# EVALUATION OF VARIOUS ANTIBACTERIAL, BIODEGRADABLE POLYMERIC COATINGS DEVELOPED ON Ti6Al7Nb SURFACE

**JOANNA JAWORSKA[1]*, KATARZYNA JELONEK[1], MARZENA JAWORSKA[2], WOJCIECH KAJZER[3], JANUSZ SZEWCZENKO[3] MAŁGORZATA PASTUSIAK[1], JANUSZ KASPERCZYK[1,2]**

[1] CENTRE OF POLYMER AND CARBON MATERIALS, POLISH ACADEMY OF SCIENCES, CURIE-SKLODOWSKA 34 ST., ZABRZE, POLAND
[2] SCHOOL OF PHARMACY WITH THE DIVISION OF LABORATORY MEDICINE IN SOSNOWIEC, MEDICAL UNIVERSITY OF SILESIA, KATOWICE, POLAND, CHAIR AND DEPARTMENT OF BIOPHARMACY, JEDNOŚCI 8, SOSNOWIEC, POLAND
[3] DEPARTMENT OF BIOMATERIALS AND MEDICAL DEVICES ENGINEERING, SILESIAN UNIVERSITY OF TECHNOLOGY, ZABRZE, POLAND
*E-MAIL: JJAWORSKA@CMPW-PAN.EDU.PL

*[ENGINEERING OF BIOMATERIALS 148 (2018) 31]*

**Introduction**

Different reports on the use of ciprofloxacin in case of severe bacterial infections can be found in the literature [1,2]. It is a broad-spectrum antiinfective agent of the fluoroquinolone class. Ciprofloxacin has *in vitro* activity against a wide range of gram-negative and gram-positive microorganisms. The mechanism of action of quinolones, including ciprofloxacin is different from that of other antimicrobial agents such as beta-lactams, macrolides, tetracyclines, or aminoglycosides; therefore, organisms resistant to these drugs may be susceptible to ciprofloxacin [5].

Aliphatic polyesters and polyestercarbonates are frequently used as a drug delivery systems for controlled release of different active substances like: antibiotics, growth factors, and hormones [3-6]. Ciprofloxacin has also been incorporated into drug delivery systems which based on polyesters, like: poly(lactide-co-ε-caprolactone). From the other hand, Titanium (Ti) is widely used as a biomedical material since it has extraordinary mechanical properties, high corrosion resistance and satisfactory inherent osseointegration ability [7]. It is used in orthopedic and dental applications. Its biomedical applications are connected with their good biocompatibility and corrosion resistance [8].

The objective of presented study was the comparison of wide range of antibacterial bioresorbable polymeric coatings developed on titanium-based prototype forms of the implants. The therapeutic function of presented metal/polymer+drug systems was confirmed.

**Materials and Methods**

Various kinds of polymers like:
1.Poly(glycolide-ε-caprolactone) (10/90) **P(G/Cap)**
2.Poly(glycolide-ε-caprolactone-L,L-lactide) (10/12/78) **P(G/Cap/L)**
3.Poly(L,L-lactide-trimethylenecarbonate)(74/26) **P(L/TMC)**
4.Poly(lactide-trimethylenecarbonate-glycolide) (10/12/78) **P(L/TMC/G)**
5. Poly(D,L-lactide-glycolide) (84/16) **P(LG)**
were used to prepare coatings on the metallic samples (rods). Polymers were synthesized in bulk by the ring opening polymerization (ROP) using Zirconium (IV) acetylacetonate $Zr(acac)_4$ (Aldrich) as a non-toxic initiator. In the next step, polymers solutions (1%w/w, solvent: $CH_2Cl_2$) have been used to coat the metallic samples by dipping method (Dip Coater, MTI Corporation, 1,2,3 layers, 30 s of immersion time). Coated rods were characterized according to the following techniques: *$^1$H- and $^{13}$C-NMR spectroscopy (*600 MHz Bruker Avance II Ultrashield Plus spectrometer), *Gel Permeation Chromatography* GPC (Physics SP 8800 chromatograph and detector: Shodex SE 61), *Optical Profilometer* (Sensofar).

Antibacterial activity of ciprofloxacin has been examined with the use of the Escherichia coli (E. coli; ATCC® 25922™). Coated titanium-based implants were placed in tubes with 10 mL of Bacterial suspension ($150x10^6$c.f.u./ml) in Trypcase Soy Broth (TSB)) and in tubes incubated at 37°C. Uncoated implants and TSB medium without bacteria was used as a control.

The bacterial growth on the media was studied at 24, 48, 56 and 72 h. The average number of bacteria was measured by Trypcase Soy Agar plate count. The experiments were independently done in triplicate and means and standard deviations were calculated.

**Results and Discussion**

In the study we present detailed analysis of the various kinds of polymeric materials based on polyesters and polestercarbonates as antibacterial coatings for Ti6Al4V implants intended for short-term therapy. The aim of using biodegradable polymers was to introduce therapeutic functions of biomedical implants. We obtained this by incorporation of the ciprofloxacin molecules into the polymeric matrix. Intended function has been confirmed. It appeared that all kinds of ciprofloxacin enriched polymeric coatings show bactericidal properties. Five different ciprofloxacin loaded polymeric coatings have been incubated in bacterial suspension. The bactericidal effect was observed after 24 h in the case of P(LG)+CFX, after 48 h in case of P(G/Cap/L)+CFX and after 72 h of exposure to P(G/Cap)+CFX and P(L/TMC/G)+CFX. The slowest bactericidal effect was observed for P(L/TMC) (96 h).

Additionally, it was analyzed that:
i) the type of material e.g. copolymer composition and
ii) the numbers of dipping influence on: release of the ciprofloxacin as well as on the coatings thickness.

**Conclusions**

Various kinds of biodegradable polymeric coatings formed on Ti6Al4V alloy were successfully developed. The antibacterial function of presented coatings has been confirmed.

**Acknowledgments**

The work is the result of the research project No. 2015/19/B/ST5/03431 funded by the National Science Centre.

**References**

[1] L.R. Wiseman, J.A. Balfour, Ciprofloxacin - a Review of Its Pharmacological Profile and Therapeutic Use in the Elderly, Drug Aging 4(2) (1994) 145-173.
[2] R. Davis, A. Markham, J.A. Balfour, Ciprofloxacin - An updated review of its pharmacology, therapeutic efficacy and tolerability, Drugs 51(6) (1996) 1019-1074.
[3] G. Verreck, I.K. Chun, Y.F. Li, R. Kataria, Q. Zhang, J. Rosenblatt, A. Decorte, K. Heymans, J. Adriaensen, M. Bruining, M. Van Remoortere, H. Borghys, T. Meert, J. Peeters, M.E. Brewster, Biomaterials 26(11) (2005) 1307-1315.
[4] C.M. Valmikinathan, S. Defroda, X.J. Yu, Biomacromolecules 10(5) (2009) 1084-1089.
[5] N. Ahola, N. Mannisto, M. Veiranto, M. Karp, J. Rich, A. Efimov, J. Seppala, M. Kellomaki, An, Biomatter 3(2) (2013).
[6] V. Waknis, S. Jonnalagadda, Drug Deliv 18(4) (2011) 236-245.
[7] H. Lee, H. Jung, M. Kang, J. Song, H. Kim, Materials and Design 145 (2018) 65-73.
[8] M. Prakasam, J. Locs, K. Salma-Ancane, D. Loca, A. Largeteau, L. Berzina-Cimdina, J Funct Biomater 8(4) (2017).