MHD effects in the industrial Czochralski growth of 300 mm Si crystals.

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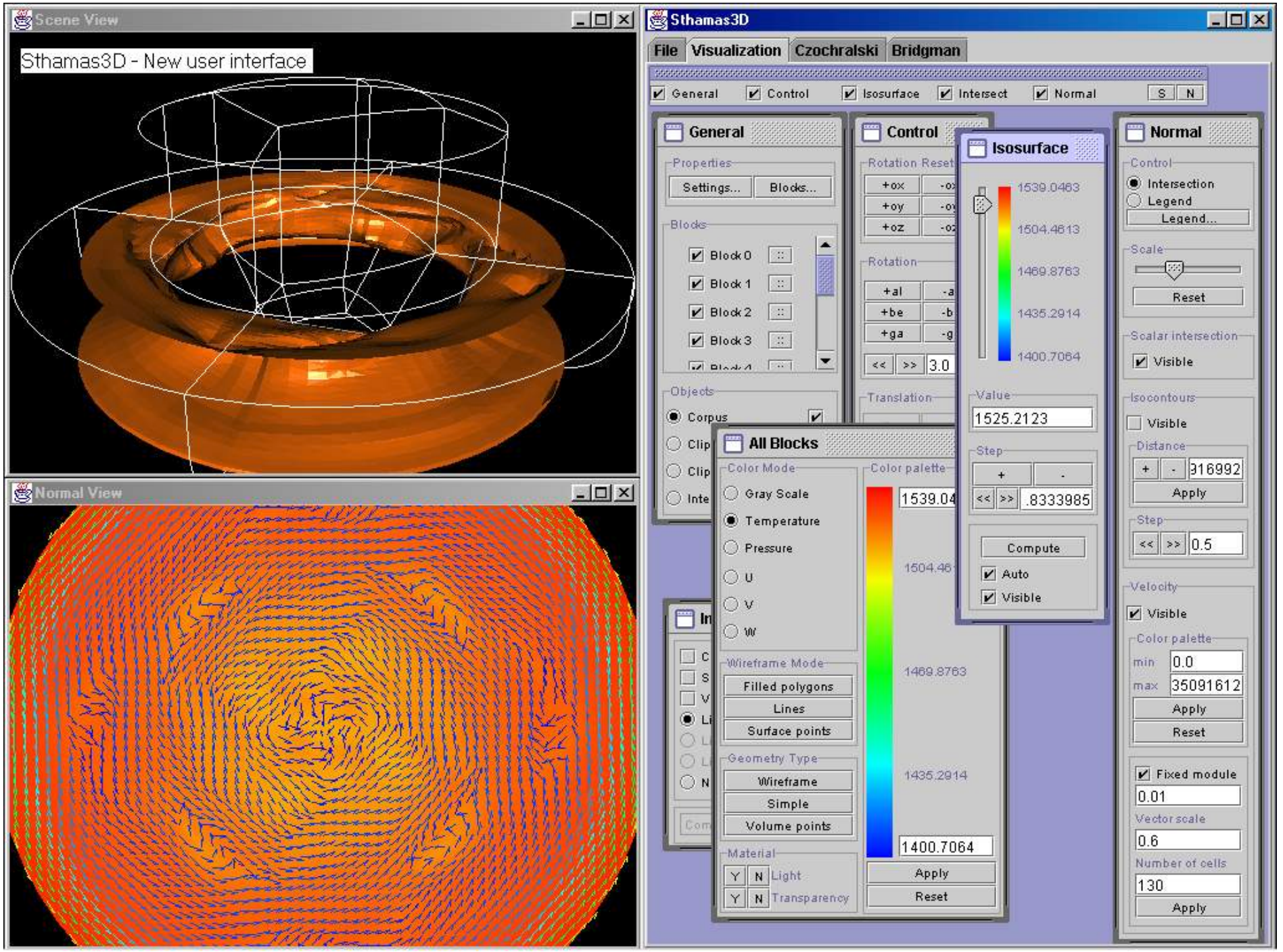
~Use of magnetic fields in crystal growth, Riga, 13-15 June~

