

Chapter I: Introduction

1.1 Transition Metal Oxide: TiO₂

Vtcpuukkp" o gvcn" qz kf gu" ctg" hcuekpcvki " eruu" qh" kqti cple" o cvgtkcu." gzej kdkkpi "c"y kf g"tcpi g"qh"et { uvcn"utwewt gu."r tqr gt vku."cpf "cr r rdecvkpu0'Vj g" xctkqv { "kp"r tqr gt vku"ugv "htqo "vj g"wpks wg"pcwt g"qh"vj g"qwwt "f/grgevtqpu"qh"vj g" vcpuukkp" o gvcn' Uqo g" qz kf gu" rknq" NcP kQ₅." TwQ₄." cpf "TgQ₅" uj qy " o gvcnle" dgj cxkqwt. "y j gtgcu"O pQ"cpf "DcVkQ₅" f go qputcvq"kpucvki "r tqr gt vku0'Vj gug" qz kf gu" uj qy " f kxgtug" o ci pgvle" r tqr gt vku." rknq" hgttqo ci pgvkuo " *gfi 0" EtQ₄." Nc₂₀Ut₂₀O pQ₅." cpk/hgttqo ci pgvkuo " *gfi 0" P kQ." NcEtQ₅." EqVkQ₅+" cpf " hgttko ci pgvkuo " *gfi 0" Hg₅Q₆." \ pHg₄Q₆." P Hg₄Q₆+0' DcVkQ₅." MP dQ₅" gzej kdku" hgttqgrgevtkv { "y j gtgcu" I f₄*O qQ₆+5"uj qy "hgttqgrvkv { 0'Vj g { "cnu" hqto "vj g" eruu" qh"Uwr gteqpf vevki " *gfi 0" [Dc₄Ew₅Q₉+" cpf "O wkhgttqle" *gfi 0'VdO pQ₅. NwHg₄Q₆+" o cvgtkcu0'Vj gug" o cvgtkcu" qh hgt "ej cmgpi gu" vq" r j { ulekvu" cu" y gm'cu" o cvgtkcu" uekpvkuu" vq" wpf gtucpf " vj gk" utwewt cn" grgevtqple." o ci pgvle" cpf " qr vkn" r tqr gt vku" hgt " vj g" r tcevkcn" cr r rdecvkpu0'Vj gtg" ctg" uqo g" qz kf gu" rknq" \ pQ." UpQ₄." J hQ₄." P kQ" cpf " VkQ₄" gve0' y j kej " dgmpi u" vq" vj g" eruu" qh" ugo keqpf vevtu0'Co qpi "vj gug" ugo keqpf vevtu." VkQ₄" ku" o quv' r tqo kuki "f wg" vq" ku" xctkqv { "qh" utwewt gu" cu" y gm'cu" r j { ulecn" r tqr gt vku" vj cv" o cng" kv" wughw" kp" f hgtgvp' hgrf u" qh" cr r rdecvkp0' Vq" dgi kp" y kvj ." y g" f kvewu" cdqw' vj g" dcule" utwewt g" cpf " r tqr gt vku" qh" VkQ₄0"

1.1.1 Structure of TiO₂

VkQ₄" j cu" vj tgg" r qn { o qtr j u' pco gn { "cpcvcug." twknq" cpf "dtqqnkv0'Co qpi " vj gug" vj tgg" r j cugu." cpcvcug" ku" nkp gvlecm { "cpf " twknq" ku" vj gto qf { pco kecm { "o quv' ucdng0'Qp" j gcv' tgcvo gpv." cpcvcug" r j cug" kttgxgtukdn { "eqpxgtu" vq" twknq" r j cug0' Dtqqnkv" ku" dculecm { "c" o gvcuvcdrng" r j cug" cej kvxgf "kp" j ki j " r tguuwt g" u { pvj guku" eqpf kvkpu" vj cv'cnuq" eqpxgtu" vq" twknq" r j cug" qp" j gcv' tgcvo gpv0"

Co qpi "vj g" vj tgg" r j cugu." twknq" ku" vj g" o quv' ucdng" r j cug" kp" dwm' hqto 0' Vj g" wpk" egm' qh" twknq" utwewt g" ku" uj qy p" cu" Hki 000" *c+0' Gcej " Vk" kvp" ku" qewj gf tcm { "eqqtf kvcvgf "vq" ulz "Q" kvpu' hqto kpi "c" VkQ₈" qewj gf tqp" kp" c" f kvvqvgf " o cppgt. "y kvj "vj g" cr kecn' Vk/Q" dqp f "rgpi vj " *30 : "x + " dgkpi "urki j v { "rgpi gt" vj cp" vj g" gs wcvtkcn' Vk/Q" dqp f "rgpi vj " *30 7" x +0' Vj g" hqwt" gs wcvtkcn' Q" kvpu" ctg"

eqr rcpct"qeewr {kpi "c"tgevpi wrct"cttcepi go gpv'y kj "vj g"mipi "gf i g"*40 76"α +
 cmipi "vj g"e"ftkgevqp"cpf "vj g"uj qtv"gf i g"*40/5"α +"n{kpi "f kci qpcm{"cetquu"vj g"
 r rcp"fg hkp"gf "d{"vj g"šc "ftkgevqp0Vj g"ej ckpu"qh"VkQ₈"qevcj gf tc"ctg"cwcej gf "d{"
 uj ct{kpi "vj g"gf i gu"cmipi "vj g"še "ftkgevqp"cpf "uj ctg"xgtvkegu"kp"vj g"c/d'r rcp"g0'

Vj g"utwewtg"qh"cpvcug"ku"uj qy p"kp"Hki Bβ*d+0Vj g"wpk'egm'eqpuku"qh"
 vy q"wpku"qh"VkQ₄0'Gcej "Vk'kqp"ku"qevcj gf tcm{"eqqtf kpcv"gf "vq"ukz"Q"kpau0Vj g"
 Vk/Q"qevcj gf tqp"ku"pqv'tgi wrct"cpf "vj g"Vk/Q"dqpf "fkvcpegu"ctg"uko krc"vq"vj qug"
 kp"twkrg0Vj g"qevcj gf tcn'hqto " | ki | ci "ej ckpu"cmipi "vj g"šc "cpf "šd "ftkgevqpu"
 y kj "gcej "qevcj gf tqp"uj ct{kpi "hqwt"gf i gu0'

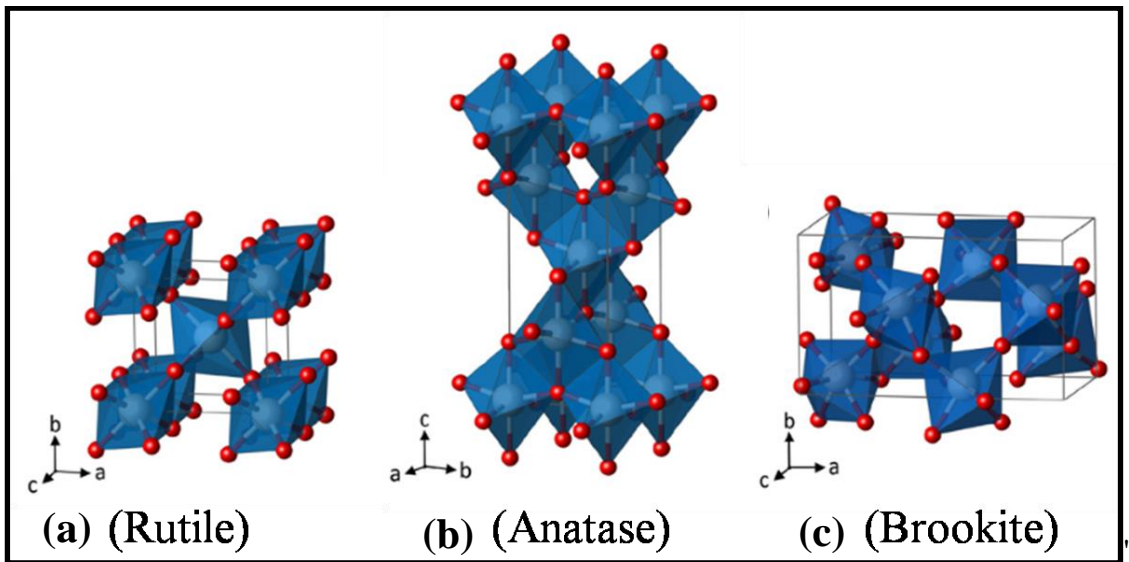


Fig.1.1 "VkQ₈" r qn{j gf tc" uj qy kpi "vj g" vj tgg" r qn{o qtr j u" qh" VkQ₄" twkrg" *c+."
 cpvcug"*d+cpf "dtqqnkvg"*e+0'Vk"ku"tgr tgugpv"gf "cu"y j kvg"cpf "Q"cu"tgf "ur j gtgu0'
]Chgt"Ncpf o cpp"gv'crl0*4234+_"

Dgukf gu"cpvcug"cpf "twkrg."dtqqnkvg"ku"vj g"nguu"gzr rqtgf "r j cug"cu"kv"ku"
 f khhewv"vq"u{pvj guk g"kp"r wtg"r j cug"hqto 0'J qy gxgt."kv"qhvgp"cr r gctu"cu"c"
 ugeqpf ct{"r j cug"cmipi "y kj "cpvcug"r j cug0'Vj g"dcule"dtqqnkvg"utwewtg"ku"
 uj qy p"kp"Hki Bβ*e+0'kp"ecug"qh"dtqqnkvg."vj gtg"ctg"ukz"fkhhgtgpv"Q/Vk/Q"dqpf "
 cpi ngu'tcepi kpi "htqo "99Å"vq"327Å'J qy gxgt."twkrg"cpf "cpvcug"j cxg"qpn{"vy q"
 nkpf u"qh"Vk/Q"cpf "Q/Vk/Q"dqpf "cpi ngu"]O wuecv'gv'crl0*4224+0'Vj g"fkhhgtgpv"
 utwewtclnr ctco gygtu"qh"vj tgg"et{ucmkpg"r j cugu"ctg"uwo o ct{k gf "kp"Vcdrg"3B0"

