

# Laser-assisted growth of carbon nanotubes : control, modeling, optimization growth kinetics, applications

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# Laser-assisted growth of carbon nanotubes

control, modeling, optimization  
growth kinetics, applications

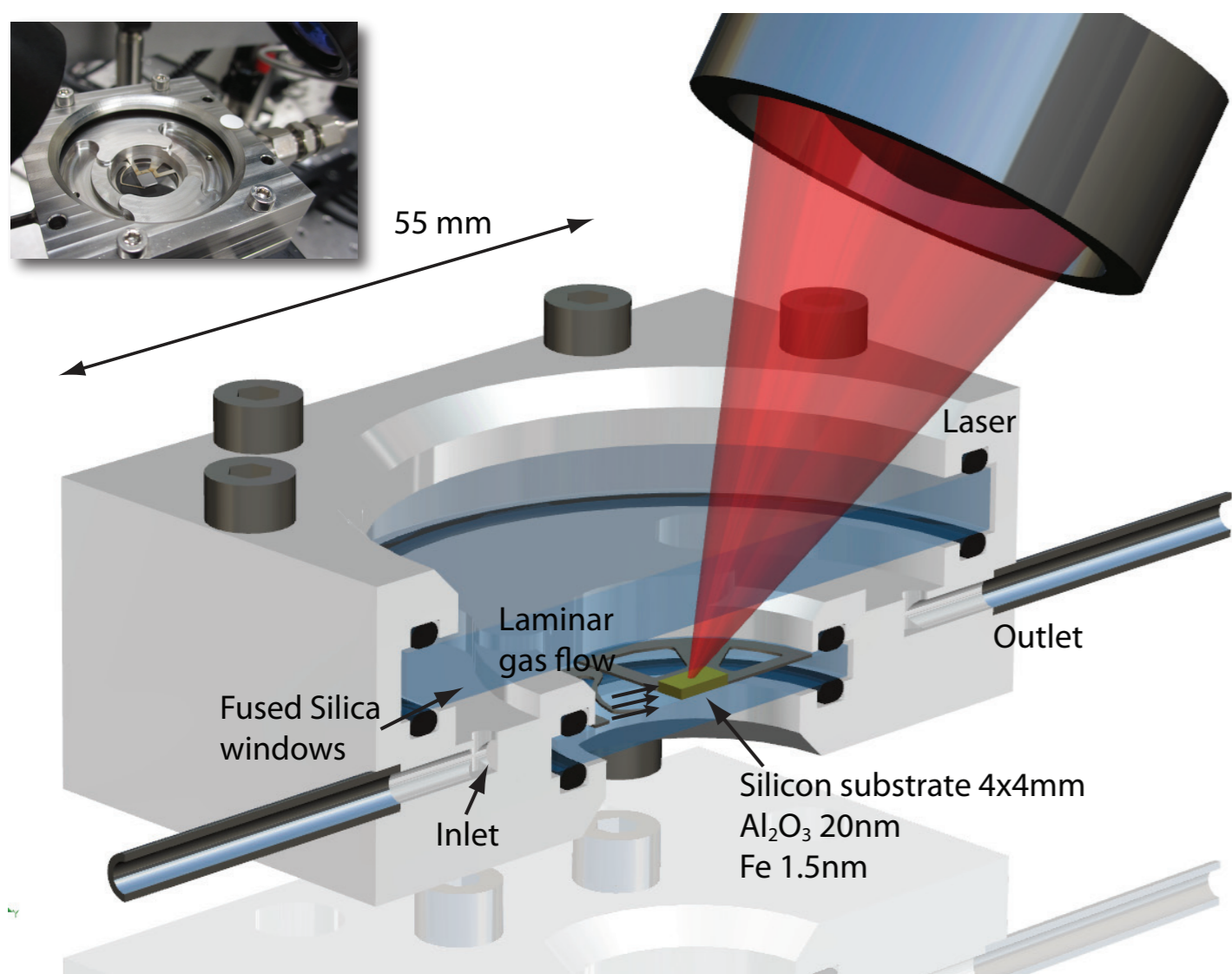
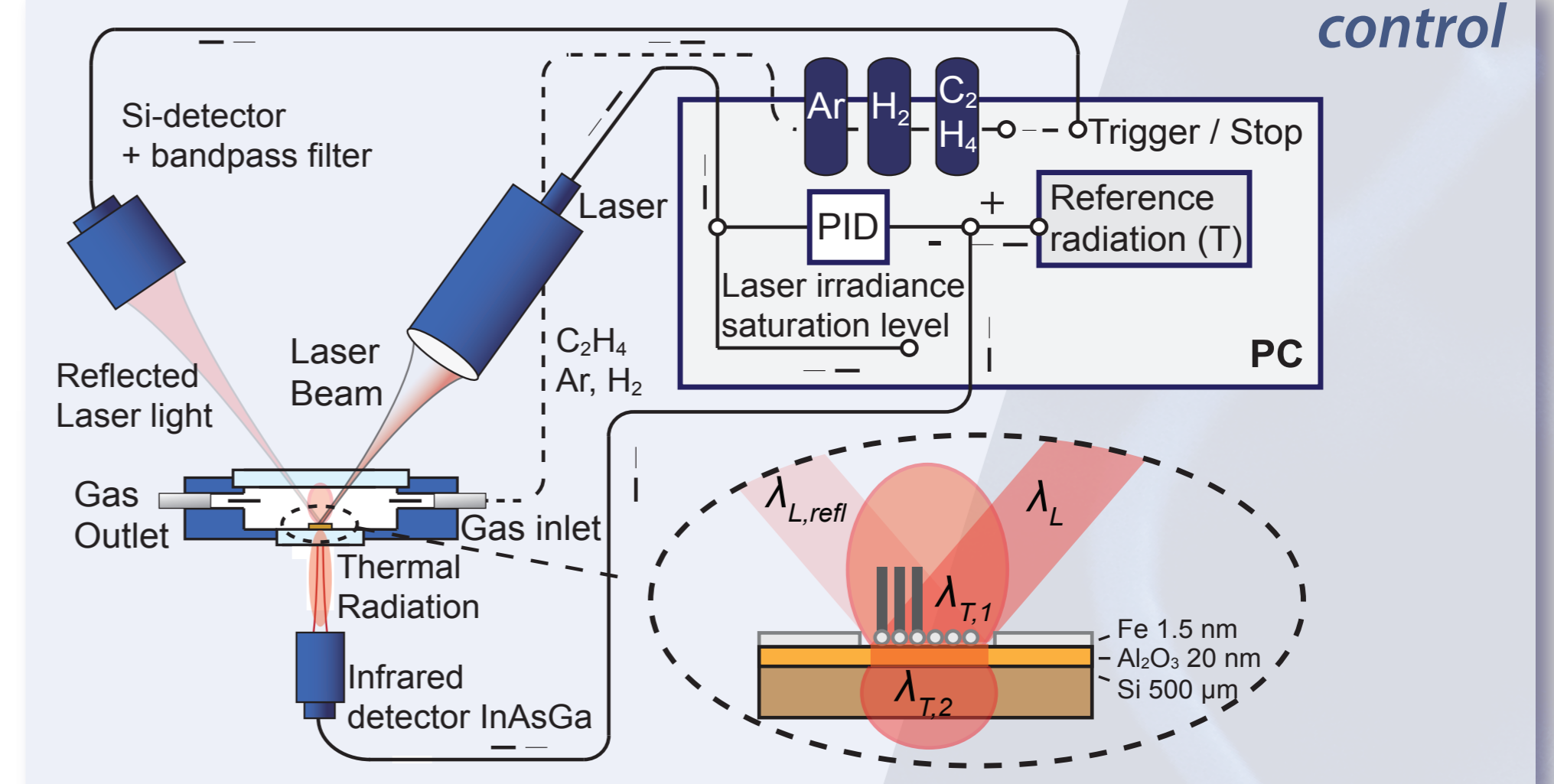
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Yves Bellouard  
Rajesh Mandamparambil  
Jaap den Toonder