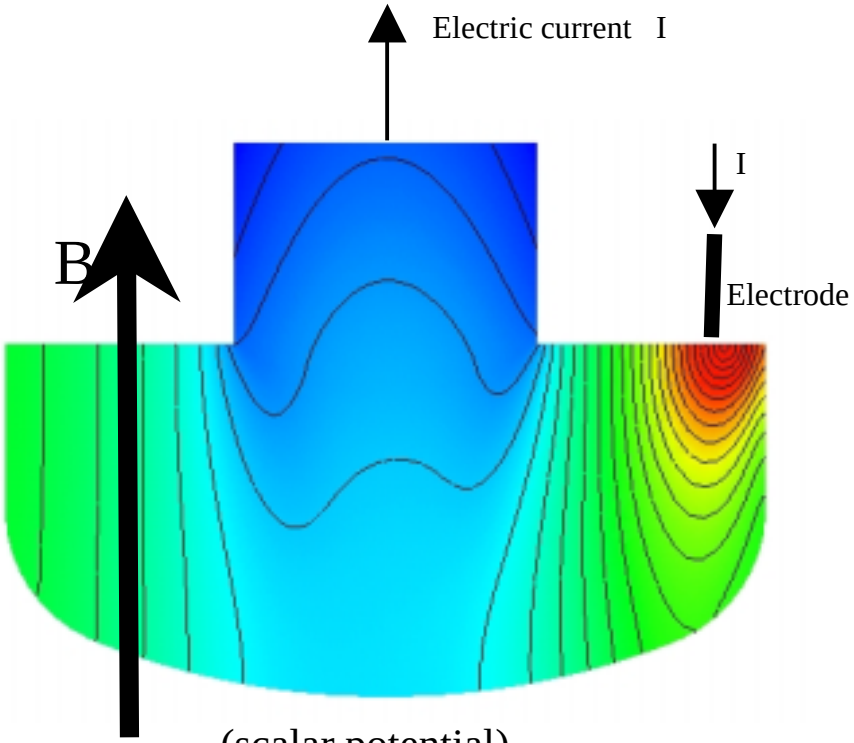
STHAMAS 3D

- Heat transport by conduction
- Heat transport by convection (incompressible flow); considering buoyant and forced convection, surface driven flow and several magnetohydrodynamic effects for electrically conducting fluids (steady,rotating,alternating and travelling magnetic fields)
- Transport of oxygen and dopants
- Phase boundary tracking
- Finite Volume Method
- Block-structured, non orthogonal grids
- Parallelization with MPI (run on PC, PC-cluster, parallel and vectorial supercomputers)

