

# Nanoscale Ferromagnetic Patterning and Geometric Frustration Imaging with Lorentz Microscopy

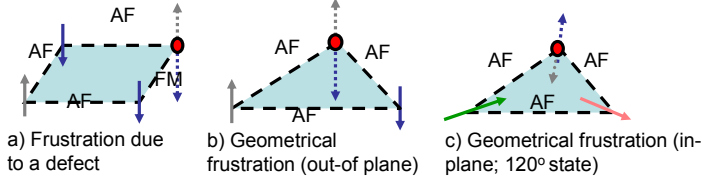
DEPARTMENT OF  
MATERIALS SCIENCE AND ENGINEERING

Nanoscale Imaging  
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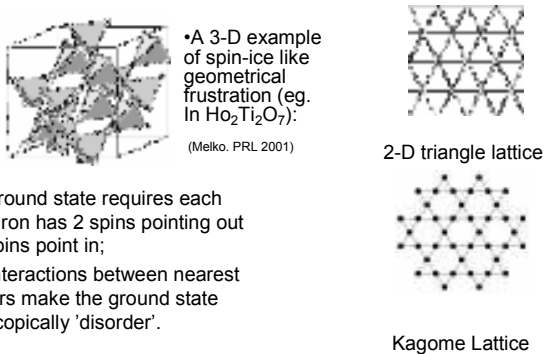
This project uses Lorentz-mode Transmission Electron Microscopy to study magnetic micro-domain structures. Particularly, we are interested in utilizing ferromagnetic Kagome lattices or other patterns to study 'spin ice' like geometrical frustration. Geometrical frustration is a very common feature in condensed matter systems. In some cases, it can be so intense that it induces novel and complex phenomena.

## Geometrical Frustration



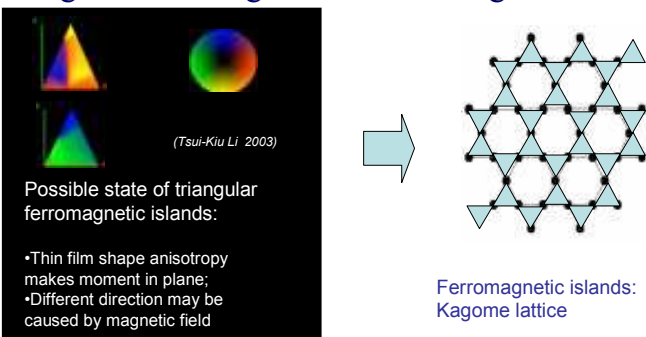
- Frustration: a competition between interactions such that not all of them can be satisfied (Red point in the figures)
- Geometrical frustration: Intrinsic geometry of lattice structure causing frustration (eg. situations in (b) and (c))

## 3-D and 2-D Geometrical Frustration

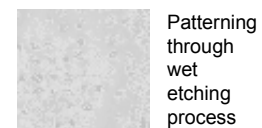
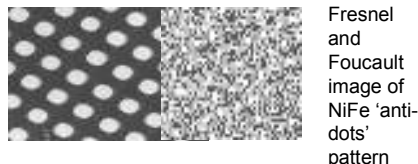


- The ground state requires each tetrahedron has 2 spins pointing out and 2 spins point in;
- The interactions between nearest neighbors make the ground state macroscopically 'disorder'.

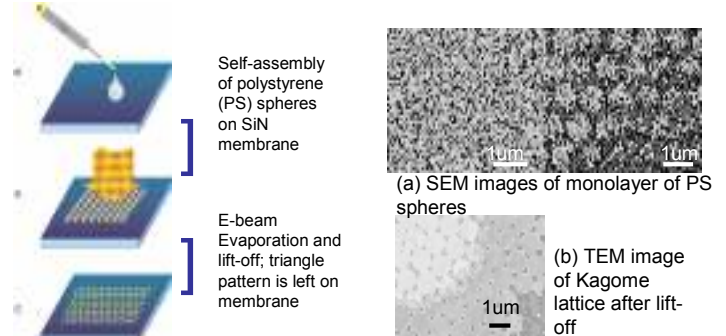
## Geometrical frustration by triangular ferromagnetic islands: Kagome lattice



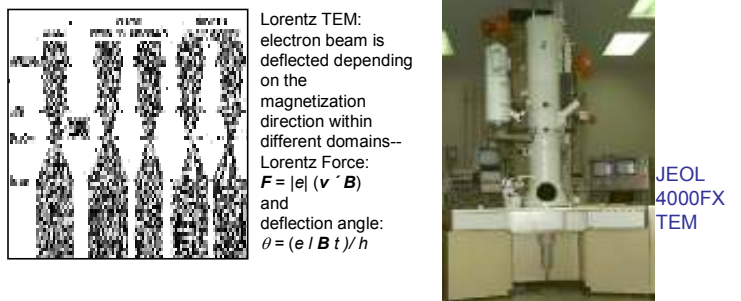
## Other measurements:



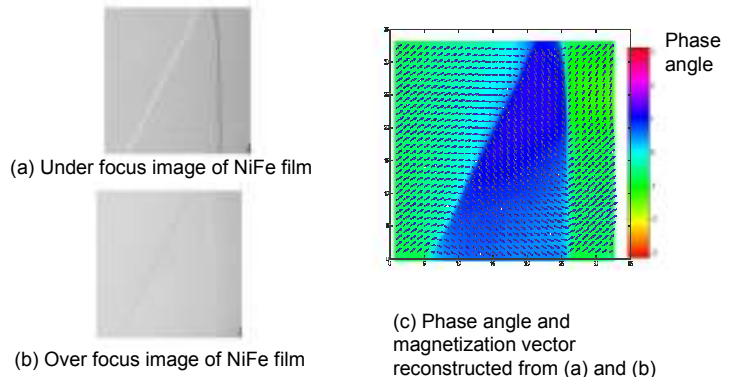
## Fabrication with Colloid Monolayers



## Magnetic domain measurement using Lorentz TEM



## Magnetic structures and Phase reconstruction



## Progress:

- Kagome lattices and other anti-dots pattern were fabricated;
- We are able to use Lorentz TEM to observe magnetic domain structures and quantitatively interpret magnetic moment using phase reconstruction
- We are making progress in fabricating magnetic features at the nanoscale.

