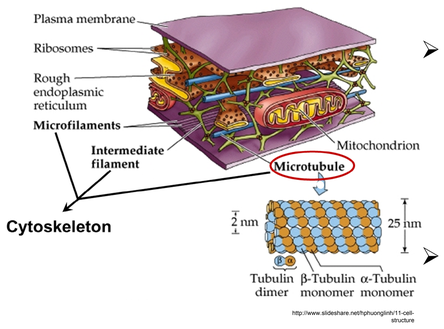
# Transformative Self-assembly of Hybrid Nanocomposite Rings

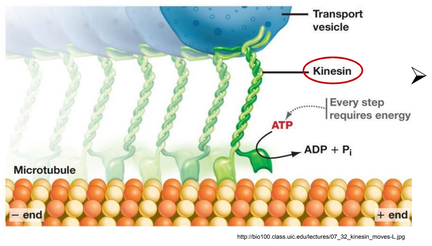
**Haneen Martinez and George D. Bachand**
**Sandia National Laboratories, Albuquerque, NM**

SAND2017-2830C

## Introduction



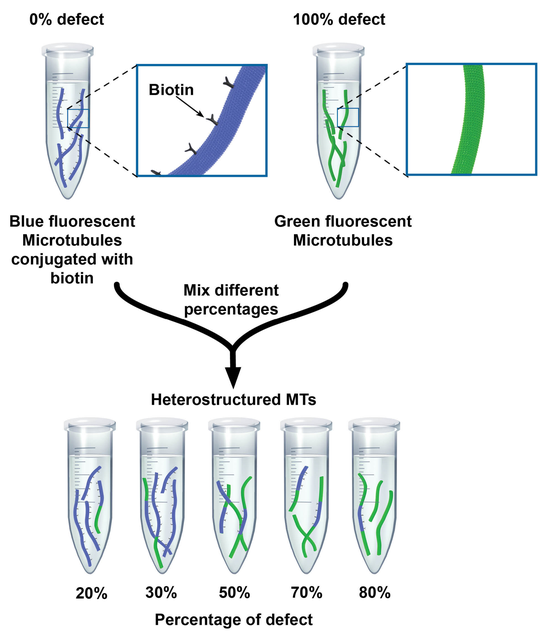

- Microtubules (MTs) are cytoskeletal protein filaments that provide mechanical support for the cell, and serve as "tracks" for motor proteins to transport organelles
- MTs are composed of αβ-tubulin heterodimers (~8nm) that assemble in a "head-to-tail" approach and form a hollow tube, with an outer diameter of ~25nm and various lengths [1,2]




- Kinesin is a microtubule–based motor protein that "walks" along MTs by dissipating chemical energy, with a force of ~ 40 pN nm and efficiency of ~50% [3]

**Dynamic self assembly involving the kinesin-MT system has been used to assemble ring nanocomposites. However, a deeper understanding of active assembly in the presence of defects is much needed in order to develop self-regulating materials**