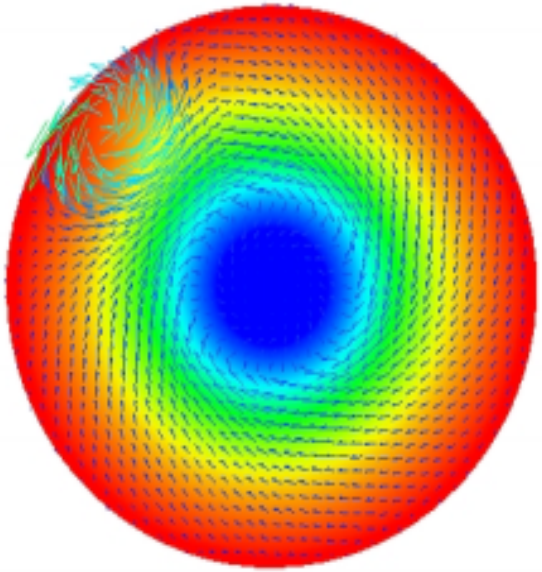

Scene View
Sthamas3D - New user interface
Normal View
Sthamas3D
File
Visualization
Czochralski
Bridgman
General
Control
Isosurface
Intersect
Normal
S
N
Properties
Settings...
Blocks...
Blocks
Block 0
Block 1
Block 2
Block 3
Objects
Corpus
Rotation Reset
+ox
+oy
+oz
Rotation
+al
+be
+ga
<<
>>
3.0
Translation
1539.0463
1504.4613
1469.8763
1435.2914
1400.7064
Value
1525.2123
Step
.8333985
Compute
Auto
Visible
All Blocks
Color Mode
Gray Scale
Temperature
Pressure
U
V
W
Wireframe Mode
Filled polygons
Lines
Surface points
Geometry Type
Wireframe
Simple
Volume points
Material
Y
N
Light
Transparency
Color palette
1539.04
1504.46
1469.8763
1435.2914
1400.7064
Apply
Reset
Control
Intersection
Legend
Legend...
Scale
Reset
Scalar intersection
Visible
Isocontours
Visible
Distance
916992
Apply
Step
0.5
Velocity
Visible
Color palette
min
0.0
max
35091612
Apply
Reset
Fixed module
0.01
Vector scale
0.6
Number of cells
130
Apply

Si-EMCZ

-proposed by M.Watanabe, M.Eguchi, T. Hibiya, Jpn. J. Appl. Phys. 38, L10 (1999)



(scalar potential)



(Velocity and temperature)

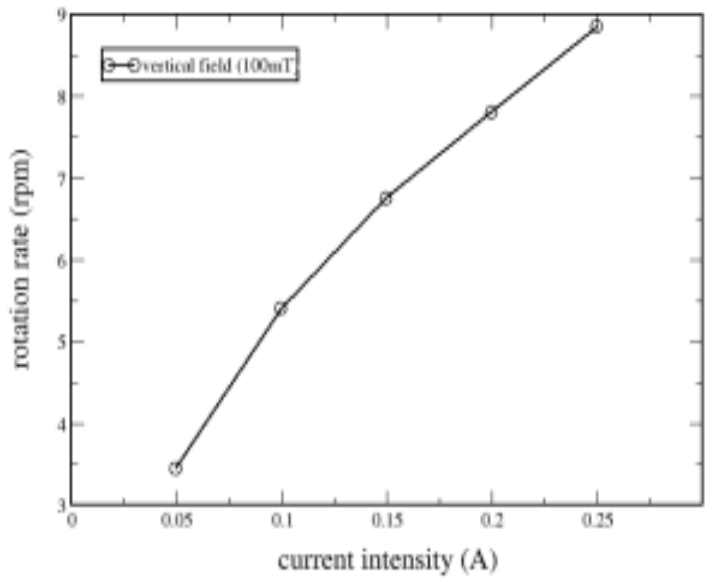
Crystal rotation: w_x = -0rpm
Crucible rotation: w_c = 1rpm
Crystal diameter: D= 30mm

