83

TUNING NANOPARTICLES SIZE VIA MICROCHANNEL GEOMETRY

MAHMOUD ABDELKARIM[1], NOURA H. ABD ELLAH[2], MAHMOUD ELSABAHY[3], MOHAMED ABDELGAWAD[1,4*] AND SARA A. ABOUELMAGD[2,5*]

[1]MECHANICAL ENGINEERING DEPARTMENT, FACULTY OF ENGINEERING, ASSIUT UNIVERSITY, ASSIUT, EGYPT; [2]DEPARTMENT OF PHARMACEUTICS, FACULTY OF PHARMACY, ASSIUT UNIVERSITY, ASSIUT, EGYPT; [3]SCIENCE ACADEMY, BADR UNIVERSITY IN CAIRO, BADR CITY, CAIRO, EGYPT; [4]DEPARTMENT OF MECHANICAL ENGINEERING, AMERICAN UNIVERSITY OF SHARJAH, SHARJAH, UAE; [5]DRUG RESEARCH CENTER, ASSIUT UNIVERSITY, ASSIUT, EGYPT.

CONTACT INFORMATION: sabouelm@aun.edu.eg

Objective

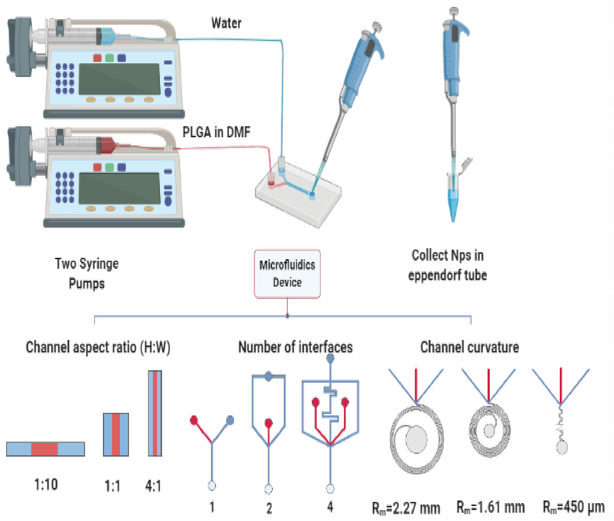
Nanoprecipitation is a popular method for formation of polymeric nanoparticles (NPs). However, it suffers from size-heterogeneity and polydispersity due to the slow and uncontrolled mixing time. Microfluidics allow flexible tuning of the fluid mixing time; thus, providing a great control over NP formation[1-2]. However, minimum attention has been given to the effect of channel geometry on nanoprecipitation process.

Objective: tuning the size of NPs by changing the channel geometry (aspect ratio, number of interfaces, channel curvature) without change the flow configuration

Method

Streams of deionized water and poly (lactic-co-glycolic acid) (PLGA) dissolved in DMF with concentration 5 mg/ml were injected into the microfluidic platform to merge in the main microchannel where NP synthesis took place via nanoprecipitation.

Channel cross section area was fixed at ~6400 μm^2 with channel length 1 cm and a flowrate ratio (FRR) (PLGA in DMF : Water) of 5:1.



Results

1- Channel Aspect Ratio (H:W)

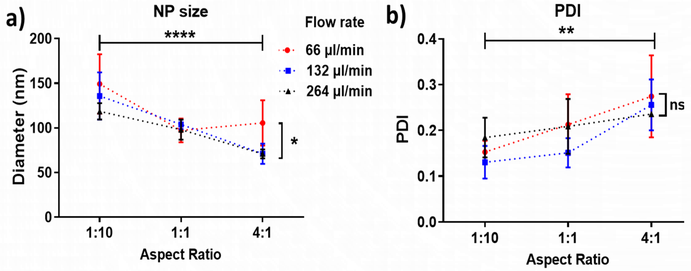


Figure 1: Effect of aspect ratio (height : width=4:1, 1:1 or 1:9) at different total flowrate (FR) on a) NP size and b) PDI. NP size decreased with increasing aspect ratio, but the PDI increased. Change in FR has the least significant effect on NPs size and no significant change was observed in PDI.

