# Microforming of Steel Sheets

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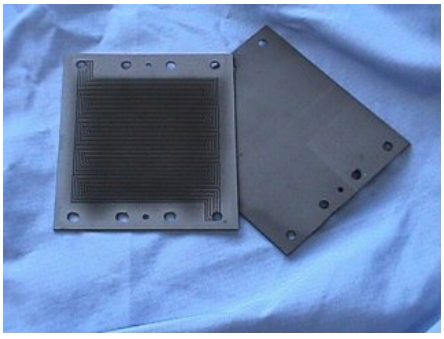
## Objectives

- To use conventional forming methods for the manufacturing of bi-polar plates for PEM fuel cell processors
- To analyze the formability of thin steel sheets using conventional forming methods to manufacture the bipolar plates

## State-of-the-Art

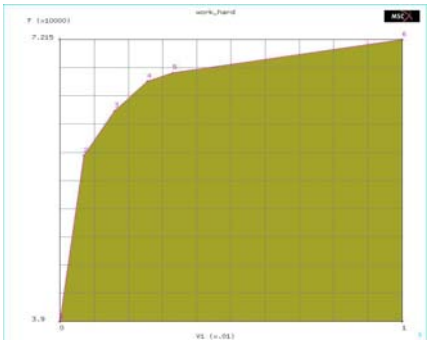
- Current fuel cells use carbon graphite based bi-polar plates resulting in very high manufacturing costs $2000-$5000 /kW due to material cost and low repeatability rates
- Use of High Carbon steels and conventional forming processes could reduce cost to $50/kW due to high repeatability rates and low cost of production



Graphite Bi-polar Plate

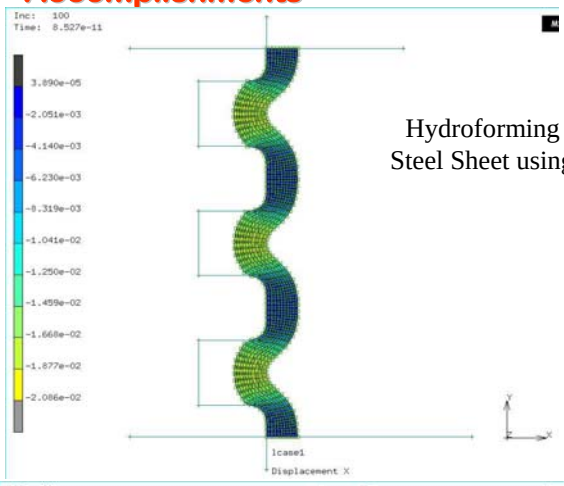
## Approaches

- FEA was conducted on 3 conventional forming processes
- Hydroforming
- Embossing
- Rolling

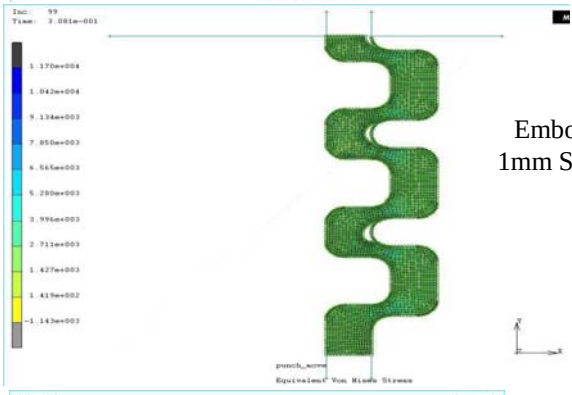


Work Hardening Curve for Steel

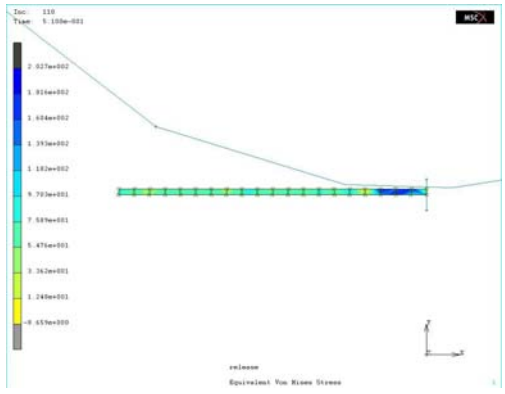
## Accomplishments



Hydroforming of 0.5mm Steel Sheet using 3e+14 psi



Embossing of 1mm Steel Sheet



Rolling of 1mm Steel Sheet

## Future Work

- Improve hydroforming FEA simulation with adaptive meshing and lower pressure.
- Improve rolling simulation with features on roller.