Table 1.1 " Utwewtcn' r ctco gvgtu" hqt" vj g" vj tgg" et {ucnkpqg" r j cugu" qh" V_kQ₄O₂} F gt {gu'Eqtpcf q'gv'crf}*422: +_"

"	rutile	anatase	brookite
Et {ucn'Utwewtgu"	Vgtci qpcn'	Vgtci qpcn'	Qtvj qtj qo dle"
Nwkeg'Eqpucpwu'*α +"	c"? "607; 58" e"? "40 7: 9"	c"? "50: 6" e"? "; 0737"	c"? "; 08: 6" d"? "7069" e"? "7067"
Urceg'I tqwr u"	R ₆₄ l ₆ po "	K ₃ l ₃ co f "	Rdec"
O qrgewrgIEgm'	4"	6"	: "
Xqmw gIO qrgewrg"	5304382"	560283"	5409"
F gpuky { "i leo ⁵ +"	605"	50; "	50; ; "
VkQ"dqpf "rgpi vj "α +"	3Q 6; *6+ " 3Q : 2*4+ "	3Q 59*6+ " 3Q 87*4+ "	3Q 9/4026"
Q/VkQ"Dqpf "cpi rg"	: 30 ^q " ; 20 ^q "	990 ^q " ; 408 ^q "	990"/327 ^q "
Dcpf "i cr "	5022"*f k'gevt"	5043"*pf k'gevt"	5085"*pf k'gevt"

1.1.2 Properties of TiO₂

F wg"vq"ku"uekp vke"cpf "r tcevecn'ko r qtwcpeg."V_kQ₄"kp'twkeg"r j cug"j cu' dggp"vj g"uwdlgev'qh'o cp { "gzr gtko gpvcn'cpf "vj gqtwvecn'kpxguki cvkqu0'Ugrgevgf " tgxky u"kp"vj ku'hgrf "ctg"vj g"y qtm'qh'I tcpv"*3; 7; + "I qqf gpqwi j " *3; 93+ "cpf " J gptlej o " *3; ; 7+0' Vj g" grgestqple" r tqr gt vku" qh' cpcvcug" ctg" cuwo gf " vq" dg" kf gpvecn'cu'twkeg0'Hqttq'gv'crf)*3; ; 6+ "j cxg"kp'xguki cvgf "vj g"t'cpur qtvr' tqr gt vku" cpf "tgxgcnc"uj cmjy "f qpqt"rgxgn'cpf "j ki j "p/v(r g"o qdkkv { "kp" cpcvcug"et { ucnu0' Vcpi "gv'crf)*3; ; 6+ "j cxg"uwf k'gf "vj g"r j qqnwo kpguegpeg"kp"vj g"uco g" cpcvcug" et { ucnu0' Nwo kpguegpeg" f wg"vq"vj g" tgeqo dkpcvqp" qh' ugrh/ tcr r gf " gzekqpu" ku' qdugt xgf "kp" cpcvcug"et { ucnu. "dw'pqv'kp'twkeg"et { ucnu0'

Kp"dwm"V_kQ₄"dgj cxgu"cu"cf²"kpuwrcvt"y kj "go r v { "f" dcpf u0'J qy gxgt." vj gtg"ku" c"eqo o qp"v'gpf gpe { "qh"j cxkpi "qz { i gp"xcepekgu"kp"vj g"V_kQ₄"nwkeg0' Vj gug"qz { i gp"xcepe { "tgrcvgf "f ghgev'ucvgu" hqto "c"uj cmjy "f qpqt" dcpf "dgmjy " vj g"eqpf wevqp" dcpf "o cngu"kv'cp"p/v(r g"ugo leqpf wevt"]Uj kpf g"gv'crf)*4225= " Hqttq'gv'crf)*3; ; 6+0'Kp"ecug"qh"j ki j n { "ppq/uvklej kqo gtle"V_kQ₄"kv'f go qpwtcvgu" o gcnle"r j cug"cv"j ki j "vgo r gtcwtg"cpf "uj qy u"ugo leqpf wevki "pcwtg"cv"mjy " vgo r gtcwtg"]Uj kpf g"gv'crf)*4225+0'Y j gp"vj g"ppq/uvklej kqo gtv { "ku"uw'kekp'v { "

j ki j . "kv"hcxqwtu"vj g"hqto cvkqp"qh"o ci pgrk'r j cugu"*V_kQ_{4p/3}+0'F wg"vq"vj g"dcule"
 kpukpev"qh"j cxkpi "qz {i gp" xcecpe { ." vj g" pqp/uvklej kqo gvt { "kp" V_kQ₄"ku" qhvgp"
 tghgtgf "cu"V_kQ₄/ 0'Dwm'V_kQ₄"ku"j ki j n{ "uwuegr vldrg"vq"qz {i gp"xcecpeku'Vj gug"
 qz {i gp"xcecpeku"hm vj gt"lpetgcug"y j gp"vj g"uk g"ku'tgf wegf "vq"pcpqo gvt "uecrg"
 qt"vj kp"hm u"i tqy p"wpf gt"qz {i gp"f ghlekpv"gpuktqpo gp'0'Kp"ecug"qh"vj kp"hm u."
 kv"ku" gcukgt"vq" eqpvtqn"vj g"qz {i gp" xcecpe { "eqpegpvcvkqp" d { "eqpvtqnkpi "vj g"
 qz {i gp"r ctvkn'r tguwtg"f wtkpi "f gr qukkqp'0'K'j cu"dggp"tgr qtvgf "vj cv'twkr"ku"
 o quv"ucdrg"kp"qz {i gp" f ghlekpv"eqpf kkp"vj cp"vj cv"qh" cpcvug"]Mko "gv' crf'
 *422; +_0'Dgukf gu"xcecpe { "eqpegpvcvkqp." vcpur qtv'r tqr gtvku"cuq" f gr gpf "qp"
 r j cug"qh"V_kQ₄"vj cv'r quugu" f hgtgpv"ghgevxg"o cuu"qh"grgevtqp"ecttktu"cu"y gm'
 cu"o qdkkv{0'K'j cu"dggp"hwpf "vj cv" cpcvug"r j cug"ecp" gcuk { "dg"uy kej gf "vq"
 o gvcme"u{uvgo "d { "xct {kpi "vj g"ecttkt "f gpukv{ "vj cp"vj g"twkr"r j cug'0'Kp"xkgy "qh"
 Oqw"vcpukvqp"kp"ugo kqpf wevtu."vj g"etkkn'f qpqt"eqpegpvcvkqp"*p_{fe}+ "hqt"vj g"
 vcpukvqp"ku"i kxgp"d { . 'p_{fe} "c" *2017 hr_H⁵ . "y j gtg"r_H* "ku"vj g"Dqj t"tcf kwu"qh"j { f tqi gp"
 rkn" f qpqt"ucv'0'K'j cu"dggp"qdugtxgf "vj cv"vj g"Dqj t"tcf kwu"hqt" cpcvug"r j cug"ku"
 o vej "rti gt"vj cp"vj cv"qh"twkr"r j cug'0'Cu" c"tguw. "eqo r ctvkn" "mqy gt"etkkn'
 f qpqt" f gpukv{ "ku"vghlekpv"vq"lpf weg"o gvcme"ej ctcevgt"kp"vj g"u{uvgo "] \ j cpi "gv'
 crf' *4229+_0' J gpeg. "y g" cwtkdwg"vj g" grgevtkn' r tqr gtv{ "qh" V_kQ₄"ku" uqrgn{ "
 f gr gpf gp'qp"i tqy vj "eqpf kkp'0'

Kp"dwm'hqto . "V_kQ₄"ku"pqpo ci pgrk'kp"pcwtg"f wg"vq"ku" f²"eqphi vtcvkp'0'
 J qy gxgt. "Ukpi j cn'gv'crf' *4233+"j cxg"tgr qtvgf "hgttqo ci pgrk' "kp"dwm'cpcvug"
 V_kQ₄"wr qp"j { f tqi gpcvkp'0'K'j cu"dggp"tgr qtvgf "dqj "vj ggtgkcm{ "cu"y gm'cu"
 gzt gto gpvcn{ "vj cv' V_kQ₄/ " f go qpucv'gu" hgttqo ci pgrk' "y j gp"vj g" uk g"ku"
 tgf wegf "vq"pcpuecrg'0'J qy gxgt. "vj g"gzcev'qtki kp"qh" hgttqo ci pgrk'"qtf gkpi "kp"
 vj gug"u{uvgo u"ku"vkn'f gdcv'f'0'Uko kn'cn{ . "tqo "vgo r gtcwtg" hgttqo ci pgrk' "j cu"
 dggp"uggp"kp"qvj gt"kpqi cple"qz kf gu"rkn"UpQ₄. "\ pQ."cpf "J hQ₄0'Vj g"r quukdr"
 tgcuppu'dgj kpf "vj g" hgttqo ci pgrk'"qtf gkpi "kp"V_kQ₄"ctg" f kuewugf "kp"Ej cr vt "KK'
 Cu" vj g" r j cug" qh" V_kQ₄"ku" cp" ko r qtvpv' r ctco gvt "vq" f gekf g" vj g" r j { ukcn'
 r tqr gtvku. "qp'g'pggf u'r tqr gt"wpf gtucpf kpi "tgi ctf kpi "vj ku"r j cug"vcpuhqto cvkqp"

hqt "r quikdng" cr r nkecvkqpu0Uq "k"ku"ko r qtvcpv"vq"wpf gtucpf "vj g"hcexqtu"vj cv"o c{"
chgevj ku"cpvcug"vq"twkrg"r j cug"vcpuhqto cvkqp0