## Introduction

The fast localized growth of carbon nanotube structures has potential applications such as interconnects, field emitters and sensors but temperature evolution and process monitoring over time are often unavailable.<sup>1</sup> Process is difficult to **control**.<sup>2</sup>

Optimization can be achieved by better understanding **growth kinetics** and catalytic mechanisms.

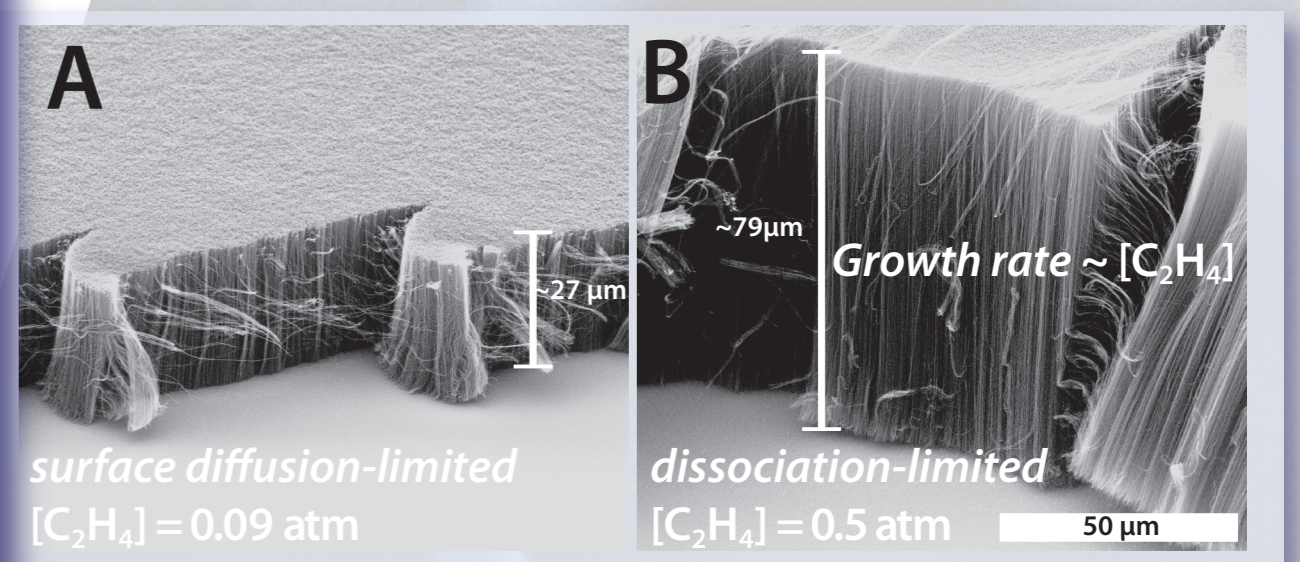
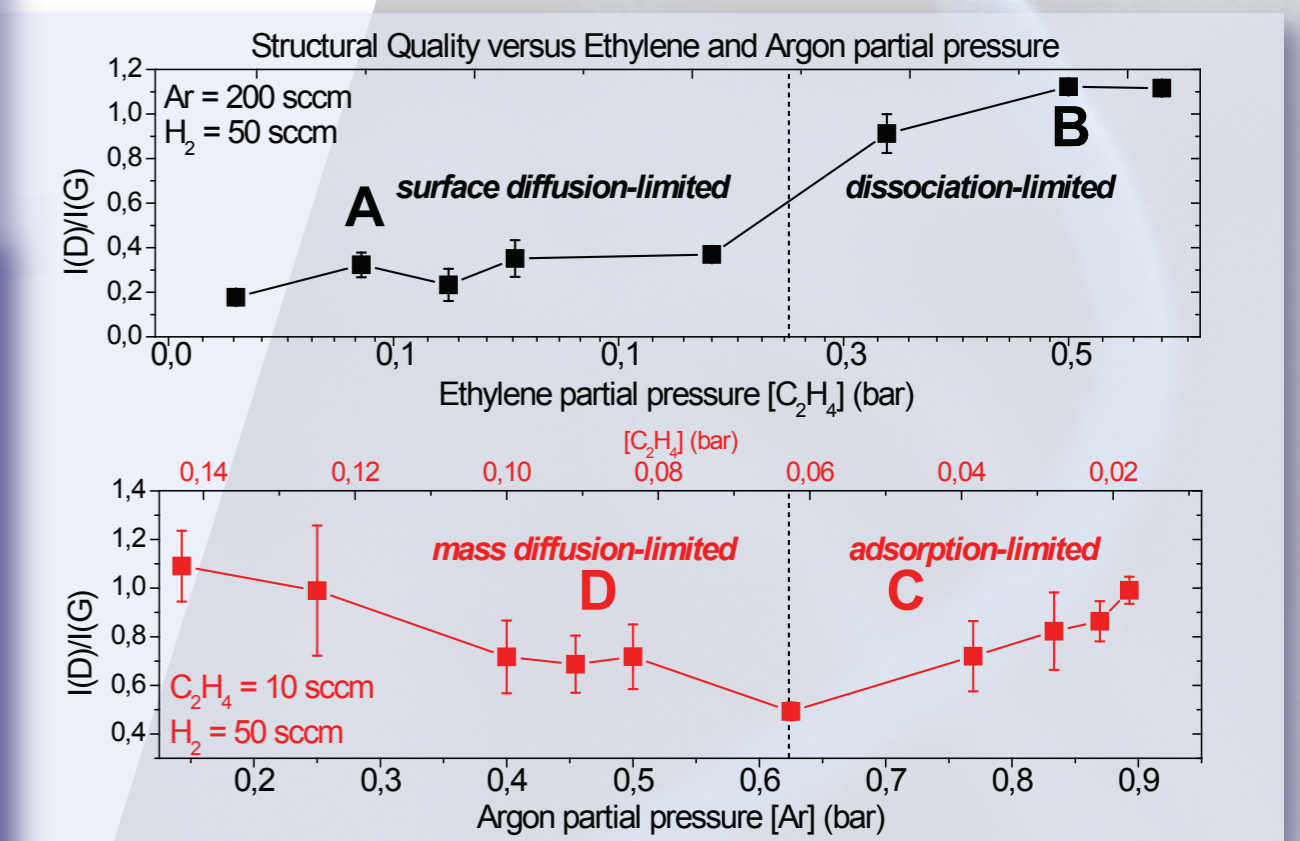
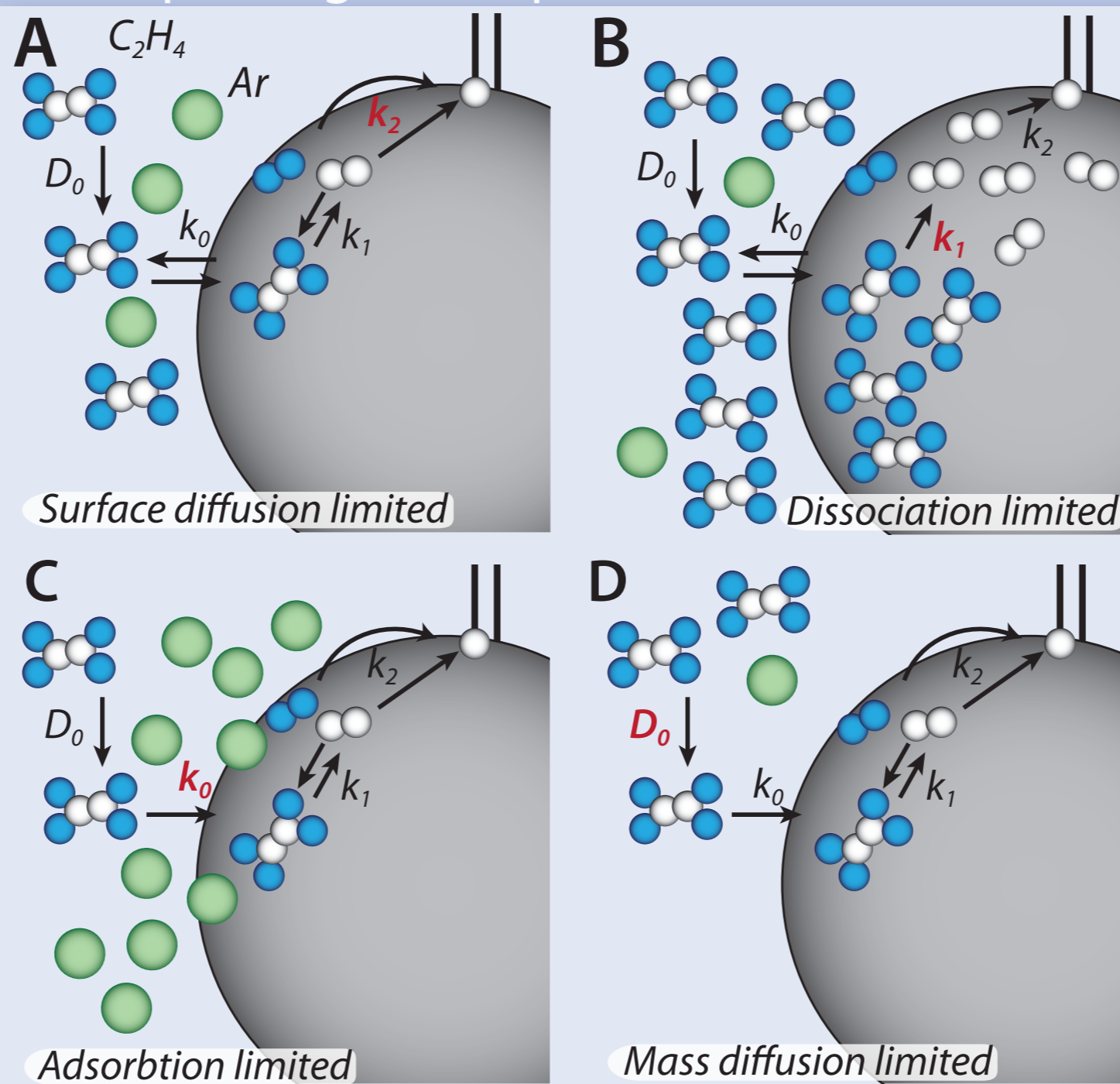
**Miniaturized reaction chamber**<sup>3</sup> for precise control of the composition of the laminar flow of process gases to study growth kinetics.