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu

# Micro deep drawing of thin sheet metals

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**Faculty:**
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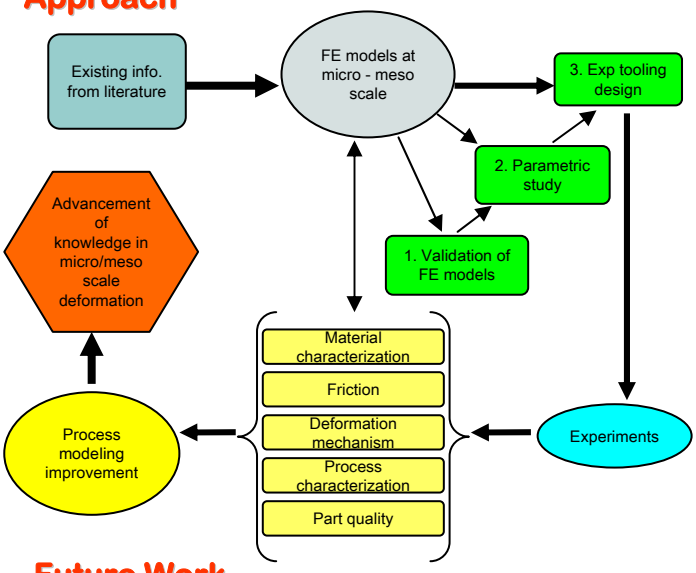
## Objectives

- Develop experimental testing methods and analytical models to understand material behavior at micro-meso scale
- Characterize the friction conditions, surface interactions, and lubrication at micro-meso scale deformation
- Develop predictive process models to characterize the deformation mechanics considering material response, forming forces, failure mechanisms; to facilitate the optimization of process conditions
- Develop guidelines for successful and optimal tooling and part designs

## State-of-the-Art

- Hundreds of micro devices have been employed in a wide array of applications including consumer electronics, medical/biomedical technology, chemical, energy, automotive, and defense and security
- Current micro fabrication technique is based on lithographic technologies, limited to 2D - 2½D and silicon material, and not amenable to mass production
- Microforming possesses an advantage edge in terms of high production rate, 3D features, and a wider range of materials

## Approach



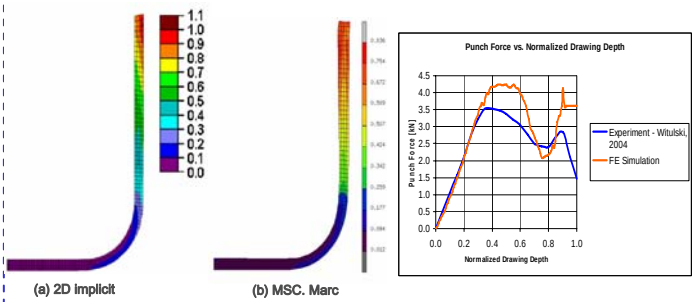

## Future Work

- Experimental tooling design/set up
- Material testing at micro-meso scale
- Friction and surface interactions investigation at micro-meso scale
- Optimum process conditions investigation

## Accomplishments

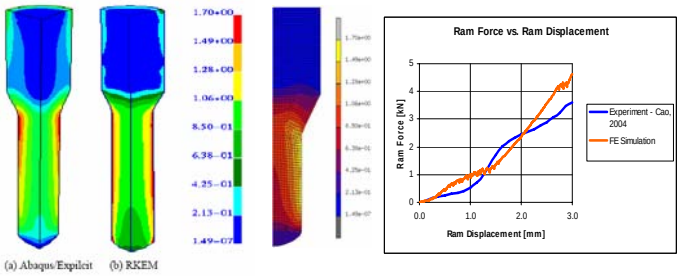
- **Validation of FE models**

✓ N. Witulski, 2004 (CuZn37, 0.3 mm thick)



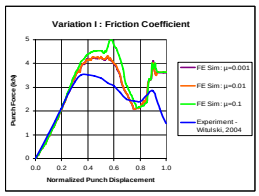

Total equivalent plastic strain

✓ J. Cao, 2004 (CuZn30, Ø1.5 mm billet)

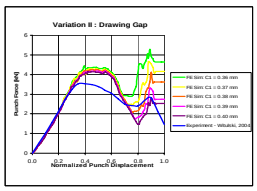



Total equivalent plastic strain

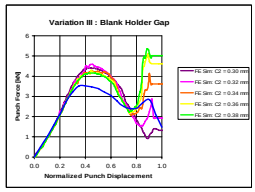
- **Parametric study**




- Higher friction coefficient requires a higher punch force
- Variation of friction coefficient only has a slightly effect on the ironing force




- An increase in drawing gap will slightly decrease the punch force and significantly decrease the ironing force




