<dot>grad(P) = nx*dx(P) + ny*dy(P)

where nx and ny are the direction cosines of the surface normal.



Electrolyte Outlet Pots

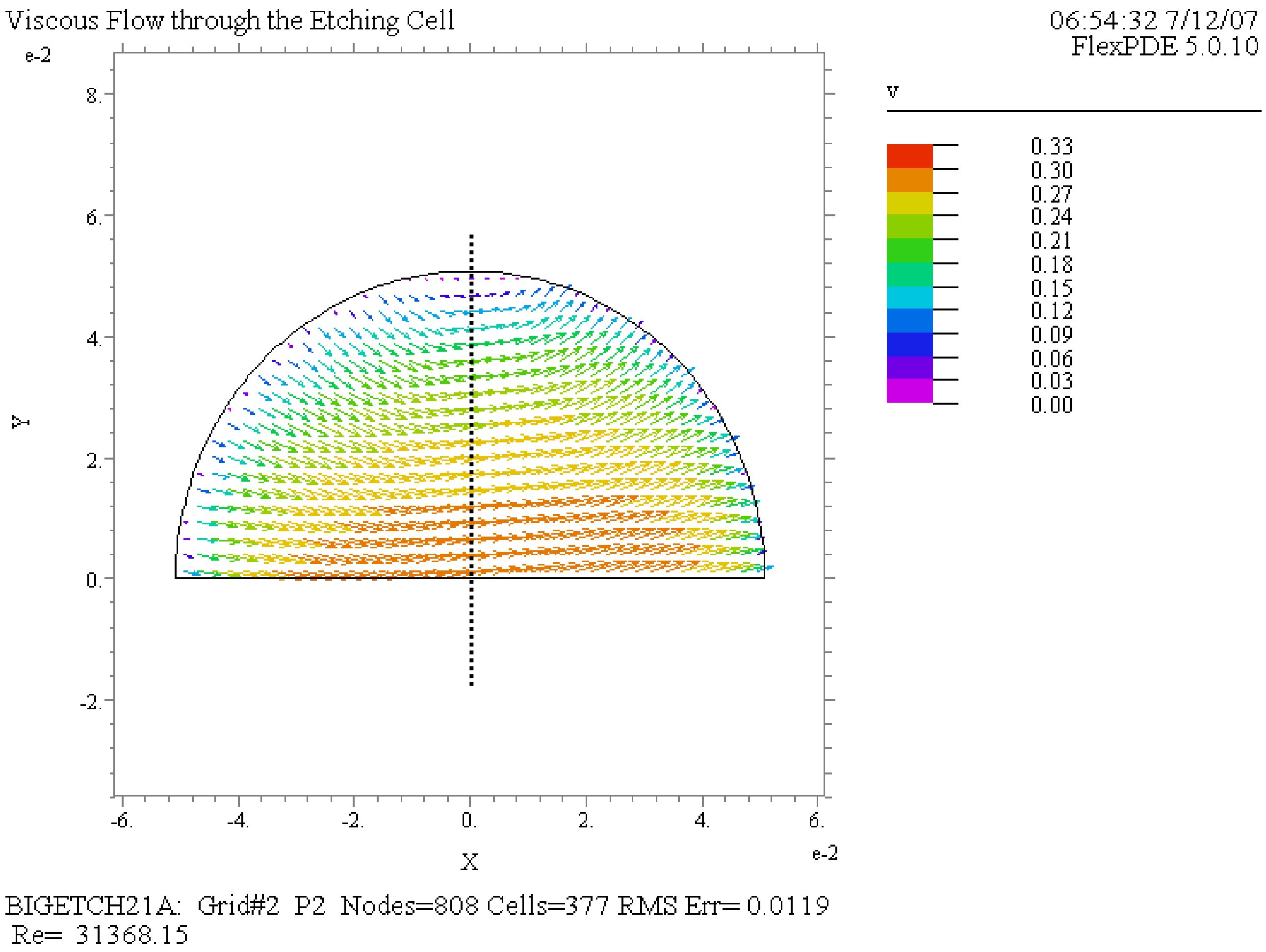
Electrolyte Inlet Ports

Line of Symetry

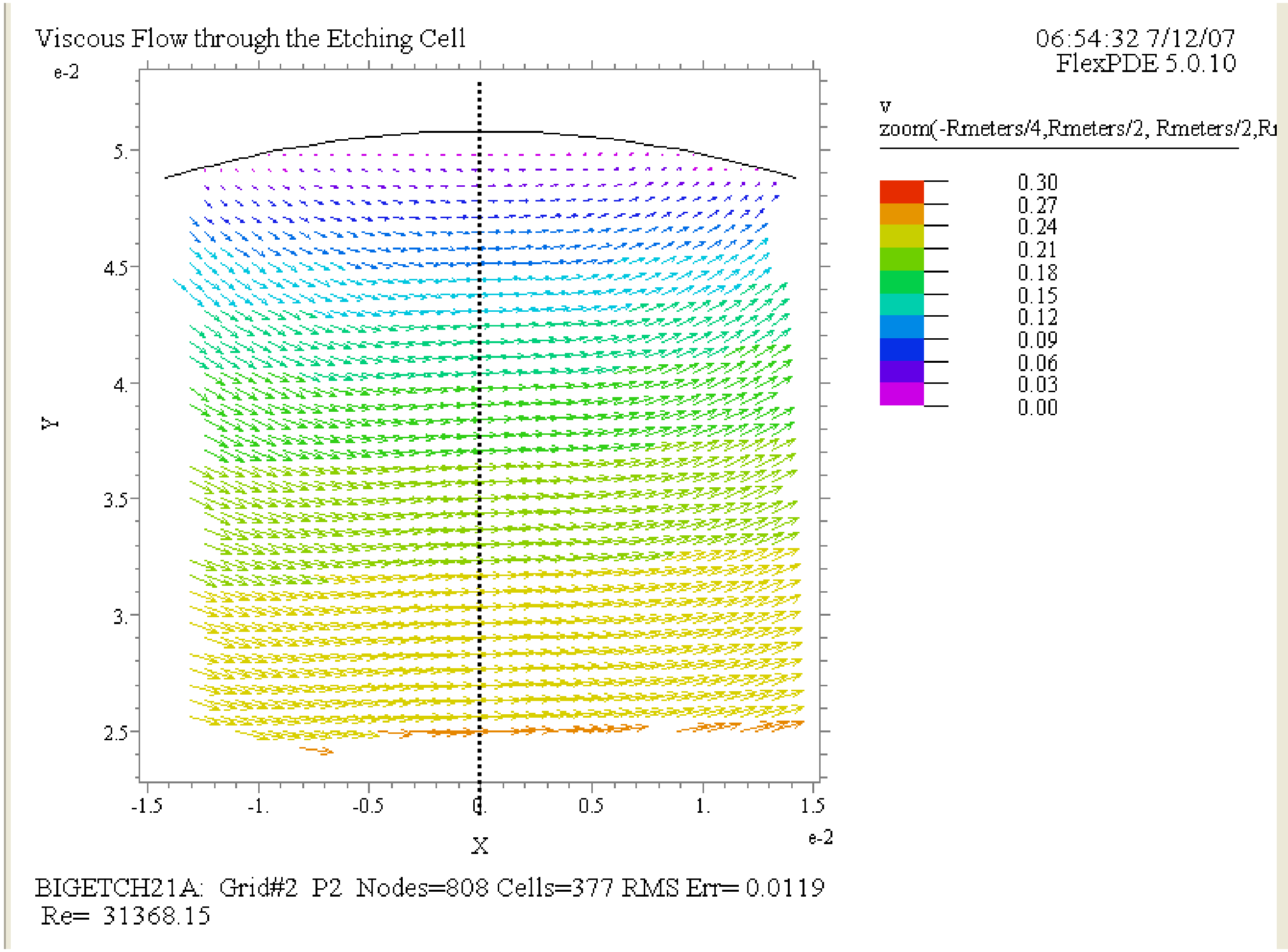
Inlet Side

Outlet Side

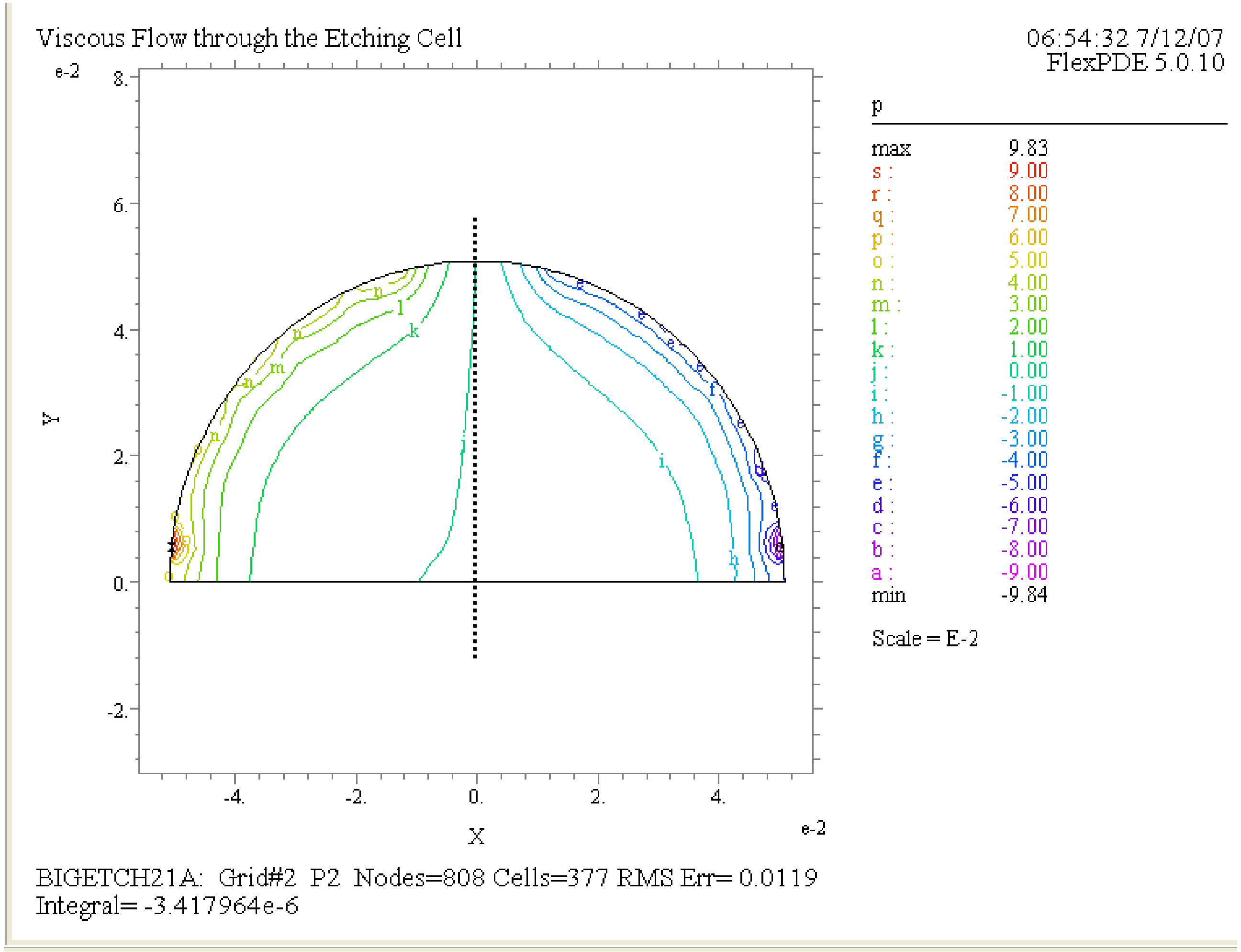
Electrolytic Etching Cell Velocity Magnitude Distribution – FEA analysis using flexPDE



Electrolytic Etching Cell Velocity Distribution – FEA analysis using flexPDE



Electrolytic Etching Cell Velocity Distribution - Expanded – FEA analysis using flexPDE



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Viscous Flow through the Etching Cell                06:54:32 7/12/07
                                                     FlexPDE 5.0.10
p
max    9.83
s :    9.00
r :    8.00
q :    7.00
p :    6.00
o :    5.00
n :    4.00
m :    3.00
l :    2.00
k :    1.00
j :    0.00
i :   -1.00
h :   -2.00
g :   -3.00
f :   -4.00
e :   -5.00
d :   -6.00
c :   -7.00
b :   -8.00
a :   -9.00
min   -9.84

Scale = E-2

BIGETCH21A:  Grid#2  P2  Nodes=808 Cells=377 RMS Err= 0.0119
Integral= -3.417964e-6
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Electrolytic Etching Cell Pressure Distribution – FEA analysis using flexPDE

Summary and Conclusions

An electrolytic etching cell suitable for producing 100 mm diameter porous silicon wafers has been designed and analyzed using finite element analysis as implemented through flexPDE

The overall design and the detailed design of the individual subsystems was successful and many hundreds … perhaps thousands of porous silicon wafers have been fabricated.