-The melt is spontaneously rotated by the electromagnetic force

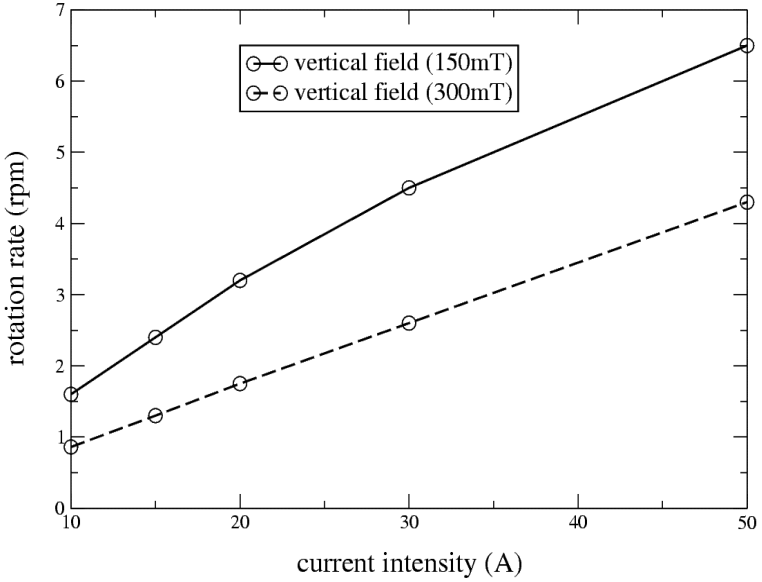
Si-EMCZ

Rotation rate

30mm



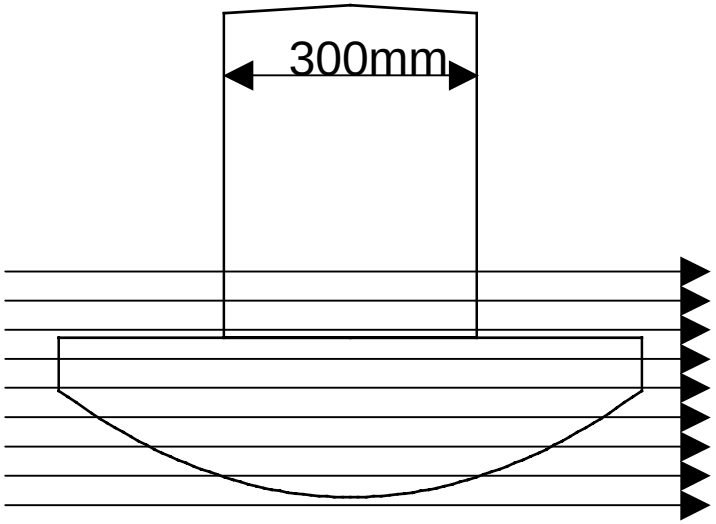
300mm

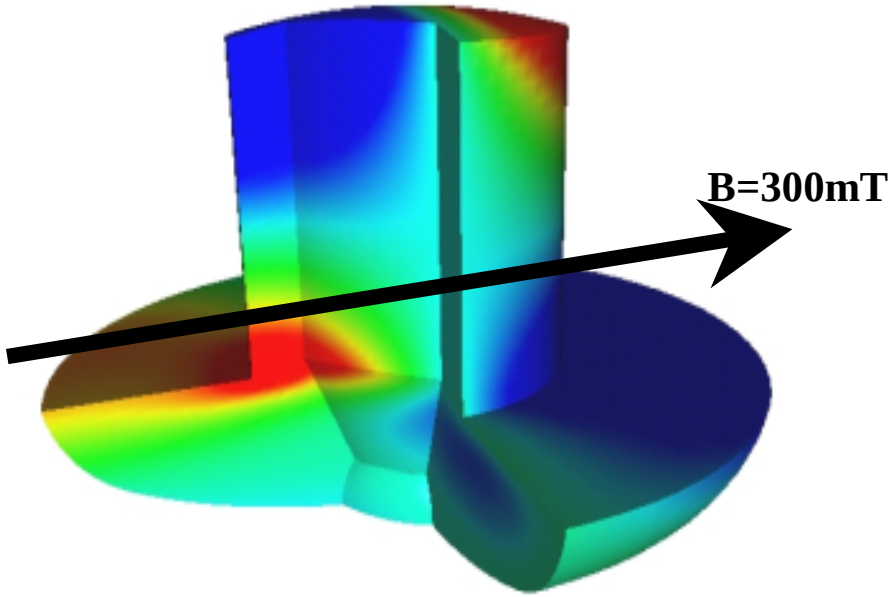


-30mm: in agreement with the experiment (M.Watanabe, et al.)