- An increase in BH gap will slightly decrease punch force (lower friction)
- An increase in BH gap will significantly increase the ironing force (larger BH gap → allow sheet thickening in flange area)

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# Micro/meso-scale sheet forming process using Soft tools

**Research Assistants/Staff:** *Linfa Peng*

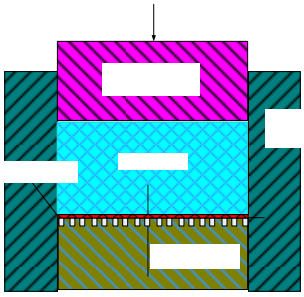
**Faculty:** *J. Ni*

## Objectives

- Investigate feasibility for mass production of micro /meso sheet parts using soft tools.
- Establish a FE model for numerical simulation of micro/ meso sheet forming process.
- Investigate the effects of some key process parameters, such as hardness of soft tools, friction condition.
- Study the effects of the sheet at various grains size.

## State-of-the-Art

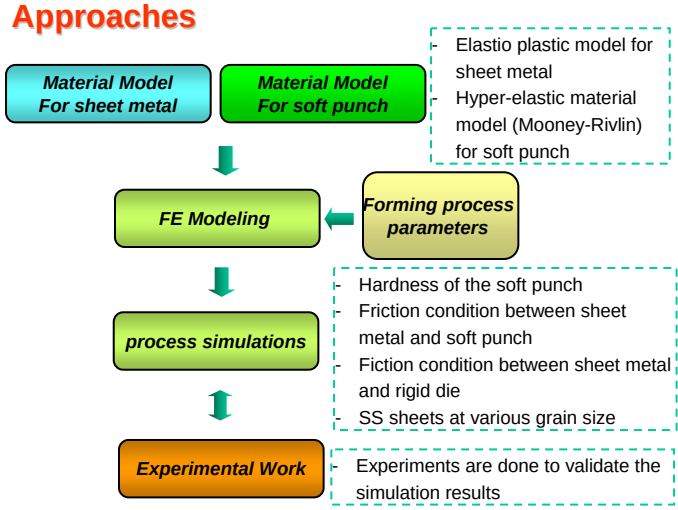
- With minimization, micro-sheet forming is a important process for mass production of micro-sheet parts due to its low cost, small space taking, low energy consumption.
- Micro sheet forming processes by soft punch have many advantages.
- Traditional know-how can not be directly used in the process procedure of soft punch forming in micro /meso scale.
- The defects in the micro /meso forming process is not clear investigate.



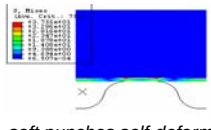
***Micro sheet forming process by soft tools***

- The forming process parameters that play important roles during forming procedure are not fully studied.

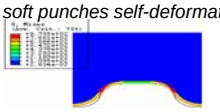
## Approaches



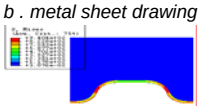

## Accomplishments



*a. soft punches self-deformation*



*b . metal sheet drawing*

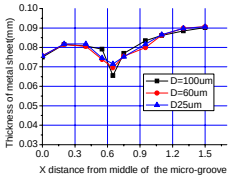


*c . metal sheet filling*

***Sheet forming process simulation***

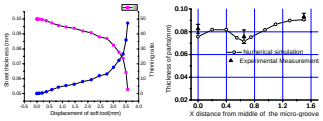
- A simulation FE model for forming process is proposed by using incompressible hyper-elastic model for soft die and discrete rigid element for rigid die.
- The whole micro-groove forming step contains three different stages.
- The most defects in this forming process are crack of the sheet during the second of forming stage.

- Metal sheet at small grain size prone to gain high formability because more grains can take part in the deformation.
- lager friction coefficient between sheet and die may make the sheet thin quickly that decrease the formability

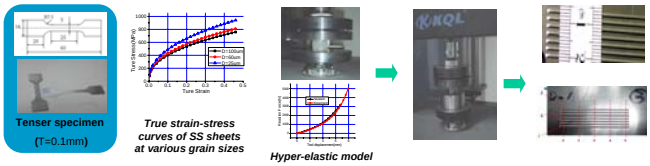



***Final thickness of sheets at various grain size***

- Experiments are done to establish the material model for SS steel sheet.
- Forming experiments validate the simulation results.



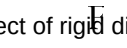
***thickness of sheets formed with good lubrications***




*Material modeling* | *Forming and measurements*

## Future Work

- Establish the model of the grain deformation during the forming process
- Study the effect of rigid die geometry design to the formability.
- Investigate effect of spring-back, improve the quality of the micro/meso sheet parts.

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