CATALYST ENHANCED MICRO SCALE BATCH ASSEMBLY

Rajashree Baskaran[1, 2], Ji Hao Hoo[1], Bowen Cheng[1], and Karl F. Böhringer[1]

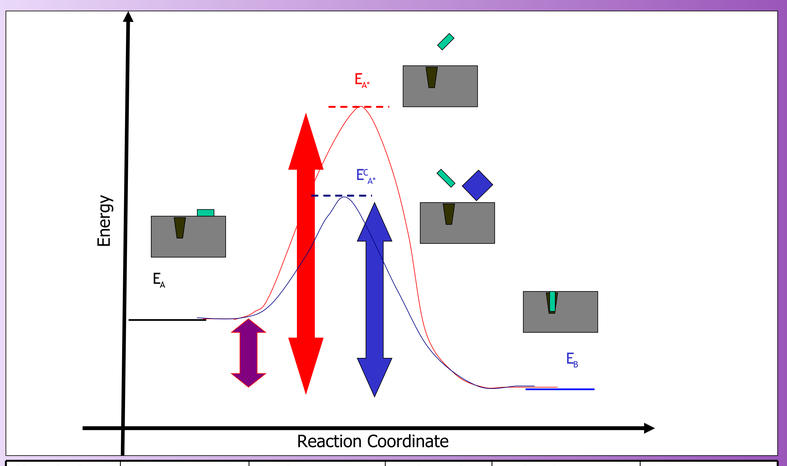
[1]Dept. of Electrical Engineering, University of Washington, WA, USA,

[2]Components Research, Intel Corporation, Chandler, AZ, USA

Abstract

We enhance the efficiency of assembly of microparts in batch dry assembly methods studied previously by our group. Here we study the system dynamics with the addition of a few non-participating millimeter scale parts that act as 'catalysts'. We present experimental results that show 25-50% reduction in acceleration needed to trigger part motion and up to 4 times increase in concentration of parts in motion due to addition of catalysts. We adapt a model from chemical kinetic theory to understand our system behavior.

Analogy with Chemical Kinetics



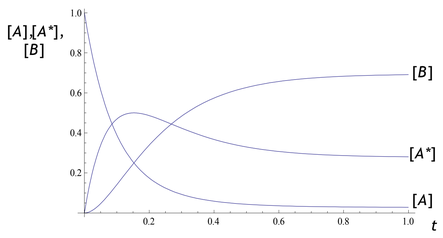
Chemical reaction	Reactant Concentration	Product Concentration	Activated Reactant	Activation Energy/ Threshold Energy	Temperature
A --> A* --> B	[A]	[B]	[A*]	E_A potential barrier	T
Micropart dry assembly	# of parts in a given assembly box outside the assembly site	# of parts assembled in site	# of parts in air (parts jumping)	Minimum acceleration of stage to overcome part van der Waal forces	Acceleration of assembly box

- Reaction: $A \underset{K_{A^*A}}{\overset{K_{AA^*}}{\Leftrightarrow}} A^* \underset{K_{BA^*}}{\overset{K_{A^*B}}{\Leftrightarrow}} B$

- ODE:
$$\begin{cases} \frac{d[A]}{dt} = [A^*]K_{A^*A} - [A]K_{AA^*} \\ \frac{d[A^*]}{dt} = [A]K_{AA^*} + [B]K_{BA^*} - [A^*](K_{A^*A} + K_{A^*B}) \\ \frac{d[B]}{dt} = [A^*]K_{A^*B} - [B]K_{BA^*} \end{cases}$$

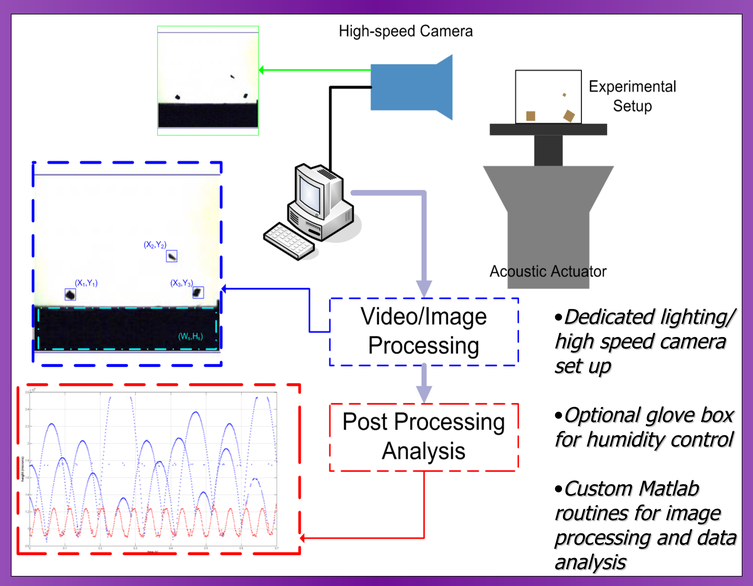
- Equilibrium:
$$\begin{cases} [A]K_{AA^*} = [A^*]K_{A^*A} \\ [A^*]K_{A^*B} = [B]K_{BA^*} \\ [A] + [A^*] + [B] = \text{const} \end{cases}$$