1.1.3 Anatase to Rutile Phase Transformation

Vj g"eqptqn"qh"cpvcug"vq"twkrg"r j cug"vcpuhqto cvkqp"ku" xkcn" hqt" vj g"
r gthqto cpeg" qh" vj ku" o cvgtkn" kp" xctkqu" cr r nkecvkqpu" uwej " cu" ugpuqtu."
r j qvqecvn{uku."r ki o gpv"cpf "grgextqpleu"}Xqi gn'gv'cr0*3; ; 6+_0Cpcvcug"vq"twkrg"
r j cug"vcpuhqto cvkqp"ku" nkpvcem{ " f gLpgf " cpf " uqrn{ " f gr gpf u" qp" f hgtgpv"
r ctco gvtu"rkn"r ctvcng"uk g."uj cr g"}[qi cpctculo j cp"cpf "Tcq"*3; 84+_."uqwtg"
ghgevu"]D{wp" gv" cr0 *3; ; 9+_."cvo qur j gtg"]O ceMgp| kg" *3; 97+_."cpf " f qr cpv"
]Tgkf {"gv'cr0"*4228+_0Cpcvcug"vq"twkrg"vcpuhqto cvkqp"ku"dculecm{ "c"pwengecvkqp"
cpf " i tqy vj " r tqegu"]F kpi " cpf " Nkw" *3; ; : +_0' K' ku" gzr gev" vj cv" r j cug"
vcpuhqto cvkqp" eqwf" dg" kpl wpegf" d{ " f ghgev" eqpegpvcv"]\ j cpi " cpf "
DcpLgrf "*4222+_."i tclp"dqwpf ct {"eqpegpvcv"}Cj p"gv'cr0*4225+_."cpf "r ctvcng"
uk g"}Mwo ct"gv'cr0*3; ; 5+_."cu"y gn0Cttq {"gv'cr0"*4224+_."cxg"uj qy p"vj g"ghgev"qh"
f qr cpv" qp"cpvcug"vq"twkrg"r j cug"vcpuhqto cvkqp" vgo r gtcwtg0'Tgkf {"gv' cr0'
*4228+_."cxg"tgr qtvgf "vj g"gpj cpego gpv"qh"cpvcug"vq"twkrg"r j cug"vcpuhqto cvkqp"
vgo r gtcwtg"y kj "cp"cf f kkp"qh" f qr cpv"uwej "cu"Uk"\ t"cpf "Cn"y j kg"Eq."O p"
cpf "X"my gt"vj g"uco g0\ j cpi "cpf "DcpLgrf "*4222+_."cxg"tgr qtvgf "vj cv"c"etkkn"
uk g"o gej cpkuo "o c{"cnuq"dg"ko r qtvcpv"kp" vj g"vwtwcn"r j cug"vcpukqp"qh"
pcpqr ctvcngu"qh" VkQ40'Vj g"vj gto qf {pco leu"qh"r j cug" hqto cvkqp"kp" vkcplc"ku"
xkxkf n{ " f kuewugf " d{ "\ j cpi " cpf " DcpLgrf "]\ j cpi " cpf " DcpLgrf " *4222+_."c+_0'
Tgkf {"gv'cr0"*4228+_."cxg"gzco kpgf "vj g"etkkn"r ctvcng"uk g"y j lej "ku"hwppf "vq"dg"
qh"¢"67"po "ktgur gev"qxg"qh" f qr cpv0'J ki j "vgo r gtcwtg"cpf "r tguwtg"kpqxrgf "
u{pvj guku"vej pls wgu" {kgrf "twkrg"cpf "dtqqnkv"r j cugu"tgur gev"xn{0'Y g" f kuewuu"
uqo g" qh" vj g" o gvj qf u" vq" u{pvj guk g" pcpquvewtgf " VkQ4" kp" vj g" hqmy kpi "
ugevqp0

"

"

"

1.2 Synthesis/Deposition of Nanostructured TiO₂

VkQ₄" pcpqr ctvkgu" ecp" dg" u{pyj gukugf " kp" f khtgpv" rj cugu" cpf " o qtr j qm i kgu'd{ "xctkqwu"vej pls wgu'rkng"uqn/i gn"o ketqy cxg"cuukugf "u{pyj guk." o ketq/go wukqp." j {ftqyj gto cn' cpf " eqo dwukqp" vej pls wgu' Vj g" uj cr g" cpf " i tqy vj "qh"vj g"pcpqr ctvkgu"ecp"dg"eqpvtqmgf "d{ "wukpi "r tqr gt"ecr r kpi "ci gpwu" cpf "o ckpckkpi "uwkcdng"i tqy vj "eqpf kkp0F gwckngf "o gyj qf "qh"u{pyj guku"qh"vj g" VkQ₄"pcpqr ctvkgu."pcpqwdgu"cpf "pcpqy kt gu"ctg'tgr qtvgf "kp"rkgtcwtg0Uqo g"qh" vj g"r qr wct"vej pls wgu"wuqf "hqt"u{pyj guku"qt"fg r qukkqp"qh"pcpqut wewtgf "VkQ₄" ctg"fkuewuqf "dgmjy 0'

1.2.1 Synthesis of Nanoparticles

Sol-gel Technique

Vj g"j kuvt { "qh"uqn/i gn'r tqeguukpi "dgi cp"kp"vj g"o kf /3: 22u'y kj "Gdgm cp" cpf "I tcj co u"uwf kgu"qp"uktec"i gn0Uqnu"ctg"fg kur gtukqpu"qh"eqmqkf cn'r ctvkgu" kp"rks wkf 0'Eeqmqkf u"ctg"uqrkf "r ctvkgu"y kj "f lco gvgtu"qh"3/322"po 0'C"i gn'ku"cp" kpvgteqppgevgf ."tki kf "pgwy qtn'y kj "r qtgu"qh"uwdo ketqo gvgf "f ko gpukqpu"cpf " r qn{o gtle"ej ckpu"y j qug"cxgtci g"ngpi vj "ku"i tgcvtg"vj cp"c"o ketqo gvgf0]J gpej " cpf "Y guv"*3; ; +0'C"v{r kecn'ugn/f guetk vxg"r kvqtkcn'tgr tguqpvckqp"qh"uqn/i gn' r tqegu'ku'uj qy p'kp'Hki 0040'

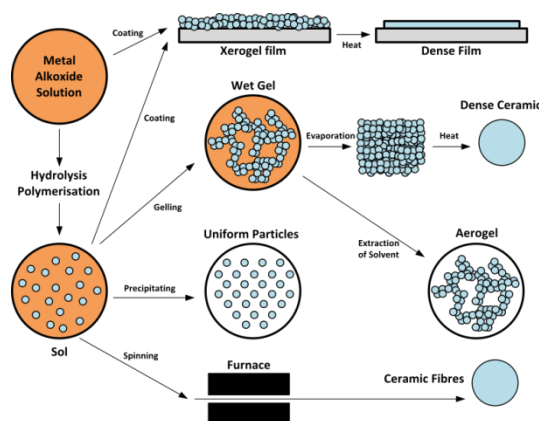


Fig.1.2 Xctkqwu"uqgr u"kpqxrkf "kp"uqn/i gn'r tqegu"vq"u{pyj guk g"pcpqut wewtgf " o cvgtkri0'

lhtqo "Y knkr gf kcj [wr <leqo o qpu0y knko gf kc0ti ly knkHkg-Uqn'I](#) gmaUej go g0uxi _"

Hqt " u{pvy guku" qh" V_kQ₄" pcpqr ctv_lengu" d{ " uqn/i gn' v_eej pls wg." v_kcpkwo " kuqr tqr qz_kf g"qt "v_kcpkwo "dwqz_kf g"ctg" wugf "k_p"r n_eg"qh"o g_vcn'cmqz_kf gu'K'pq" i grv_kqp"kp_f w_ek_pi "t_gci gpw"*j { f tqn{ uku"ecv_n{ uvu+"ctg" wugf . "v_j g"kp_kcn'j { f tqn{ uku" qh'v_kcpkwo "cmqz_kf gu't_guwu"kp"v_j g"ht_o cv_kqp"qh'v_kcpkwo "j { f tqz_kf g"o qp_qo g_tu" ceeq_tf k_pi "v_q"gs w_ev_kqp"*3₃+"

V_k*Q_T+₆- 6J₄Q₄*****V_k*Q_J+₆- 6TQJ í í í í í 0í í í 0000*3₃+"

y j gtg'T'tgr tgugpw"v_j g"qti c_ple"ej c_kp"qh'v_j g"ht_o w_{nc}/'E_zJ_{4z-3}"

V_kcpkwo "f_kz_kf g"j c_xk_pi "Q_J"v_gt_o k_pcv_gf "u_wth_cegu"ht_o u"cp_f "r t_gek_r k_cv_gu" v_j tq_wi j "v_j g"eq_pf g_puc_vqp"r t_qegu"qh'j { f tqz_kf g"o qp_qo g_tu"v_q"ht_o "c"eq_pv_kpw_qwu" p_gwy q_tn'qh"V_kQ" d_qp_f u₀V_j ku't_gce_vqp"ku" f g_uet_kd_gf "k_p"gs w_ev_kqp"*3₄+"v_j cv'v_cngu" r n_eg"v_j tq_wi j "c"p_weng_cv_kqp"cp_f "i tqy v_j "r t_qegu₀"

V_k*Q_J+₆*****V_kQ₄"- "4J₄Qí í í í í í í í í í í 00*3₄+"