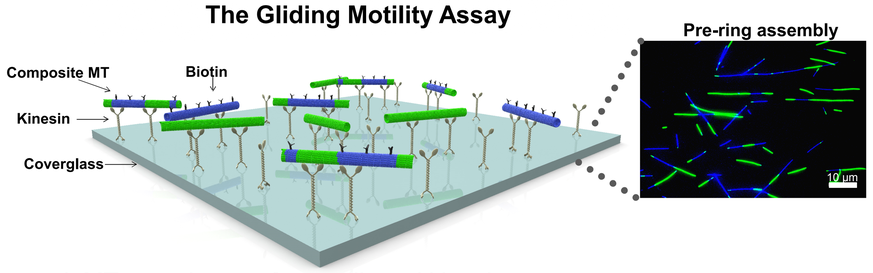
## Approach



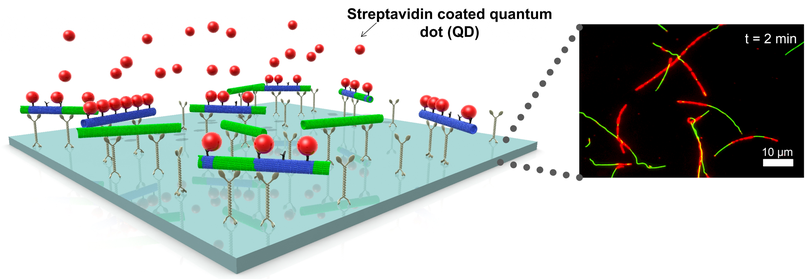

- Heterostructured MTs were formed by manipulating MT building blocks through mixing of biotinylated (blue) and non-biotinylated (green) MTs at different percentages
- Biotinylated blue MT segments serve as the major platform for binding streptavidin-coated quantum dots (QDs) and assembling nanocomposite rings
- Non-biotinylated **green MT** segments act as "**defects**" since they lack biotin, an essential component for active self-assembly of nanocomposite rings

## Formation of composite rings

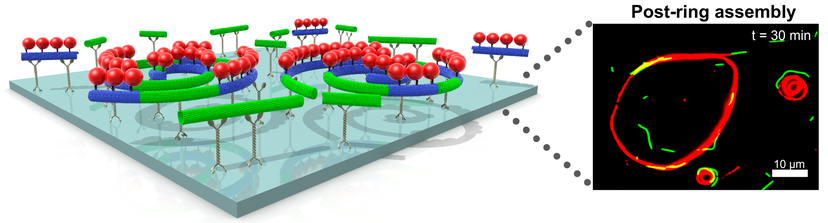
**The Gliding Motility Assay**




i. MTs attach to surface- adhered kinesin motors

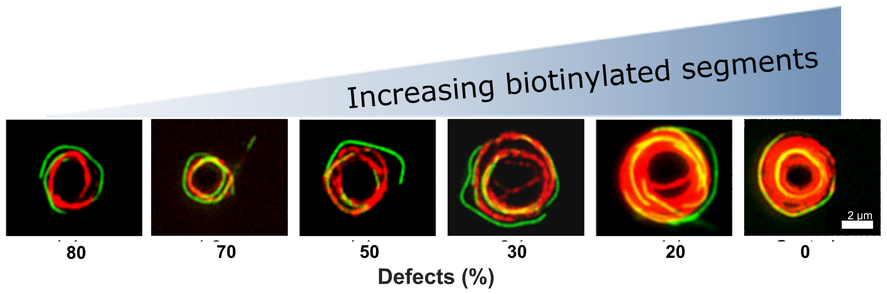



ii. Non-covalent biotin-streptavidin bonds form between blue MTs and QDs



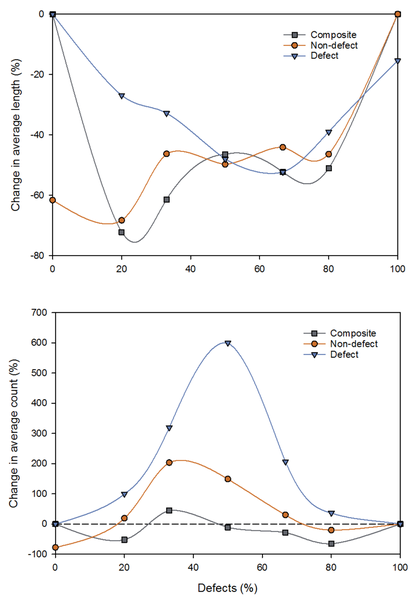

iii. Motor-propelled MTs cross link and form composite rings

## Evolution of ring structure




- Morphology of rings depend on the relative concentration of non-defected segments (i.e. red QDs attached to blue MTs), where structures evolve from open loop to tightly packed rings as more non-defected MTs are available

## MT count and length




- Change in average length and count for linear MTs were determined as:

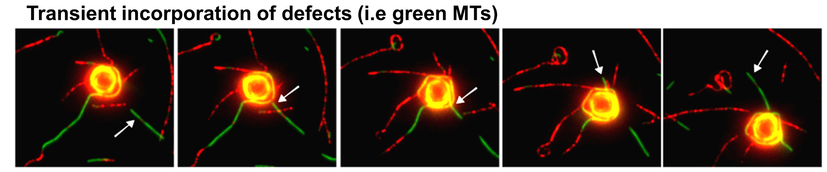
$$\Delta\% = \frac{\text{Final}_{C,L} - \text{Initial}_{C,L}}{\text{Initial}_{C,L}} \times 100$$

