DOI 10.5162/SMSI2020/B3.4

Synthesis of MIP Nanoparticles for Selective Sensing of Penicillin V

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Summary:

Molecularly imprinted polymers (MIP) based on an acrylic system have proven useful for sensing Penicillin V in aqueous solvents by the means of quartz crystal microbalances (QCM). Herein we carry that concept further by synthesizing MIP nanoparticles as sensitive matrices. This preliminary study discusses the effects of different parameters, namely solvent type and cross-linker amount, on the morphology of nanoparticles, i.e. particle size, polymer agglomeration and porosity. Overall, this resulted in particles with 300 nm diameter synthesized with trimethylolpropane trimethacrylate (TRIM) in both acetonitrile and methanol. The results indicate narrower size distribution in acetonitrile.

Keywords: Penicillin V, Molecularly Imprinted Polymer, Quartz Crystal Microbalance, Polymer Nanoparticles

Introduction

Most pharmaceuticals are deposited in the environment through human consumption and excretion, and are often filtered ineffectively by municipal sewage treatment. Persistence of pharmaceuticals and active drugs in wastewater are detrimental, because they are not only potential environmental pollutants, but are also pharmaceutically active. They also have the potential to accumulate in soil and plants that have been irrigated with wastewater and reclaimed water. Especially antibiotics are considered harmful for promoting the development of the antibiotic-resistant bacteria in nature. Various analytical techniques can be utilized for measuring concentrations of antibiotics in wastewater effluent. Molecular imprinting is a comparably recent method for generating artificial recognition matrices toward both biological and synthetic species. Combined with suitable transducers, e.g. QCM, they allow for rapid and reproducible measurement [1]. The project underlying this presentation aims at sensing the antibiotic Penicillin V (Pen V) with both MIP nanoparticles and bulk MIP via QCM measurements. During the first stage, we studied corresponding MIP thin films based on radical polymerization of acrylic monomers. QCM sensor characteristics revealed limit of detection at 0.02 mg/ml. Selectivity was investigated against Penicillin G and Amoxicillin, which have similar chemical structures [2].

The second step involving preparation of polymer Nanoparticles (NPs). The advantages of MIP NPs compared to bulk polymer is to enhance sensing efficiency due to their increased surface-to-volume ratio: it provides larger number of accessible binding sites for molecular recognition. This study reports on synthesis methods for improving the recognition properties of MIP NPs.

Preparing Penicillin V MIP NPs

Herein, we used the initial bulk polymer recipe as a starting point to obtain nanoparticles in range of 200 nm by precipitation polymerization in MeOH and Acetonitrile (ACN). The other optimization parameter was employing Ethylene glycol dimethacrylate (EGDMA) and trimethylolpropane trimethacrylate (TRIM), respectively, as cross-linkers, as well as different ratios of monomer to cross-linker, type of solvent and type of cross-linker.

Results

Using TRIM instead of EGDMA for preparing MIP nanoparticles led to uniform size distribution, where type of cross-linker strongly influences the final size and yield of MIP nanoparticles. Varying the fractions of TRIM or EGDMA, respectively, in the polymer allowed us to control particle diameters (Table. 1).

Tab. 1: Nanoparticle size corresponding to the monomer to cross-linker ratios of TRIM and EGDMA

Ps	*MAA:TRIM*	*MAA:EDGMA*	*NPs size (nm)*
MIP	*1:1*	–	*360*
MIP	*1:2*	–	*540*
MIP	*1:6*		*1.170*
MIP	–	*1:6*	*570*
MIP	–	*1:3*	*1.400*

This data clearly shows that the TRIM structure provides more polymerizable groups – namely three per molecule, than EGDMA. Therefore, one can choose lower cross-linker:monomer ratios to obtain smaller particles.

The precipitation solvent also has substantial influence on the particles. For instance, Fig. 1 shows SEM images of MIP NP precipitated from ACN. As one can see, this leads to very appreciable, clearly defined, globular NP with a smooth surface.

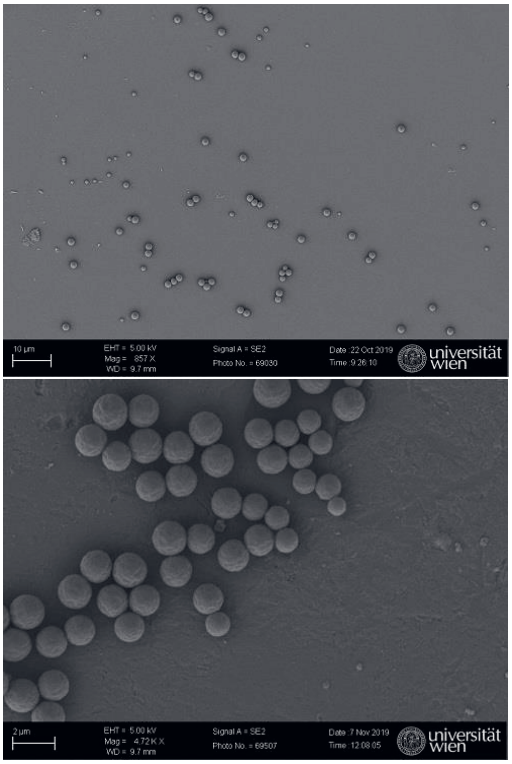

Fig.1. the SEM images of a. NPs synthesized in ACN

However, ACN is a bad solvent for the potassium salt of Pen V. Therefore, we decided to change to MeOH. This allows us to increase amount of template to achieve maximum Pen V binding sites in synthesized MIP NP.

Figure 2, shows how using MeOH - this solvent is protic - influences the aggregation of NPs. Moreover, in terms of using high amount of template in MIP particle shape increased roughness compared to NIP NPs (see Fig. 2b).

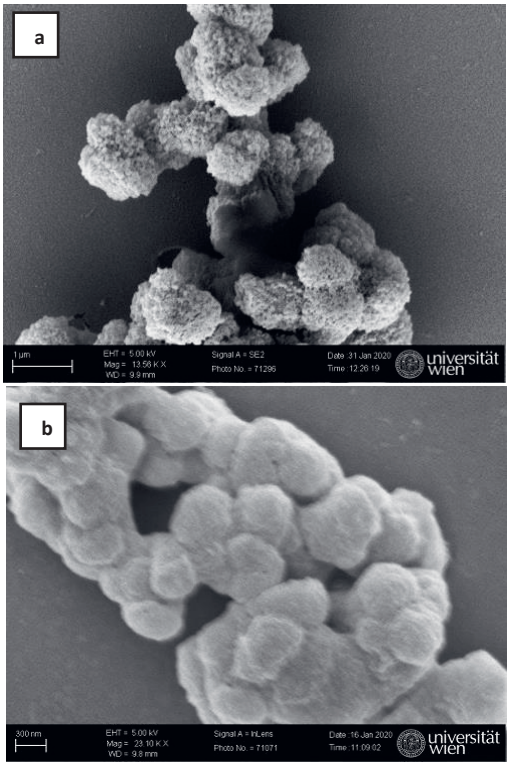

Fig. 2. SEM images illustrate the prickly shape of MIP particles synthesized in MeOH (b) compare to smooth surface of NIP particles synthesized in MeOH (a).

Acknowledgement

Authors gratefully acknowledge funding of this work by the Austrian Research Promotion Agency (FFG) through project AquaNOSE (Grant agreement no. 864893)

References

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