G_s w_ev_kqp" *3₃+" f_qgu" p_qv" r t_qegg_f " u_wq_ej k_qo g_tl_ecm{ " cp_f " k_p" v_j g" c_dug_peg" qh" r gr v_kk_pi "c_i gp_w. "v_j g't_cr k_f "ht_o cv_kqp"qh'r ct_vcm{ "j { f tqn{ ug_f "ur g_ek_gu"q_eew_tu"cu<"

V_k*Q_T+₆"- "zJ₄Q₄*****V_k*Q_J+_z*Q_T+_{6/z}"- "zTQJ 'í í í í í í 0*3₅+"

V_j ku'ku"cee_qo r c_pk_gf "d{ "v_j g"eq_pf g_puc_vqp"t_gce_vqp"cp_f "t_guw_ncp_v"r t_gek_r k_cv_kqp"ku" f g_uet_kd_gf "d{ "gs w_ev_kqp"*3₆+"

V_k*Q_J+_z*Q_T+_{6/z}"- "V_k*Q_T+₆*****Q_T+_{6/z} V_kQ_z/V_k*Q_T+_{6/z}- zTQJ 'í 0*3₆+"

K_p"v_j g"r t_qegu_kp_i . "v_j g"V_k"v_q"J₄Q"t_cv_kq"qt"v_j g"rJ "u_ki p_hl_ecp_v{ "f v_gt_o k_pgu" v_j g"u_k g."o q_tr j q_mi { "cp_f "et { u_vcn_kp_k{ "qh'v_j g"h_kpc_n'r tq_f w_ev₀F q_r g_f "cp_f "w_pf q_r g_f " V_kQ₄"p_cp_qr ct_vl_engu"j c_xg"dg_gp"u{p_vj gu_kg_f "d{ "o cp{ "i tq_wr u₀"

Hydrothermal Technique

K_p" v_j ku" v_eej pls wg." v_j g"t_gce_vqp" v_cngu"r n_eg" k_p" r_ks v_kf "o g_f k_c" c_dq_xg" v_j g" d_qk_kp_i "r q_kp_v"qh'y cv_gt"y k_j "j k_i j "r t_gu_wt_g0 V_j g"t_gce_vqp" v_cngu"r n_eg" k_pu_kf g" c" e_mu_gf " x_gu_gn' e_cm_gf " c_wq_er_xg₀ F g_uk_tg_f " u_qi_kg_pwu" ct_g" w_ug_f " v_q" u_j c_r g" v_j g" p_cp_qr ct_vl_engu₀V_tg_cv_kp_i "v_j g"t_gce_vqp"o k_zw_tg"ht"r t_qm_pi g_f "v_ko g"gp_cd_rgu"wp_ks wg"

tgcevkqpu"vj cv'o c{"pqv'r quukdrng"lp"co dlgrpv"eqpf kkkqpu0'VkQ4"pcpqr ctvkengu"y kj " cpcvcug."twkng" cpf " dtqqnkkg" rj cug"j cxg" dggp" u{pvj guk gf " d{" y ku" vgej pls wg"]Tg{gu/Eqtqpcf q"gv'cr0*422: +_0'Dgukf gu"u{pvj guku"qh"pcpqr ctvkengu."pcpqy kt gu." cpf "pcpqwdgu'hcegvgf "ukpi ng"et {ucnu'o c{"dg'i tqy p"wukpi "y ku"vgej pls wg"}[cpi " gv'cr0*422: +_0'

Microwave assisted Technique

F wg"vq"j ki j "ur ggf .]j qo qi gpgqwu"ugrgevkg"j gcvkpi ."cpf "gcu{"uecndkrk\." vj g" uqnwkq/pcugf ." o letqy cxg/cuukugf " cr r tqcej " vq" u{pvj guk g" qz kf g" pcpqr ctvkengu"j cu"i ckpgf "o wej "cwgpvkqp"lp"tgegpv{"gctu0'Ej go kecn{pvj guku"lp" c"rks wkf "rj cug"vj tqwi j "o letqy cxg"ktcf kcvkqp"lqt"fhgtgpv"fwcvkqp"cpf "r qy gt" kpxqmg"j gcvkpi "qh"vj g"o cvgtken"vj cv'vng"u"r rceg"o quv\ "dgecvug"qh"fk qrt r qrtk cvkqp"cpf "kqple"eqpf wcvkqp"o gej cpluo u0'Wukpi "y ku"vgej pls wg" cpcvcug" VkQ4"pcpqr ctvkengu"j cxg"dggp"u{pvj guk gf "]F kpi "gv'cr0*4229+=F ct"gv'cr0*4236+_"

Microemulsion Technique

O letqgo wukqpu"ctg"eqpukf gtgf "cu"eqmqkf cni'spcpq/f kur gtukqpu "qh"y cvgt" lp" qki" qt" xleg" xgtuc" ucdkrk gf " d{" c" uwthcecpv" hko 0' Vj gug" f kur gtukqpu" ctg" vj gto qf {pco kecm{"s wkg"ucdrng"cpf "ecp"dg'tgi ctf gf "cu"pcpqtgcevqtu"vj cv'ecp"dg" wugf " vq" kpkcvg" ej go kecn' tgcevkqpu" hqt" vj g" u{pvj guku" qh" pcpqo cvgtken0' O letqgo wukqpu"vgej pls wg"j cu"dggp"wugf "vq"u{pvj guk g"VkQ4"pcpqr ctvkengu"wukpi " vkcpkw "kuqr tqr qz kf g"*VRR+:"r qn{qz {gvj {rpg"vgtvqev{r j gp{n'gvj gt "*VtkqpZ/ 322+:"j gr vcpg"cpf "j gzcpgn"]Nk'gv'cr0*4236+_"

Combustion Technique

K'f gcu"y kj "vj g"i cu/rj cug"r tqeguukpi "qh"o cvgtken that"qhgtu"o kpo wo " gpgti {"tgs wkt go gpv."uko r ng"gs wkr o gpv"cpf "hcu"tgcevkqp" wukpi "c" uwuvcpcdrng" gzqy gto le"uqrk/ uqrk "tgcevkqp"co qpi "tcy "o cvgtken0'k"eqo dwukqp"u{pvj guku." vj g"cf kdcvke" hco g"vgo r gtcwtg"fwg"vq" gzqy gto ke"j gcv"gzeggf u"vj g" dqkpi " r qkp"v"qh"vj g"r tqf wew0' k" vj ku"r tqegu." pcpqr ctvkengu"ecp" dg" kpuvcpcpgqwu\ " hqto gf "cu"r tqf wew"fwg"vq"i cukhcvkqp"lp"vj g"dwtplpi "r tqegu"cpf "pwengcvkqp"cu"

y gm'cu'et { ucn'i tqy vj "kp"vj g"eqqrkpi "uwrko cvkqp"r tqegu0Wukpi "vj ku'vej pls wg" cpcvug"V₄"pcpqr ctvngu"j cxg"dgpp"u{pvj guk gf "]P ci cxgpk'gv'crf0*4226+_"

1.2.2 Synthesis of TiO₂ Nanowires/Nanotubes

P qy /c/f c { u."u{pvj guk"cpf "cr r nekckqp"qh"V₄"dcugf "qpg" f ko gpukqpcn' ugo leqpf wekpi "pcpqrctvngu"j cxg"tgegkxgf "tgo ctndng" cwgpvkqp" hqt "vj gkt" uelgpvhe"cpf "vej pqm'i lecn'cur gew0'Chgt "vj g" f kueqxt { "qh"V₄"pcpqrwdgu"d { " Mcuwi c"gv'crf0*3; ; : + "gz vgpukxg"uwf lgu"tgrvfg "v"vj g"i tqy vj "cpf "r tqr gtvku"qh" V₄" dcugf "qpg" f ko gpukqpcn' pcpqrctvngu" ctg" dgkpi "ectkfg" qw0' F hgtgpv' o gjv qf u'v'i tqy "pcpqy ktgu"wej "cu'vgo r rvgu."go wukqpu'qt"r qn{ o gtle"u{vgo u." xcr qwt"tcur qtv' o gjv qf u."uqnrkqp" o gjv qf u."grgextqej go kmt { "gve0'ctg"tgr qtvfg " kp"rkgtcwtgu"}\ qw'gv'crf0*4228+0'Dgukf gu"vj gug"vej pls wgu."j { f tqv gto cn'qhhtu" xctkfv{ "qh" o letqutwe { vtgu"v"vj g"r tqf wev'y kj "uko r n{ "xct { kpi "vj g"u{pvj guk" r ctco gvtu'rkng"vgo r gtcwtg."rJ "qh"r tgekr kcvkqp."tgc'i gpwulwthcecpw."tgcevkqp" vgo r gtcwtg."uqrxgpw" gve0']D{ tcr r c" cpf " [quwj ko wtc" *4223+0' Dcukecm{ ." kp" j { f tqv gto cn' vej pls wgtgcevkqp" vj g" o cvgtkn' ku" j gcvgf " kp" vj g" r tgugpeg" qh' cwqi gpqwu'r tguuwtg'tguwukpi "htqo "vj g"j" gcvkpi "dg{ qpf "vj g"dqkpi "r qkv'qh"vj g" cs wqwu" uqrxgpv0' Vj ku" uwr gt/etk'lecn' y cvgt " gzej kdku" ur gekn' hwpevkqpu" kp" hcekrkcvkpi "vj g"eqo r ngz"tgcevkqpu."cpf "tguwuu"kpq'vpls wg"utwewtcn'hgcwtgu"vq" vj g"hkpcn'r tqf wev"}\ qw'gv'crf0*4228+0J qy gxgt."kp" o quv'qh"vj g"ecugu."f wtkpi "vj g" u{pvj guk"qh"V₄"pcpqy ktgu."vj g"r j cug"ej cpi gu"vq" c" o gvc/ucdng" o qpqer'kle" V₄" *D+r j cug"chgt"j { f tqv gto cn'tgcwo gpv'][quj kf c"gv'crf0*4227+_"qt" c"tceg" qh' dtqqnkvg" r j cug" hqto u" cm'pi " y kj " cpcvug" r j cug"]\ j cpi " gv' crf0' *4224+0' J { f tqv gto cn'tgcwo gpv'y kj "eqpegpvcvgf "P cQJ "qt"MQJ "qhvgp"ej cpi gu"vj g" r j cug"qh"vj g"V₄"vq"wpf gukcdng"P c₄V₈"qt" M₄V₈"t gur gevkxgn{ "]O gpi "gv'crf0' *4228="F w'gv'crf0*4225+0'U{pvj guk"qh'pcpqy ktgu"wukpi "uwr/o letqueqr le"V₄" r ctvngu"ctg"cnq"tgr qtvfg "]F w'gv'crf0*4225+0'T gi ctf kpi "vj g" o gej c'kuo "qh"vj g" pcpqy ktglwdg" i tqy vj ." tgr qtw" uwi i guv' vj g" hqto cvkqp" qh' kvgt o gf kvg" pcpquj ggw' f wg" vq" j { f tqv gto cn' tgcwo gpv' vj cv' tqm' wr " vq" hqto " wdgw" chgt" y cuj kpi "kp" f knwg"cekf "]Y cpi "gv' crf0' *4224+0'J qy gxgt." \ j cpi "gv' crf0' *4227+_" tghwgu" vj g" ghgev' qh' y cuj kpi " r tqegf wtg" qp" vj g" o qtr j qm'i { " qh' vj gug"