- At t=0, $[A] = 1$, $[A^*] = [B] = 0$
- $K_{AA^*} = 10$, $K_{A^*A} = 1$, $K_{A^*B} = 5$, $K_{BA^*} = 2$

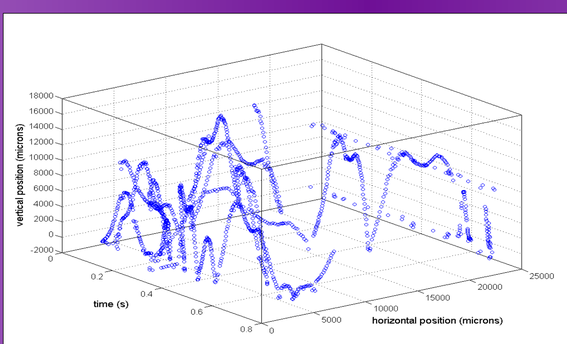


Experimental Setup and Data Collection/Analysis Capabilities

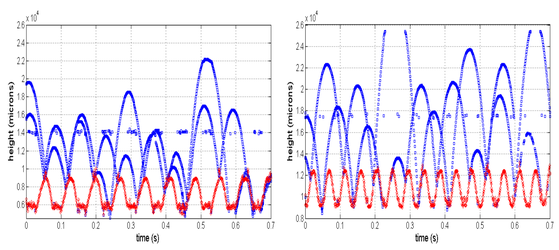
- Parts (800x800x50μm³) and catalysts (2x2x.5mm³) are made respectively from SOI/silicon wafers using standard lithography and DRIE etching.
- High speed camera is used to capture part motion
- Dedicated Matlab routines were developed for image processing and subsequent data reduction



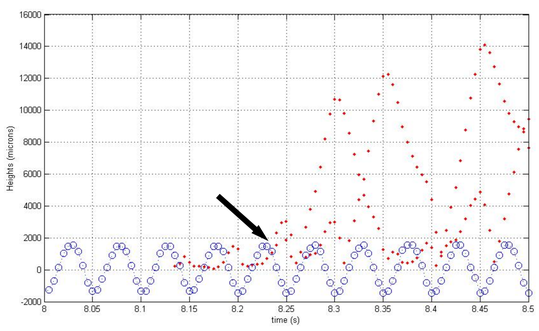
- *Dedicated lighting/ high speed camera set up*
- *Optional glove box for humidity control*
- *Custom Matlab routines for image processing and data analysis*



Spatio-temporal Motion Visualization

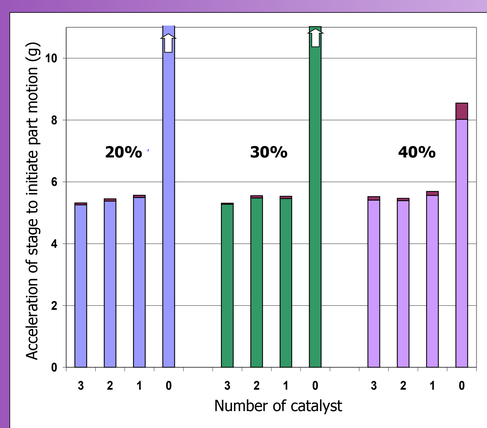


Effect of frequency of stage on parts motion



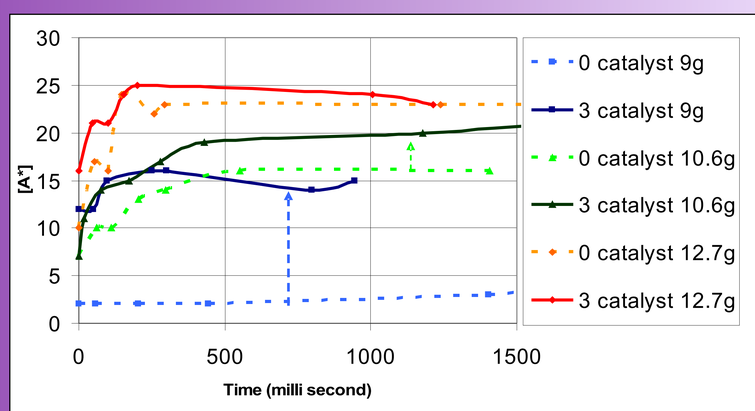
Two parts initially in contact and moving as one, separates

Results



- *Without 'Catalysts', the average external energy required to initiate part motion depends on the part density (chances of overlap of parts)*
- *With catalysts, the initiation is mainly a function of the catalyst vdW force and NOT dependent on part density*

Average (standard deviation on top of each bar) acceleration (in 'g') of the stage required to initiate part motion for different total number of parts in a given area.



Experimentally observed elementary transitions

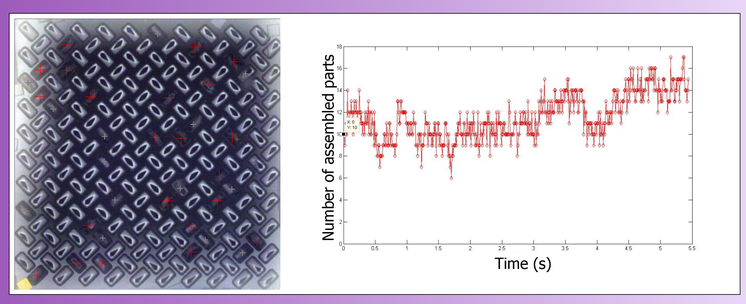
$$A \rightarrow A^*$$
$$A^* + A \rightarrow 2A^*$$
$$A + C \rightarrow A^* + C$$

Arrhenius Equation: how temperature affects reaction rates. Results above shows the effect of catalyst is equivalent to increasing 'T' of reaction.

$$K \propto e^{\frac{-\Delta E}{RT}}$$

Conclusion

- 'Catalyst' is a promising new concept in dry self-assembly
- Infrastructure for automated assembly analysis is developed
- Chemical Kinetics analogous models and empirical data are available
- Future developments include automated accounting of assembly in assembly sites



Acknowledgements

- This work was supported by research grants from Intel Corporation.
- Authors thank the feedback and assistance from members of UW-MEMS Lab.

Please also visit related works from our group: posters number 225M and 221M.

UNIVERSITY OF WASHINGTON