


Surface Energy of Biomaterials Depending on Contact Angle: Effect of Pulsed Laser Deposition on Contact Angle

Zaineb Fadhil K.

 <http://orcid.org/0000-0002-8287-1314>


College of Materials Engineering, University of Babylon, Iraq

Lina Fadhil Al-Obaidi

 <http://orcid.org/0000-0003-3784-7611>

University of Babylon, Iraq

Hasanain Kamil Owadh

 <http://orcid.org/0000-0003-0547-622X>

College of Pharmacy, Al-Mustaqbal University, Iraq

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ABSTRACT

One of the essential characteristics of biomaterial implants is the wettability, which acts as a rising function in daily life. Profiting from the revelation of biological models and improving manufacturing technology, the aim of this research was the investigation of the effects of surface modification on the wettability of nitinol surface alloys as biomaterials by using pulsed laser deposition (PLD) as a type of physical vapor deposition method. The deposited film after the PLD method was a diamond-like carbon, using distilled water and body fluids as ringer solutions, as well as fetal bovine serum to find contact angles among them and the surface energy of biomaterials. The advancing angle, receding angle, and equilibrium contact angle of nitinol before and after deposition were calculated. There was decreasing surface energy of all surfaces after deposition with increasing in contact angle. After 300 pulses and 200 mJ, the specimen 203PLD had the lowest value of equilibrium contact in fetal bovine serum at 39.466° and the highest value with water and ringer solutions at 65.102° and 63.128° , respectively.

KEYWORDS

Nitinol, Pulsed Laser Deposition, Diamond Like Carbon, Advancing, Receding

INTRODUCTION

Nitinol alloy represents the equiatomic composition of nitinol. It displays individual features such as shape memory effect and superelasticity. It has high mechanical amplitude rapprochement with its weight during which advances the capability of recovery. A distortion is created by a huge conversion and another distortion because of heating and cooling (Cimpoesu et al., 2020). Nitinol's unique characteristics—shape memory and superelasticity—result from a reversible, solid-state phase transformation between high-temperature austenite—cubic structure—and low-temperature martensite—monoclinic/twinned structure (Kvasnytskyi et al., 2025).

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It has excellent biocompatibility, low Young's modulus, good corrosion resistance, an uncommon incorporation of strength and ductility, high fatigue strength, and a high tendency for self-passivation (Rudolf et al., 2021). The mechanical and biomedical characteristics of its lattice structure set up by reiterating unit cells oriented in diverse directions make it appropriate for bone implant implementation (Wang et al., 2025).

These properties make it appropriate for biomedical applications such as orthodontic treatment, orthopedic surgery for various staples and rods, and maxillofacial and reconstruction surgery. Stents and directory wires from nitinol alloy are used in cardiovascular surgery. There are different applications of nitinol in aerospace, automotive, marine, chemical industries, civil and structural engineering (Patel et al., 2020).

A lot of hardships seem to come from biomaterial handicaps that are often displayed after a lengthy amount of time. Occasionally biomaterial tricks can emancipate metal in the body, raising allergic responses such as thrombogenicity of the blood and hostile physiological environments (Sunthornpan et al., 2019). The high content of nickel in nitinol is capable of bringing about decline in DNA, creating of oxygen radicals and familial changes (Nasakina et al., 2019).

Nowadays there are a lot of efforts to improve the biological characteristics of biomedical materials to decrease the need of antibiotics during and after the procedures of surgical implantations (Patel et al., 2020). Plenty of methods of surface modifications exist to escape problems such as oxidation in boiling water and autoclaves, laser oxidation, chemical passivation, electro spinning, physical vapor deposition, and chemical vapor deposition methods (Nasakina et al., 2019).

Physical vapor deposition is a thin film deposition procedure whereby the coating is grown on the substrate atom by atom. Physical vapor deposition encompasses the material to atomize and vaporize from a solid source, also known as the target (Baptista et al., 2018). It is the most important application of vacuum systems to produce thin films. Physical vapor deposition can be categorized in several kinds such as thermal evaporation, sputtering, pulsed laser deposition (PLD), and plasma immersion ion implantation (Gambaro et al., 2025; Kadhim et al., 2025; Kölbach et al., 2020).

In the PLD technique, the laser ablated species have high kinetic energy up to a few keV, allowing adherent thin films to deposit at relatively low temperatures compared to other techniques. It cements monitoring film deposition parameters, inclusive thickness, stichometry, and crystallinity. The laser pulses with high energy expediting stoichiometric transportation from target to substrate, subjecting a thick, crystalline depositing film with superior adhesion even on complex geometries of the substrate (Farooq et al., 2026). Inside the vacuum chamber (ultra-high vacuum), targets of elementary or alloy elements are struck at an angle of 45 degrees by a high energy focused pulsed laser beam (Bleu et al., 2018).

Carbon has plenty of allotropic shapes such as graphite, graphene, diamond, glassy carbon, pyrolytic carbon, and diamond-like carbon (DLC). Some of the carbon phases present superior biocompatibility characteristics with tissues and have the best properties of mechanical resistance, density, and elasticity resemblance with many tissues. It can be adapted to use as thick or low thin films. The bands of them are sp^3 (tetrahedral), sp^2 (trigonal planar), and sp (linear). DLC is one of the most interesting blood-contacting biomaterials. It is used in artificial heart valves, stents, and rotary blood pumps. It comprises amorphous forms of carbon atoms containing sp^3 and sp^2 (Torrissi & Scolaro, 2017).

Prevailing the surface wettability of a material is pivotal for different enforcements in industry, agriculture, and daily life. For bio applications, it is more substantial because the wettability straightway controls the interfacial attitude of cells and biomolecules on material flatten (Ferrari et al., 2020): protein adsorption, platelet adhesion-activation, blood coagulation, cell, and bacterial adhesion. In general, hydrophobic surfaces are counted as more protein adsorbent than hydrophilic surfaces due to the sturdy hydrophobic interaction placing at them (Xu & Siedlecki, 2007). The flattening of biomaterial adsorbs the proteins (such as collagen, laminin, fibronectin, and vitronectin) from blood or a further cellular matrix. After that cells link to the flattening of biomaterials by integrins. Protein

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