Development of refractory element based complex concentrated alloys for biomedical applications

Thesis submitted in partial fulfillment for the Award of Degree

Doctor of Philosophy

By

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I, **Dharmendra Kumar Yadav**, certify that the work embodied in this Ph.D. thesis is my own bonafide work carried out by me under the joint supervision of **Dr. Subhasis Sinha and Dr. Surya D. Yadav** for a period from **July 2019 to May 2025 at the "Department of Metallurgical Engineering",** Indian Institute of Technology (BHU), Varanasi, India. The matter embodied in this Ph.D. thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the researchers wherever related works has been cited in this thesis. I further declare that I have not copied any other's work, paragraphs, text, data, results, *etc.*, reported in journals, books, magazines, reports dissertations, thesis, *etc.*, or available at websites and have not included them in this thesis and have not cited as my own work.

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Abbreviations

AFM	**A**tomic **F**orce **M**icroscopy
AR	**A**s **R**eceived
ASTM	**A**merican **S**ociety for **T**esting and **M**aterials
BCC	**B**ody **C**entered **C**ubic
CCA	**C**omplex **C**oncentrated **A**lloy
COF	**C**oefficient **O**f **F**riction
CPE	**C**onstant **P**hase **E**lement
cp-Ti	**C**ommercially **P**ure **T**itanium
CR	**C**orrosion **R**ate
DMEM	**D**ulbecco's **M**odified **E**agle **M**edium
EBSD	**E**lectron **B**ack **S**cattered **D**iffraction
EDS/EDX	**E**nergy **D**ispersive **X**-ray **S**pectroscopy
EIS	**E**lectrochemical **I**mpedance **S**pectroscopy
FBS	**F**etal **B**ovine **S**erum
FCC	**F**ace **C**entered **C**ubic
FESEM	**F**ield **E**mission **S**canning **E**lectron **M**icroscopy
HCP	**H**exagonal **C**losed **P**acking
HEA	**H**igh **E**ntropy **A**lloy
HEI	**H**igh **E**ntropy **I**ntermetallics
HPT	**H**igh **P**ressure **T**orsion
IPF	**I**nverse **P**ole **F**igure
MEM	**M**inimum **E**ssential **M**edium

MPEA	**M**ulti **P**rincipal **E**lement **A**lloy
MTT	3-(4,5-Di-**M**ethyl-**T**hiazol-2-yl)-2,5-Diphenyl **T**etrazolium bromide
NCCS	**N**ational **C**entre for **C**ell **S**cience
OCP	**O**pen **C**ircuit **P**otential
ODF	**O**rientation **D**istribution **F**unction
OM	**O**ptical **M**icroscopy
PD	**P**otentio **D**ynamic
ROS	**R**eactive **O**xygen **S**pecies
SAED	**S**elected **A**rea **E**lectron **D**iffraction
SBF	**S**imulated **B**ody **F**luid
SEM	**S**canning **E**lectron **M**icroscopy
SPD	**S**evere **P**lastic **D**eformation
SS	**S**tainless **S**teel
SWR	**S**pecific **W**ear **R**ate
TEM	**T**ransmission **E**lectron **M**icroscopy
VAM	**V**acuum **A**rc **M**elting
VEC	**V**alence **E**lectron **C**oncentration
XRD	**X**-**R**ay **D**iffraction

SYMBOLS

a	Lattice parameter
ρ	Density
σ	Sigma
λ	Wavelength
ν	Poisson's Ratio
ºC	Degree Centigrade
K	Kelvin
E	Elastic Modulus
R	Ideal Gas Constant
N	Newton
Pa	Pascal
MPa	Mega Pascal
GPa	Giga Pascal
µm	Micrometer
nm	Nanometer
Å	Angstrom
θ	Theta
δ	Delta
Ω	Omega
at.%	Atomic Percent
wt.%	Weight Percent
ml	Milliliter

J	Joule
R_q	root mean square roughness
R_{sk}	skewness
R_{ku}	kurtosis
mm	Millimeter
gm	Gram
χ	Chi
min	Minute
s	Second
I_{corr}	Corrosion Current Density
V_{corr}	Corrosion Potential