pcpquwtwewtgu0J {ftqvj gto cn'tgcevkap"cv"j ki j "vgo r gtcwwtg"qhvgp"rgcf u"vq"vj g"
hqtocvkap"qh'pcpqy ktgu'kpugcf "qh'wdgu"]Cto utqpi "gv'cn0*4226+0"

1.2.3 Deposition of Thin Films

" Uxgtcn'vej pls wgu"j cxg"dggp"go r m{gf "hqt"vj g"i tqy vj "qh"vj kp"hkro u"qh"
VlQ40Vj gug'ctg'r wugf "rcugt" f gr qukkap"*RNF +."o gcn'qti cple"xcr qwt" f gr qukkap"
*O QEXF +."ur wwtkpi ."o qrgewrt"dgco "gr kcz {"*O DG+."vj gto cn'gxcr qtcvkap."
uqn'i gn"cpf "g/dgco "gxcr qtcvkap0'Vq" f gr qukv'hkro u."f khgtgpv"uwdutcvgu"j cxg"
dggp"wugf "rkg"Uk"S wctv."NcCrQ5."UtVlQ5."e/r rpg"CnQ5"cpf "i ruu0'Cu"vj g"
o gxcvcdng"cpvcug"htoc "qh"VlQ4"ku"fkhlkwn"vq"r tqf weg"lp"dwm"vj g{"ecp"dg"
hcdtkcvgf "kp"vj kp"hkro "htoc "d{"ej qqulpi "cr r tqr tkvg"rcwleg/o cvej gf "uwdutcvg0'
Hkro u"ecp"dg"i tqy p"gr kczkcm{"qp"uwdutcvgu"y kj "o kpk wo "rcwleg"o kuo cvej 0'
Cpvcug"VlQ4"j cu"o kpk wo "rcwleg"o kuo cvej "hqt"NcCrQ5"uwdutcvgu0'

Pulsed Laser Deposition (PLD) Technique

" K'ku"vj g"o quv'xgtucvkg"vej pls wg"vq" f gr qukv'uvkqj kqo gvtke"vj kp"hkro u"d{"
qr vko k kpi "vj g"fkhlgtgpv" f gr qukkap"r ctco gvtu0'K'wugu" c"r wugf "rcugt"dgco "vq"
cdrcvg" vj g" vcti gv" o cvgtkcn' vq" f gr qukv' k' qp" vj g" uwdutcvg" ngr v' cv' c" hkgf "
vgo r gtcwwtg0'Vj g'cdrcvkap"r tqegu"i gpgtcvgu"vj g'r ruo c"npqy p"cu'r nwo g"vj cv'ku"
cewcm{"eqpf gpugu"qp"vj g"uwdutcvg0'Vj gtg"ku"cp"qr vkap"vq"hmjy "tgcexg"i cugu"
rkg"qz {i gp'lpvq"vj g"ej co dgt" f wtkpi "vj g" f gr qukkap"vq"eqo r gpucvg"vj g"qz {i gp"
ruu0'J qy gxgt."r tqr gt"xcewo "o wuv'dg"o clpvkpgf "hqt"vj g'r ruo c"htocvkap0'
VlQ4"cpf "tcpukskap"o gcn'f qr gf "VlQ4"hkro u"qh"cpvcug"cpf "twkrg"r j cugu"j cxg"
dggp"i tqy p'wukpi "vj ku'vej pls wg"][co co qvq'gv'cn0*4223+0'

Sputtering Technique

" Vj g" y qtf "ur wwtkpi "o gcpu" vq" glgev" o cvgtkcn' htqo " vj g" vcti gv" vj cv"
wnko cvgn{"i gw" f gr qukvgf "qp" vj g" uwdutcvg" vq" o cng" c" hkro 0' Vj gug" ur wwtg" f "
glgev" f " vcti gv' cvqo u" j cxg" c" y kf g" gpgti {" f kvtkdvwkap0' " Vj gug" cvqo u" o c {"
dcnkvkcm{"h{"htqo "vj g"vcti gv'lp"utcki j v'rkpgu"cpf "dqo dctf "qp"vj g"uwdutcvgu0'
Vj gtg"ku" c"r tqdcdng"ej cpeg"qh'tg/ur wwtkpi "kp"vj cv'ecug0'Vq"umjy "f qy p"vj gug"

dcmkxk"ur wwtgfg "cvqo u."uqo g"tgcevkxg"i cugu"ctg"wguf 0'Vj gug"i cugu"o cmg"vj g" ur wwtgfg "cvqo u'tgcev'cpf "vj gp"vj g{ "unqy n{ "i gwu'f gr qukvgf "qp"vj g"uwduxcvg0Hqt" ur wwtgkpi . "kpgt v'i cu'rkmg"Ct "ku'r tghgtt gf 0'J qy gxgt."hqt"eqo r ctcdrg"o qo gpwo " vcpuhgt. "vj g"cvqo ke"y gli j v'qh"vj g"ur wwtgkpi "i cu"o wuv'dg"enqugt "vq"vj g"cvqo ke" y gli j v' qh" vj g" vcti gv0'J gpeg." hqt" ur wwtgkpi " qh" rki j v' cvqo u." P g" ku" uwkcdrg" y j gtgcu"vq"gxcr qtcvg"j gcx{ "cvqo u"Mt "ku'r tghgtcdrg0'Vj g"tcvg"qh'o qvkvq"qh"vj g" ur wwtgfg "r ctvkngu'ecp"dg"eqpvtqmgf "d{ "ej cpi kpi "vj g"dcemi tqwpf "r tguuwtg0'Vj g" eqo r qwpf u"j cxkpi "grgo gpw"qh" f khgtgpv"o gmkpi " r qkpw"ctg" uwkcdrg" hqt "vj ku" o gvj qf "hqt" f gr qukvkvq0'VkQ4 "cu"y gm'cu"vcpukkvq"o gvcn'f qr gf "VkQ4"j cxg"dgpp" f gr qukvgf "d{ "vj ku"vgej pks wg"]\ go cp"cpf "Vcmædc{ cuj k*4224+_0'

Thermal Evaporation Technique

" Vj gto cn'gxcr qtcvkqp"vgej pks wg"ku'dcugf "qp"vj g"tgukvkvxg"j gcvkpi "r tqegu0' K'wugu"ct'gukvcpvg"j gcvkpi "grgo gpv"kp"vj g" hqto "qh" c"dqcv"qt"eqki"vq"o gm"vj g" o cvgtkcn' vq" tckug" ku" xcr qwt" r tguuwtg0' Vj g" gxcr qtcvkqp" vcmgu" r mæg" kp" j ki j " xcewwo 0'Vj g"o cvgtkcn'i gwu'f gr qukvgf "kp"vj g"i cu"r j cug"qp"vj g"ugrgevfg "uwduxcvg" r mægf "kp"htqpv'qh"vj g"j gcvg0'Rt guugf "r gmrv'qh"VkQ4"r qy f gt"o cvgtkcn'ku"o ckpn{ " wugf "cu" c"vcti gv0' Kp"cpqvj gt"y c{. "vj kp" hkn u" qh"VK'o c{ "dg" f gr qukvgf "qp"vj g" uwduxcvgu."cpf "uwdugs wgpv"cppgcnkpi "kp"qz {i gp" cvo qur j gtg"o c{ "mgf "vq"vj g" hqto cvkvq"qh'r j cug'r vtg"VkQ4'hkn u"][cf cx"gv'cn0*4229+_0'