## Growth Regimes

## growth kinetics

Linked to rate-limiting mechanisms for specific gas composition

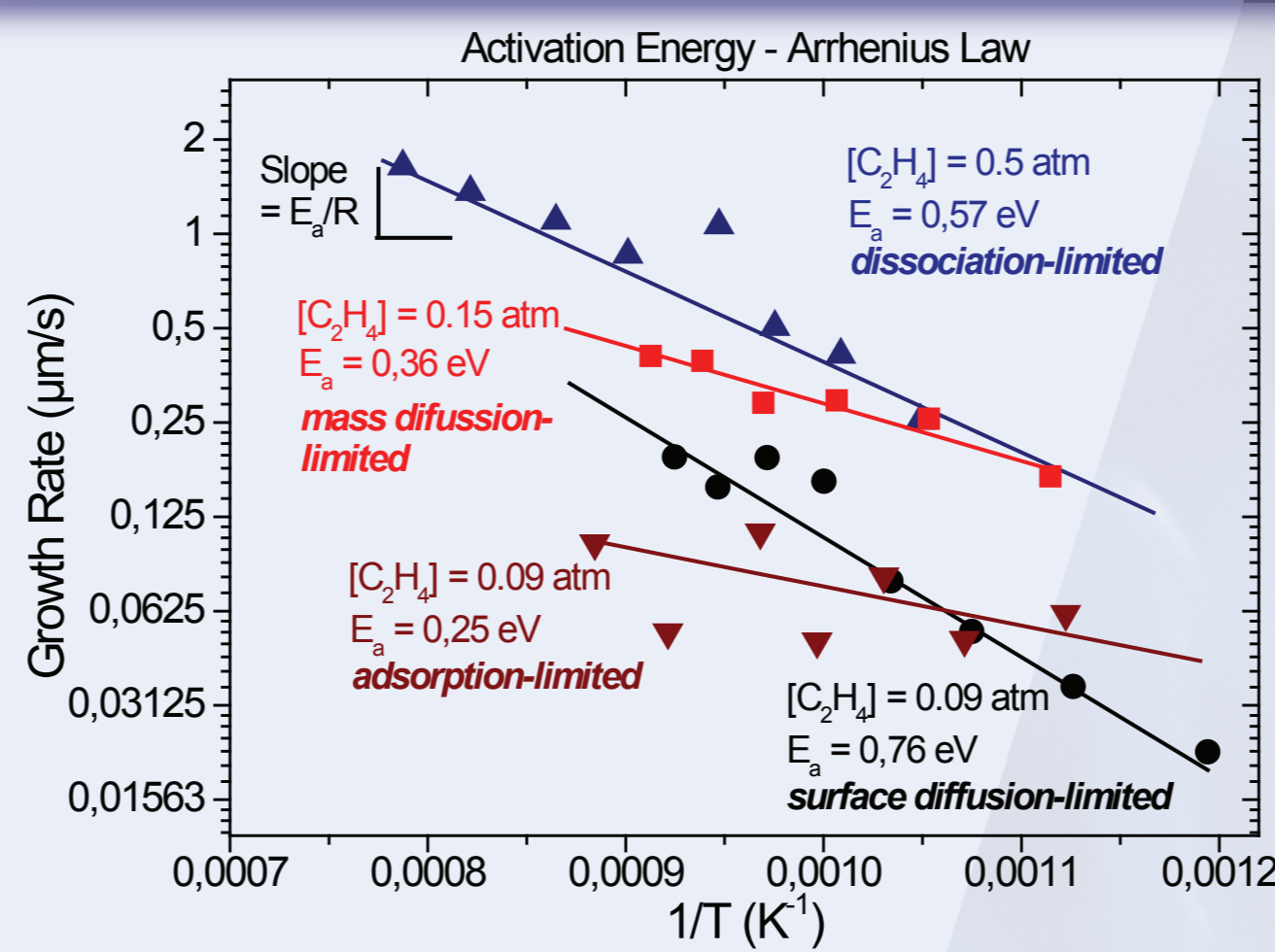
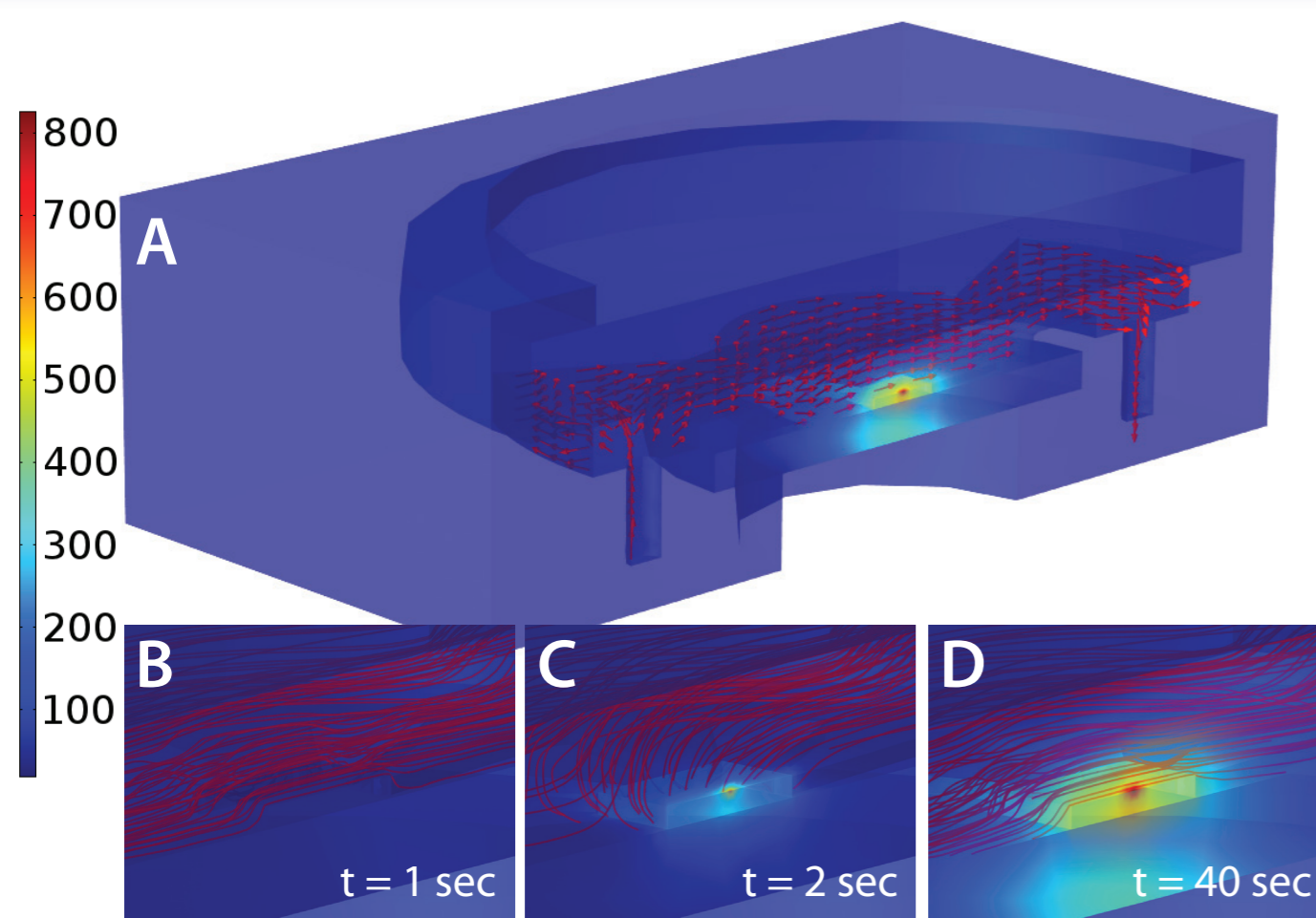