2- Number of Interfaces

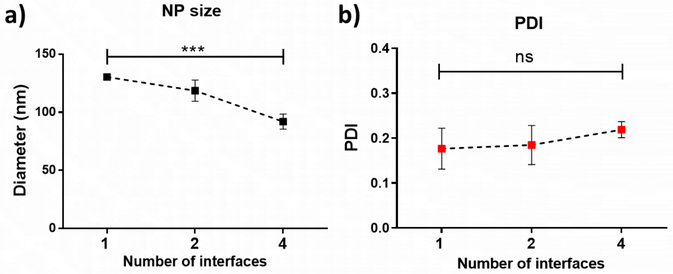


Figure 2: Effect of number of interfaces (1, 2 or 4) on a) NP size and b) PDI. Aspect ratio was fixed at 1:9, while total flowrate was fixed at 264 μl /min (to avoid pulsating flow); NP size decreased with increasing aspect ratio, but the PDI remained unaffected.

3- Channel Curvature

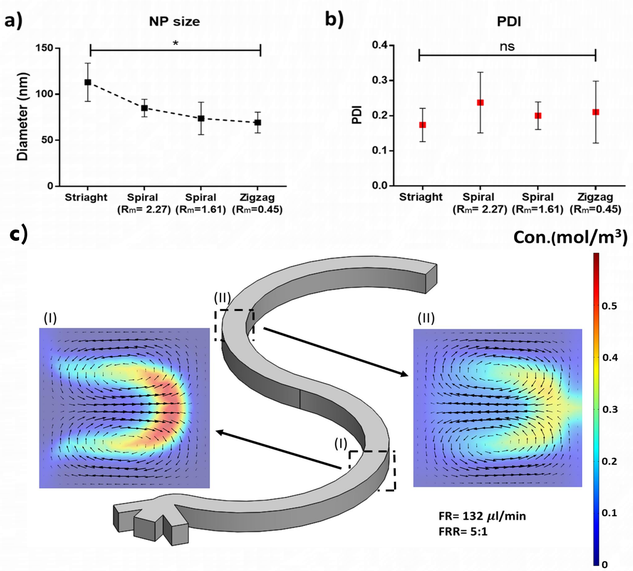


Figure 3: NPs a) size and b) PDI for channels with different geometries. NP size decreased with the reduction in radius of curvature (R_m) and the consequent increase in the average velocity of Dean flow , while PDI was not affected, c) The concentration distribution within a wavy channel and the generated Dean flow (numerical simulation using COMSOL Multiphysics 5.4); (I), (II): simulation results showing the concentration distribution and the two counter vortices that enhance mixing. Microchannel cross section area (h×w=80×80 μm) and FR was fixed at at 132 μL/min .

4- Drug Loading

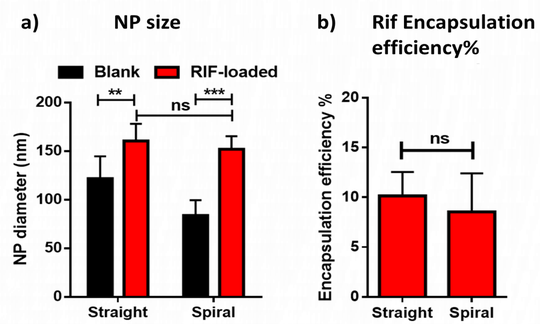


Figure 4: Effect of RIF loading on the nanoprecipitation in straight vs spiral channels (R_m=1.61). PLGA NPs a) Size was significantly affected by introduction of RIF for both channel shapes, while PDI remained unaffected. b) RIF encapsulation efficiency (EE%) was not affected by channel shape. FR was fixed at 132 μL/min.

Conclusion

Modification of channel geometry enabled tuning of NPs' size using simple designs that can be easily adapted. Here, microchannel aspect ratio, curvature, and number of solvent/anti-solvent interfaces were examined for controlling the mixing time, and consequently, the particle size of PLGA NPs. These parameters can be adapted instead of flow parameters (flow rate and flow rate ratio) in situations where the latter cannot be altered. Moreover, we examined how drug loading affects properties of NPs prepared in microchannels of different designs, where rifampicin (RIF) was used as a model drug. RIF loading increased particle size for NPs prepared in both straight and spiral channels, but RIF encapsulation efficiency was not affected by channel shape.

References

[1] Rai, R., et al., Polymers, 2019. 11(4): p. 745-745.

[2] Kamaly, N., et al., Chem Soc Rev, 2012. 41(7): p. 2971-3010.

Acknowledgment

This work was supported by an internal funding grant from Faculty of Engineering and Faculty of Pharmacy, Assiut University, Assiut, Egypt. The clean room of Assiut University was established through grant #4918 from the Science and Technology Development Fund (STDF).