E-beam Evaporation Technique

" Kp" g/dgco "gxcr qtcvkqp"vgej pks wg."vj g"vcti gv"o cvgtkcn'ku"r mægf "kpukf g" c" eqr r gt"etwekdrj"vj cv'cew"cu"cp"cpqf g0' Cp"grgestqp"dgco "ku" dgo dctf gf "htqo "cp" grgestqp"i wp"qp"vj g"o cvgtkcn'r mægf "kp"vj g"etwekdrj0'Wr qp"utknkpi "vj g"o cvgtkcn" kv'gxcr qtcvqu"cpf "hqt o u" c"i cugquw"r j cug"vj cv"i gwu'f gr qukvgf "qp"vj g" f guktgf " uwduxcvgu'r mægf "cv'c"egtckp" f kvcpvg'htqo "vj g"vcti gv0'Dgukf gu"vj g"uwduxcvg."vj g" o cvgtkcn'i gwu'f gr qukvgf "kpukf g"vj g"y j qng"ej co dgt0'Vq"r tqj kdk"vj ku" f gr qukvkvq" qp"vj g"grgestqp"i wp."vj g"dgco "qh"grgestqp"ku"dgpv"vj tqwi j "cp"qdwug"cpir ng"d{ "c" o ci pgv."uq"vj cv'kv'f qgu"pqv'eqo g"kp"htqpv'qh"vj g"vcti gv'f wtkpi "f gr qukvkvq0'VkQ4" vj kp" hkn u" j cxg" dgpp" uweeguuhwn{ " f gr qukvgf " d{ " vj ku" o gvj qf "][cpi " gv' cn0

*4226+_0'Kp"cpqvj gt"y c{."VK'hkm u"ecp"dg"f gr qukvf "d{"y ku"o gjv qf ."cpf "y gp" yj gug'hkm u"qp"qz kf cvkqp" {kgrf u"VKQ4"}Ej qpi "gv'cr0*4228+_0'

Sol-gel Spin Coating Method

" Uqn'i gr' ur kp" eqcvkpi " ku" yj g" o quv' kpgzr gpukxg" o gjv qf " hqt" yj kp" hkm " f gr qukvkqp0'K'f qgu"pqv'tgs wkt g'j ki j "xcewwo "qt"uqr j kvkcevgf "o cej kpgt {"hqt"yj g" f gr qukvkqp0'C"rks wkf "r tgewtuqt "r tgr ctgf "yj tqwi j "uqn'i gr'vgej pls wg"ku"wugf "hqt" f gr qukvkqp0'Vj g'uqrx gpv'ku"guugpvkcm{ "xqrcvkg"o cvgtkcn'yj cv'o wuv'gxcr qtcvg"chvgt" r quv'f gr qukvkqp"cppgcrkpi 0'C"f tqr "qh"uqnvkqp"ku"r w'qp"yj g"uwdutcvg"yj cv'ku" o qwpvgf "qp"yj g"ur kp"eqcvgt "d{ "gxcewcvkqp."ku"o cf g"vq"tqvcvg"d{ "c"o qvqt"y kj " f khgtgpv'tr o 0'Kp"yj ku"y c{."yj g"gzeguu"qh"yj g"uqnvkqp"ku"tgo qxgf "htqo "yj g" uwdutcvg"uwthceg"cpf "c"yj kp"rc{gt "hqt"o u"qxgt "kv'f wg"vq"egpvtkhw' cn'hqteg0'Vj g"cu" f gr qukvf "hkm "pgeguuctk{ "dg"f tkgf "cpf "cppgcrkf "vq"cej kxg"et {ucmkpg"r j cug0' D{"eqpvtqmkpi "yj g"cp' wrc"ur ggf "cpf "uqnvkqp"eqpegpvtcvkqp"yj g'yj kempguu"qh'yj g" hkm "ecp"dg"eqpvtqmgf 0'O cp{ "rc{gtu"ecp"dg"htqo gf "d{ "tgr gcvkpi "yj g"f gr qukvkqp" cpf "cppgcrkpi "r tqegu0'Vkcpcwo "kuqr tqr qz kf g"qt "kpcpkwo "dwqz kf g"f kuqrx gf "kp" cduqnvw"gy cpqn'ku"i gpgtcm{ "wugf "hqt"yj g"f gr qukvkqp"qh"VKQ4"yj kp"hkm u"d{ "ur kp" eqcvkpi "vgej pls wg"}Qj {c"gv'cr0*3; ; 8="Tcvj "gv'cr0*422; +_0'Hqt "f qr kpi "vtcpukvqp" o gvcn'kp"VKQ4."eqttgur qpf kpi "o gvcn'cegvcvgu"ctg"f kuqrx gf "kp"creqj qn'ku"o kz gf " y kj "yj g"r tgewtuqt "uqnvkqp"dghqtg"ur kp"eqcvkpi 0'Vj g"tr o "cpf "f gr qukvkqp"vo g" ecp"dg"eqpvtqmgf "yj tqwi j "eqo r wgt"r tqi tco u0"

Molecular Beam Epitaxy (MBE) Technique

" O DG"ku"wugf "vq"f gr qukv'j ki j "r wtkv{ "gr kczkcn'yj kp"hkm u0'Vj ku"f gr qukvkqp" vgej pls wg"ku"c"htqo "qh"uqr j kvkcevgf "xcewwo "gxcr qtcvkvqp"vgej pls wg."kp"y j kej " f ktgevgf "pgwtcn' yj gto cn'cvqo ke" cpf "o qrgewrc" dgco u"ko r kpi g"qp" c"j gcvgf " uwdutcvg"wpf gt"wrc/j ki j "xcewwo "WJ X+"eqpf kvkqp0'Hqt "yj g"etgcvkqp"qh"j ki j " xcewwo ." et {q/r wo r u" ctg" wugf 0' Kp" yj ku" o gjv qf " hkm u" qh" wpkhqt" " yj kempguu"***** *c'po +ecp"dg"i tqy p"}Lq{eg*3; ; 7+_0'Wpf qr gf "cu'y gm'cu" f qr gf "VKQ4"yj kp"hkm u" j cxg"dggp" f gr qukvf "d{"yj ku"o gjv qf "eqo dkpki "qvj gt"vgej pls wgu"htq"yj g"vcti gv" gxcr qtcvkvqp"r tqegu"}Mko "gv'cr0*4226+_0'

MOCVD Technique

" O gvcnqti cple" ej go kecn' xcr qwt" f gr qukkqp" *O QEXF+" ku" dculecm{ " c'ej go kecn' xcr qwt" f gr qukkqp" vgej pls wg" eqo o qpn{ " wugf " vq" r tgr ctg" ukpi ng" qt" r qn{ et { uvcnkp" vj kp" hkm u" qp" f khtg gpv' uwdut cvgu' Vj g" f gr qukkqp" r tqegu" ku" s wkg" eqo r ngz" cpf " ku" dcugf " qp" ej go kecn' tgcevqp" vq" cej kxg" et { uvcnkp" vj kp" hkm u' Kpugcf " qh' j ki j " xcewwo " tgs wkt go gpw' r kng" O DG. " vj g" f gr qukkqp" ecp" dg" f qp" g" kp" vj g' i cu' r j cug" cv' o qf gtcv" r tguuwt gu' Vj ku" vgej pls wg" j cu' dggp" wugf " hqt" r tgr ctg" hkm u" hqt" eqo o gtekn' qr vqngvtpkleu" f gxlegu' Hqt" vj g" f gr qukkqp" qh' V₄Q " hkm . " V₄Q' dcugf " qti cpqo gvcnke" r tgewtuqtu" ctg" wugf "] Y qp" gv' crf' *4223+ D{ wp" gv' crf' *3; ; 9+_0'

1.3 Applications of TiO₂

V₄Q " ku" c" r qvgnvkn' ugo leqpf vevkpi " o cvgtkn' vj cv' hkp' u" cr r necvqp" kp" f kxgtug" hknf u' Kku" c" y gm/npqy p" o cvgtkn' hqt" r j qvqecvkn{ kuku"] Nkpugdkl ngt" gv' crf' *3; ; 7+J" kuj ko qvq" gv' crf' *4227+_0F wg" vq" ku" cdkkv{ " vq" f gi tcf g" eqo o gtekn' f kgu" wpf gt" vj g" WX" kttcf kvqp. " kv' j cu' dggp" uwf kfg " hqt" vj g" y cvg" y cvgt " vgcvo gpv'] Nk" cpf " NK" *4223+ T w r gtv' gv' crf' *3; ; 6+_0Kku" eqo o qpn{ " wugf " cu' vj g" y j kg" r ki o gpv' kp" eqmwtu. " r clpw. " equo gvku" cpf " kp" vj g" r j cto cegwku" kpf wutkgu"] O qtvgttc" gv' crf' *3; ; 4+ C { qp" *4228+ Eqpvcf q" cpf " Rci pqp" *422: +_0Kku" pqp/ vqzke" kp" pcwtg" cpf " j cxkpi " cpvdcvgtkn' r tqr gtv{ " vj cv' o cngv" kv' cr r necdng" hqt" vj g" wug" cu" eqcvkpi u"] [w' gv' crf' *4225+_0V₄Q " dcugf " r qn{ o gt" eqo r qukvgu" ctg" pqy /c/f c{ u" i clkpi " o wej " kvgtguv' hqt" f khtg gpv' cr r necvqp" r qkv' qh' xkgy "] J cp" gv' crf' *4232+ Rgpc" gv' crf' *3; ; 9+_0Kp" r ctvkwrt. " V₄Q " pcpqy ktgu" ctg" ko r qtvcv' f wg" vq" vj gkt" r qvgnvkn' cr r necvqp" kp" f { g" ugpukk gf " uqjrt" egm" *F UUE+] Rcvwug" gv' crf' *4228+_ " cu" cp" gngvtf g" hqt" NK" kqp" dcwgtkgu"] Cto utqpi " gv' crf' *4228+_ cpf " r quukdng" wug" kp" pcpq" hknf " ghge' v' tcvkuvqtu" *HGV+] Dckm' gv' crf' *422: +_0V₄Q " ku" wugf " cu" ugpuqt" hqt" f gvgt o kpcvqp" qh' ej go kecn' qz { i gp" f go cpf " } j gpi " gv' crf' *422: +_ " i cugu" r kng" j { f tqi gp"] O qt" gv' crf' *4226+_ cpf " j { f tqi gp" uwr j kf g"] Nkp" gv' crf' *3; ; 7+_ cpf " i nveqg"] Dcq" gv' crf' *422: +_0V₄Q " f qr gf " y kj " tcvkuvqp" o gvcn' gzj kdk' tqgo " vgo r gtcwgtg" hgttqo ci pgvkuo " vj cv' o cngv" kv' c" r quukdng" qz kf g" f kwwg"

o ci pgvle"ugo leqpf wevqt "FOU"o cvgtkcn'Dghqtg"i qlpi "v"vj g"fgvcku"qh"qzkg" FOU.y g'r tguvp'dgmy "c"dtlgh'qxgtxlgy "qh"vj g'FOU"o cvgtkcn'