## Thermal Model

## modeling

Heat and flow coupled simulation **evaluates** forced and natural convection as a function of input parameters such as gas flow and laser irradiance.<sup>3</sup>

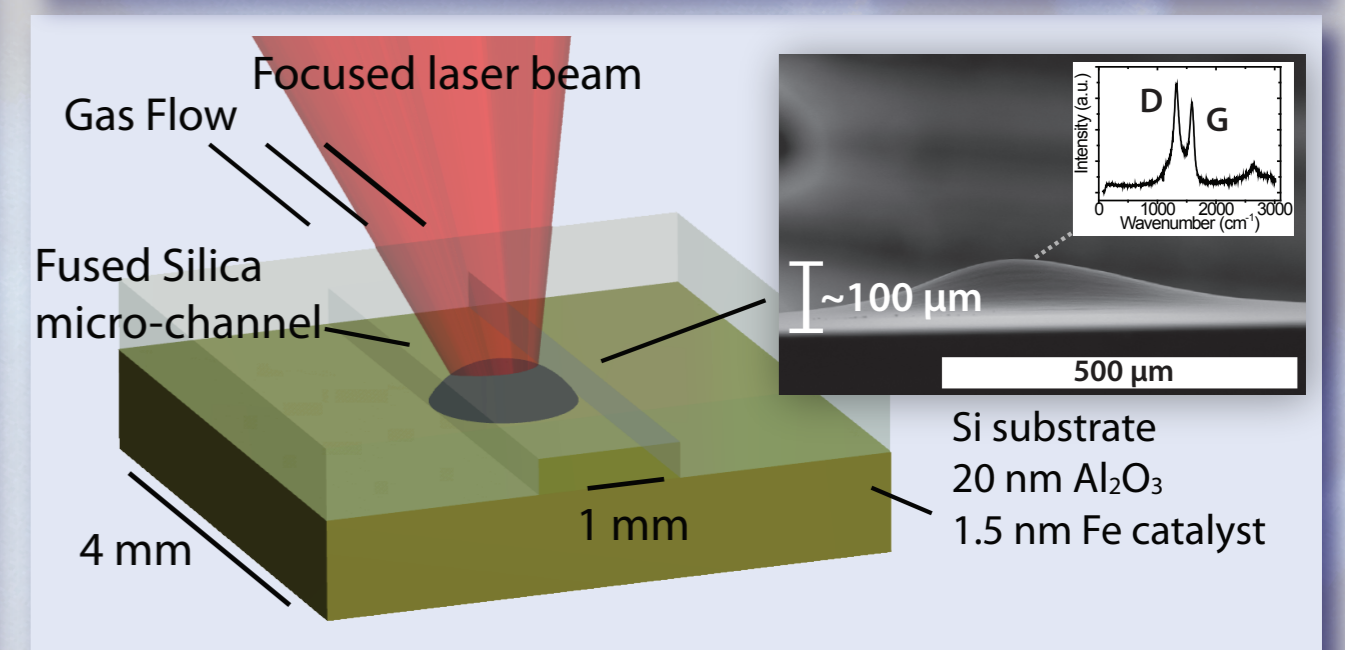
Radiation linked to temperature



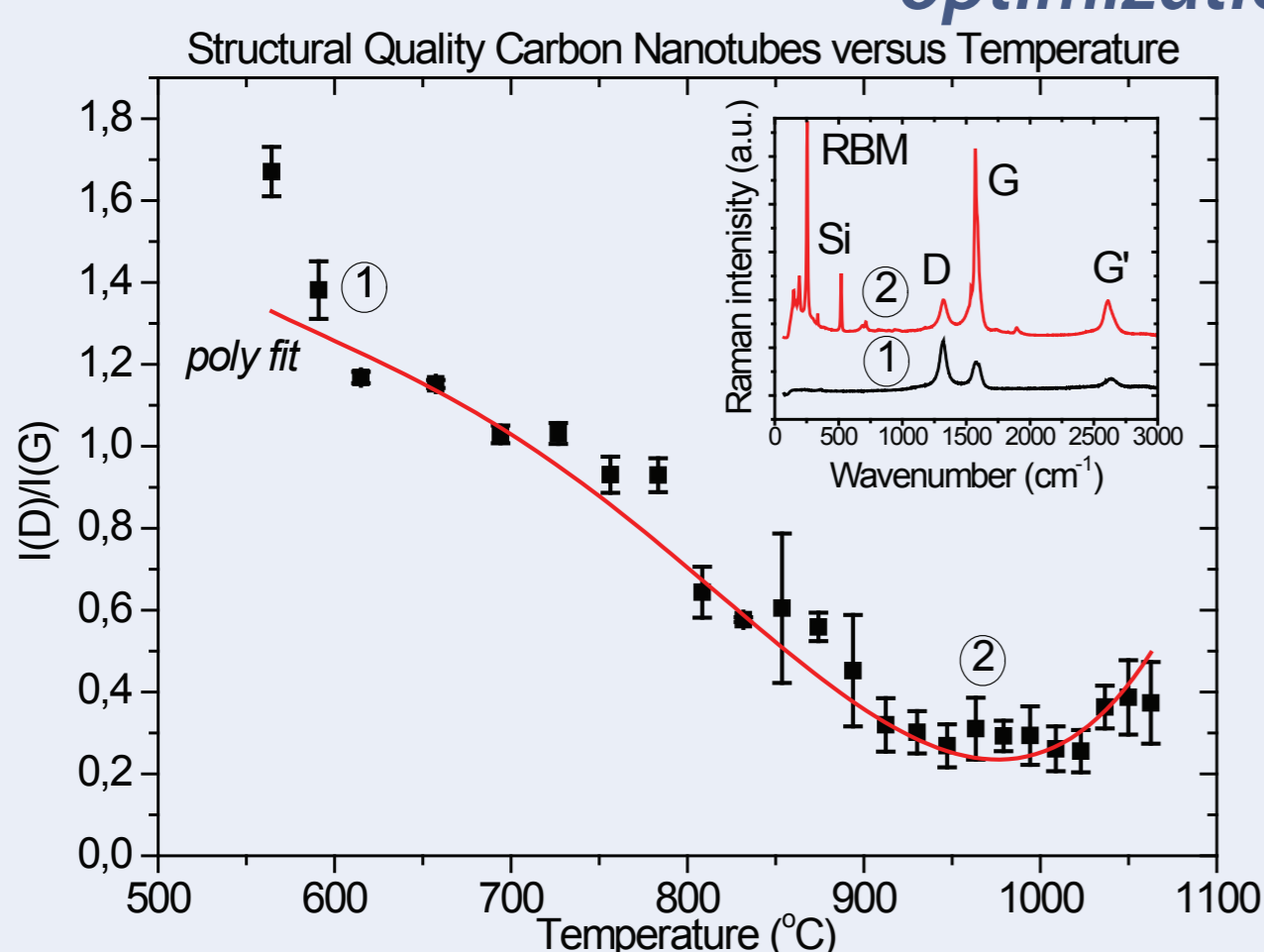
## Channel growth

## applications

Direct local growth inside a partially sealed micro-channel.<sup>4</sup>



## optimization



## Conclusions

Rapid and **controlled** growth of local carbon nanotubes using **miniaturized** reaction chamber

Temperature evaluation using FEM, structural optimization

Investigation of growth **kinetics** and **rate-limiting** mechanisms

Local growth inside **micro-channel**

## Outlook

Dynamical evaluation of growth rate using absorbance spectrum

Femto-second laser patterning of catalyst and carbon nanotubes

Further optimization

1. Haluška *et al.* Nanotechnology 21, (2010).
2. van de Burgt *et al.* J. Appl. Phys. 112, (2012).
3. van de Burgt *et al.* Proc. LPM (JLPS), (2013).
4. van de Burgt *et al.* AIP Adv. 3, (2013).