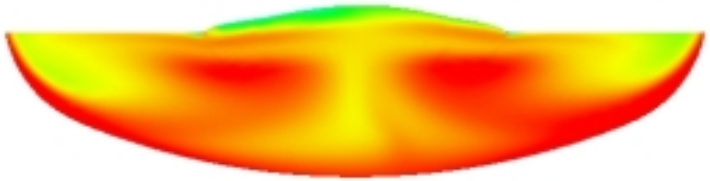
300 mm Si-HMCZ

Crystal rotation: w_x = -15rpm
Crucible rotation: w_c = 4rpm





3D view: scalar potential



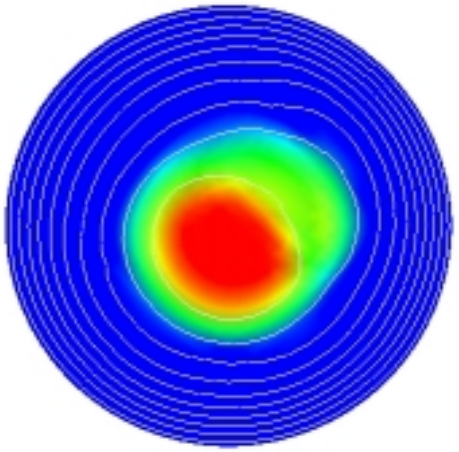
2D view: temperature field

300mm Si-HMCZ

Influence of the electrical conductivity of the crystal

Horizontal section i
the crystal close to
the free melt surface

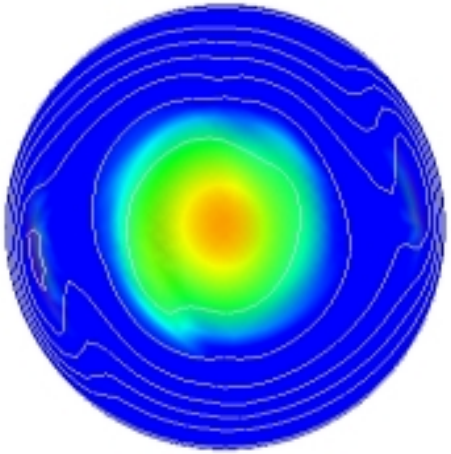
Conducting crystal
($\sigma = 2.4 \cdot 10^6$ S/m)



temperature field

B

Insulating crystal
($\sigma = 0$S/m)



temperature field

!!Experiment show a homogeneus
temperature field in crystal

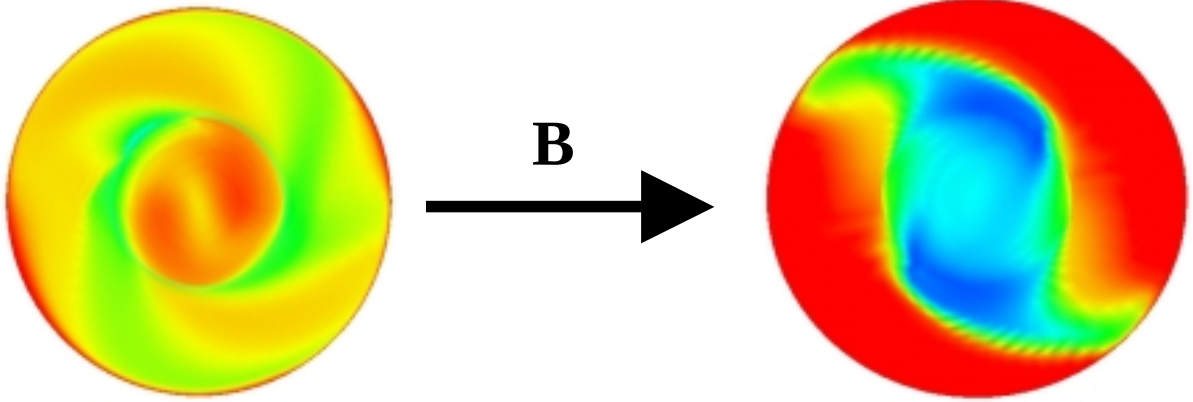
300mm Si-HMCZ

Influence of the electrical conductivity of the crystal

Conducting crystal
($\sigma = 2.4 \cdot 10^6$ S/m)

Insulating crystal
($\sigma = 0$S/m)

Horizontal section close to the free melt surface



temperature field

temperature field

Vertical section perpendicular to the magnetic field

Conclusions

- Three dimensional numerical simulation of melt flow in industrial melts is possible with our software STHAMAS3D.
- Two order of magnitude higher intensity of electrical current is necessary to obtain the same rotation rate of the melt in 300mm Si-EMCZ than in 30mm Si-EMCZ.
- Electrical conductivity of the crystal should be considered in order to obtain realistic results for 300mm Si-HMCZ.
- Experiments are necessary in order to validate the results of numerical simulations.