1.4 Dilute Magnetic Semiconductors

Ugo leqpf wevqtu"fqrgf "y kj "o ci pgvle"kpuc"tg"dgkpi "uwf kgf "kp"cp"ffqtv" vq"fgxgmr "ur kvtpkleu."vj g"pgy "nkp"qh"grgevtqpleu"vj cv"uggm"vq"gzr mkl"dqj " ej cti g"cpf "ur kp"fgi tggu"qh"htggf qo "] \ wke"gv'cnf"4226+_0"Vj g"Łtuv"uq/ecmgf " f kwwg"o ci pgvle"ugo leqpf wevqtu"FOU"y gtg"KKXK"ugo leqpf wevqt"cmj {u"rkng" \ p_{3/2}O p_zVg"cpf "Ef_{3/2}O pVg"qtki kpcmf "uwf kgf "kp"vj g"3; : 2u"]Hwtf {cpc"3; : : +_0" Vj gug"o cvgtkcn"ctg"gkj gt"ur kp"i rcuugu"qt"j cxg"xgt {"mly "hgttqo ci pgvle"*HO + etkklcni'vgo r gtcwtgu"*V_E" chgy "M"]Hgttcpf "gv'cnf"4223+_ "cpf "ctg."vj gtghqtg." kpcf gs wcvg"ht"vej pqmji kcn'cr r dncvqpu"y j lej "y qwf "tgs vktg"hgttqo ci pgvle" qtf gt"pgct"tqqo "vgo r gtcwtg'0'Hwtj gt."Op"fqrgf "KKX"ugo leqpf wevqtu"K_{3/2} O pCu"]O wpgnvc"gv'cnf"3; : ; =Qj pq"gv'cnf"3; : ; 4+_ "cpf "I c_{3/2}O pCu"]Qj pq"gv'cnf"3; : ; 8=Lxpi y ktvj "gv'cnf"4228+_ "uj qy gf "hgttqo ci pgvkuo "cv"co wej "j ki j gt" vgo r gtcwtg"fwg"vj g"fgxgmr o gpv'qh'o qrgewrt"dgco "gr kcz {"*ODG+i tqy vj " vej pls wgu'Vj g"ewtgpv"j ki j "V_E"tgeqtf "qh"395"M"ku"cej kxgf "kp"Op/fqrgf " I cCu"d {"wukpi "mly "vgo r gtcwtg"cppgcrkpi "vej pls wgu"]Gf o qpf u"gv'cnf"4224+= Ej kdc"gv'cnf"4225+_0"K'ku'r tqo kulpi ."dw'u'kn'vq"mly "ht"r tcevkcn'cr r dncvqpu' Hqt"cm'vj gug"o cvgtkcn."hgttqo ci pgvkuo "j cu'dggp"rtqxp"v"dg"ecttkt"o gf kcvf ." c"pgeguuct {"rtqr gtv {"ht"ur kvtpkleu" ukpeg"vj ku"gpdrgu"vj g"o qf kLecvqp"qh" o ci pgvle"dgj cxkqwt"vj tqwi j "ej cti g"o cplr wrcvqp'0"Vj ku"j cu"o qvxcvfg "c"s wguv" ht" cngtpevkg"ur kvtpkle"o cvgtkcn" y kj "tgrvkg"j ki j gt" V_E"cpf "ecttkt" o gf kcvf "hgttqo ci pgvkuo 0'K"vj ku"fkgevkp."fkwwg"o ci pgvle"ugo leqpf wevki " qzkgu"]Lcpkuej "gv'cnf"4227+_ "uwej "cu"tvcpu'kqp"o gcn'f qrgf "V_kQ₄"]O cuwo qvq" gv'cnf"4223+_ "\ pQ"]Wgfc"gv'cnf"4223+_ "cpf "UpQ₄"]Qi cmg"gv'cnf"4225+_ "eqwf " tgr tguvp"vj g"cngtpevkg"y kj "V_E"u"cdqyg"tqqo "vgo r gtcwtg"cpf "cu"j ki j "cu"č" 922M"]Uj kpf g"gv'cnf"4225+_0"Co qpi "vj g"qzkg"FOU"o cvgtkcn."y g"hgewu"qpn {" qp"vj g"V_kQ₄"dcugf "FOU'

"

1.4.1 TiO₂ Based DMS

Tqqo "vgo r gtcwtg"hgttqo ci pgvkuo "y cu"htuv"fkueqxtg"gf "kp"Eq"*9"cv" +
 f qr gf "VlQ₄"d{ "O cwwo cvq"gv'cn0"*4223+"hmqy gf "d{ "Ej co dgtu"gv'cn0"*4223+0'
 Ncvgt"mqw"qh"tgugctej "y qtn'go gti gf "vq"f go qpuctevg"hgttqo ci pgvkuo "kp"vj gug"
 u{uvgo u"d{ "f khtgtpv"gr qukkqp"vej pls wgu"cu"o gpvkqpgf "gctrtgt0Vj g"qdvkpgf "
 tguwmu" kpf kecvg" utqpi " f gr gpf gpeg" qh" i tqy vj " r ctco gygtu" qp" vj g" utwewtcn"
 grgextkcn' cpf " o ci pgvke" r tqr gtvgu' O ci pgvke" r tqr gtvgu" qh" vj g" f qr gf " VlQ₄"
 etkkkcm{ "f gr gpf "qp"vj g" f qr cpw"uqndkkr{ "kp"VlQ₄"o cvtkz0Cdqyg"uqo g"etkkkcn'
 xcng." vj g" f qr cpv"uctw" ci i mqo gtcvpi "cu" ko r wtk{0J qy gxgt." vj g" o ci pgvke"
 o qo gpv"htq" vj g"uco g" f qr cpv"eqpegpvtcvkp"ku"cnq"pqv'cej kxgf "d{ "f khtgtpv"
 vej pls wgu'0Hqt"gzco r ng"kp"ecug"qh"9"cv0 "Eq" f qr gf "VlQ₄"vj g" o ci pkwf g"qh"
 ucwvcvkp" o ci pgvkvkqp"tcpi gu"htqo "2054"vq"30μ_B0'K' uwi i guw"vj g" i tqy vj "
 r ctco gygtu"rkng"uwdutcvg."qz {i gp"r ctvkn'r tguwtg."f gr qukkqp"vgo r gtcwtg"cpf "
 r j cug"qh"VlQ₄"f gvgto kpgu"vj g"uqndkkr{ "qh" f qr cpv"kp"j quv'o cvtkz"uj qy kpi "vj g"
 hgttqo ci pgvke" qtf gt0J qy gxgt." vj g" tguwmu" ctg" cny c {u" pqv' tgr tqf wekdrng" cpf "
 qhvgp" etkkkē gf " hqt" vj g" r quukdrng" tqng" qh" eqpvc kpcvkp" i kkpī " tkug" vq" vj g"
 qdugt xgf "o ci pgvkuo 0Dgukf gu'Eq"ugxgtcn'ecvkqpu'rkng'X.'Et.'Hg.'P k'cpf 'Ew'j cxg"
 dggp" f qr gf "kp"VlQ₄"vq"uwf { "vj g" qdugt xgf "o ci pgvkuo 0'Chgt"vj g" f kueqxtg { "qh"
 hgttqo ci pgvkuo "kp"wpf qr gf "VlQ₄." vj g" r tqdcdng" tqng" qh" f qr cpw" kpf wekpi " vj g"
 o ci pgvke" qtf gt" dgeqo gu" eqpvtqxgtukcn'0Y j gj gt" vcpukkp" o gvcn' f qr cpw" qt"
 qz {i gp"xcecpelgu"ctg"vj g" r quukdrng"uqwtg"qh"o ci pgvkuo "ku"uvkn'pqv'gucdrkuj gf 0'
 Vj gtg"ctg"ugxgtcn'r tqr qugf "o gej cpkuo u"kp"rkgtcwtg"vj cv'g zr nkpū"vj g" r quukdrng"
 hgttqo ci pgvkuo "kp"FOU"o cvgtkcn'0J qy gxgt."pq"ukpi ng"o qf gn'eqwf "g zr nkp"vj g"
 qdugt xgf "hgttqo ci pgvkuo "eqo r ngvgn{0Vj g"rkgtcwtg"qp"xctkqu" f qr kpi "kp"VlQ₄"
 ctg"i kxgp"kp'Ej cr vgt "KO"

"
 "
 "
 "

1.4.2 Possible Origins of Ferromagnetism in DMS

Kp"vj ku"ugevkqp."y g"f kuewuu"f khhgtgpv'o gejc pkuo u"kp"vgtu u"qh"kpvtcevkqp" qh" ur kpu" r tqr qugf " hqt" vj g" qtki kp" qh" o ci pgvkuo " kp" f kwwgf " o ci pgvke" ugo keqpf wevtu0' Hqt" gzco r ng." f qwdrg" gzej cpi g" kpvtcevkqp" vj cv" ngcf u" vq" hgttqo ci pgvkuo "y j gtgcu"vj g"qvj gt"o gejc pkuo u"ngcf "vq" gkij gt" hgttqo ci pgvke"qt" cpv hgttqo ci pgvke" kpvtcevkqpu" f gr gpf kpi " qp" vj g" pcwtg" qh" vj g" dqpf kpi ." utwewtg."v{r g"qh'f ghgev'."cpf lqt'ecttkgt"eqpegpvtcevkqp0'