(C= count, L=length)

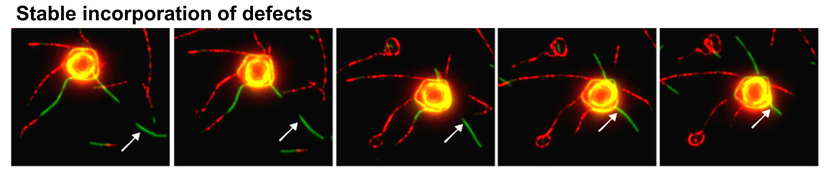
- Reduction in length was independent of defect presence. However, defected MTs were preferentially released from ring structures

## MT incorporation into nanocomposite rings

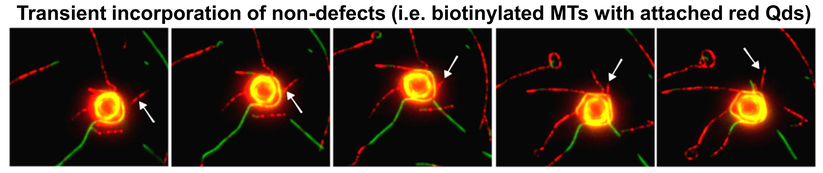
**Transient incorporation of defects (i.e green MTs)**



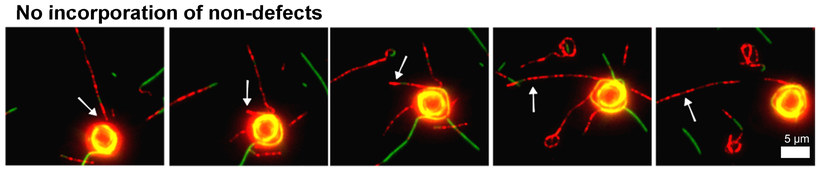
**Stable incorporation of defects**

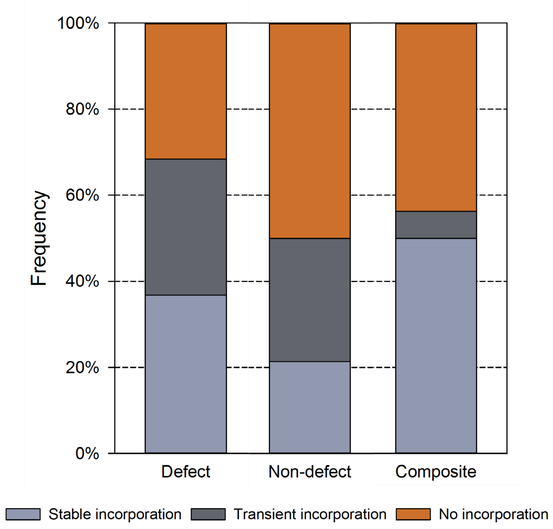


**Transient incorporation of non-defects (i.e. biotinylated MTs with attached red Qds)**



**No incorporation of non-defects**




- Defected MTs incorporated into ring structures frequently, while saturation of biotin-streptavidin bonds reduced integration of non-defect MTs

## Conclusions

- Hybrid nanocomposite rings were formed by altering MT composition to produce composite MTs with varying percentage of "defects"
- Structurally induced defects in MTs initiated self-repair that influenced morphology of rings via incorporation and release of MTs from nanocomposite rings
- Results provide a better understanding of the dynamic self-assembly and adaptability of hybrid nanostructures needed for future development of self-regulating nanostructured materials

**References:**
[1] Bachand et al., (2014). *RSC Adv.* **4**, 54641-54649
[2] Liu, H. and Bachand, G.D. (2011). *Soft Matter,***7**, 3087-3091
[3]Liu et al.,(2008). *Adv. Mater.* **20**, 4476-4481

This work was supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering (BES-MSE)