Exchange Interaction in Insulators: direct and superexchange

(a) Direct exchange

O ci pgvke" gzej cpi g"kpvtcevkqpu"ctg" wuwcm{ "y tkwgp"kp"vj g" hqto "qh" c"ur kp" j co kxqpkcp"cu"

$$\mathcal{H}_d = \sum J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j$$

Vj g" r ctco gvgt" \mathcal{H}_d eqwr ngu" vj g" ur kp" cv" r wkeg" ukvku" k" cpf "I0' F kt gev" gzej cpi g" kpxqkxgu" cp" qxgtxr "qh" grgevtqple"y cxg" hwpevkqpu" htqo "vj g" vy q" ukvku" cpf "vj g" Eqwqo d" grgevtqucvke" tgr wukqp0' Vj g" Rcwkr u' gzenwukqp" r tkpek r ng" o cngu" vj g" grgevtqpu" y kj " r ctcmgil ur kp" cy c{ "htqo " gcej "qvj gt." vq" tgf weg" vj g" Eqwqo d" tgr wukqp0' Vj g" f khhgtgpeg" kp" gpgti { "hqt" r ctcmgil'cpf "cpvkr ctcmgil'eqphki wtcvkqpu" ku" npqy p" cu" vj g" gzej cpi g" gpgti { 0' Dcukecm{ ." cp" cpvkr ctcmgil'eqphki wtcvkqp" ku" r tghgttgf " cu" vj g" uko r ngu' ecug" qh" vj g" j { f tqi gp" o qrgewrg0' Ukpeg" vj g" y cxg" hwpevkqpu" qh" vj g" o ci pgvke" šf " qt" šh" grgevtqpu" f getgcug" gzer qpgpvckm{ " y kj " f kwcpeg" htqo "vj g" pwengwu." vj g" J_d " qdvckpgf " htqo "vj g" qxgtxr "kpvgi tcn' ku" s wkg" uo cm'vq" r tqxkf g" vj g" pgeguuct { "eqwr r kpi 0' K' vj g" kpvtcevkqp" vcngu" r nceg" dgw ggp" mqecik gf " grgevtqpu" qp" f khhgtgpv' pgki j dqwtkpi " cvqo u." J_d " vgpf u" vq" dg" pgi cvkxg" eqttgur qpf kpi "vq" c" ukwcvkqp" y j gtg" vy q" grgevtqpu" crki p" cpvkr ctcmgil' vq" hqto "c" dqpf kpi "ucvgo0' K' c" uqikf "j cxkpi "wpr cktgf "pwo dgt" qh" grgevtqpu." vj g" uki p" qh" J_d " kp" r tkpek r ng" dg" gkij gt" r qukxg" qt" pgi cvkxg. "dw" kp" o quv' qh" vj g" ecugu" pgi cvkxg" r ctv' f qo kpcvgu" ngcf kpi "vq" cpv hgttqo ci pgvke" crki po gpv' qh" vj g" pgki j dqwtkpi "ur kpu"]O { f quj *3; ; 5 = Lcpkuej "gv'ci0*4227+0'

(b) Superexchange

Kp" ecug" qh" vcpukkp" o gvcn' qz kf gu" cpf " tgrcvf " o cvgtkcu." o ci pgve" kpvgtcevqpu" dgvy ggp" vj g" vcpukkp" o gvcn' kpu" ctg" o gf kcvf " d{ " vj g" kpvgt o gf kcvf "cpkpu"ngcf kpi "vq" c"Uwr gtgzej cpi g" kpvgtcevqpu'Uwr gtgzej cpi g" kpvgtcevqpu"ecp"dg"f guetkdgf "d{ "c"J gkugpdgti "J co knqpkcp."y j gtg"vj g"uki p"qh"Jk" ku" f gvgt o kpgf " d{ " vj g" o gvcn/qz {i gp/o gvcn' dppf " cpi ng" cpf " vj g" f" grgevqp" eqphk vcevqpu" qp" vj g" vcpukkp" o gvcn' Vj g" eqttgur qpf kpi " tguwmu" ctg" uwo o ctk gf " kp" vj g" eqo r gpf kwo " qh" y qtm' dcugf " qp" vj g" ugo k/go r klcen' I qgf gpqwi j /Mcpco qtk/Cpf gtuqp'twgu"]Lcpkuej "gv'cr0*4227+0'

Carrier mediated exchange interaction (RKKY, Zener carrier mediated exchange and Zener double exchange)

Vj g" rj tcug" secttltg/o gf kcvf " gzej cpi g " v{r kcm{ " tghgtu" vq" vj g" kpvgtcevqpu"co qpi "vj g"meci k gf "o qo gpw"vj cv'ctg"o gf kcvf "d{ "tgg"ecttkgtu"kp" vj g" u{uwo 0' Dgruy " y g" go r j cuk g" qp" vj tgg" rko kkp i " ecugu< vj g" TMM[" kpvgtcevqpu." \ gpgt" ecttkgt " o gf kcvf " gzej cpi g" cpf " \ gpgt" f qwdng" gzej cpi g" kpvgtcevqpu'Kp"o quv'qh"vj g"ecugu."vj g"u{uwo "gzj kdk'hgcwgtgu"qh"vy q"qt"cm'qh"vj g" o qf gu"]Lcpkuej "gv'cr0*4227+0'

RKKY: Hqt"vj g"o ci pgve"cmq{u."vj g"eqpf vevqpu"grgevqpu'ngcf "vq"utqpi gt"cpf " mqi /tcpi g" kpf kgev" gzej cpi g" kpvgtcevqpu'Vj ku"ku"vj g"pqy "hco qwu"Twf gto cp/ Mkwgn/Mcuw{c/[qukf c" *TMM[+ kpvgtcevqpu" y j qug" J co knqpkcp" ku" \mathcal{H} ?" $J^*t+S_k S_l$ 'OGo dgf f kpi "vj g"o ci pgve"ko r wkv{."kq0" c"meci'o qo gpv"*ur kp"S_{k+}."kp" c" ugc"qh"eqpf vevqpu"grgevqpu"y kj "kkgpvtcpv'ur kp"s*r+"ecwugu" c" f co r gf "queknevqpu" kp" vj g" uwegr vdkkv{ " qh" vj g" eqpf vevqpu" grgevqpu." cpf " vj gtgd{ " c" eqwr kpi " dgvy ggp"ur kpu"*S_k"cpf "S_l+"hqmny kpi "vj g"tgrcvqpu"

$$J(r) = 6\pi Z J^2 N(E_F) \left[\frac{\sin(2k_F r)}{(2k_F r)^4} - \frac{\cos(2k_F r)}{(2k_F r)^3} \right] \dots \dots \dots (1.6)$$

y j gtg\ "ku"vj g"pwo dgt"qh"eqpf vevqpu"grgevqpu'r gt"cvqo ."L"ku"vj g"u/f" gzej cpi g" eqpuwcpv."P*E_F+"ku" vj g" f gpukv{ " qh" ucvgu" cv' vj g" Hgto k'ngxgn" k_F" ku" vj g" Hgto k'

o qo gpwo "cpf 't'ku'vj g'f kucpeg"dgwy ggp"vy q'ko r wtkku0Vj g'cdqyg"gzr tguukqp" tgf wegu'vq"

$$J(r) = \frac{J_0 \cos(2k_F r + \phi)}{(2k_F r)^3} \dots \dots \dots (1.7)"$$

hqt"nti g'f kucpeg0C"r j cug"hcexqt" "j cu"dgpp"kvqf wegf "vq"ceeqwpv'hqt"vj g" ej cti g' f hgtgpeg" dgwy ggp" ko r wtkv{" cpf " j quv' cpf " vj g" hqto gt u" cpi wxt" o qo gpwo "]O {f quj *3; ; 5+0"

Zener carrier mediated exchange: U{uvgo u" j cxkpi " dqj " mcecn' o ci pgve" o qo gpwu"cpf "kkgtpcv"ecttkgtu"*f qr gf "F O U+"y j gtg"vj g"ecttkgtu"ecp"r quukdn{" o gf kvg" c" hgttqo ci pgve" kvgtcevqp" co qpi " vj g" mcecn' o ci pgve" o qo gpwu" ku" vto gf "cu" \ gpgt"ecttkgt/o gf kvgf "gzej cpi g"] \ gpgt" *3; 73c=" \ gpgt" *3; 73d+0 Vj g" hgttqo ci pgve" qtf gkpi "ku" guxcdkuj gf "d {" mvy gkpi "qh"vj g"ecttkgt u"gpgti {" f vq" vq" tgf kvtkdwkqp" dgwy ggp" ur kp" uwddcpf u" ur kv" cr ctv" d {" vj g" gzej cpi g" kvgtcevqp"]Lcpkuej "gv'cn0*4227+0"

Zener double-exchange < K' j cu" dgpp" r tqr qugf " vq" gZR rkp" vj g" qdugtvgf " o ci pgvuo "kp" f qr gf "r gtqxunkg" utwewtg" o cpi cpkvu. "Nc_{3/2}C_zO pQ₅." y kj "C"?" Ec." Ut. "qt" Dc0Hqt" kvgtg gf kvg"xcnvgu"qh"2">"z">"3"dqvj "O p⁶⁻ *y kj "vj tgg"5f " grgevtpu+"cpf "O p⁵⁻ *y kj "hwt"5f "grgevtpu+"ctg"r tgugp0K' vj g" o ci pgve" kvpu" crki p" r ctcnrgn "vj g" kvpgve" gpgti {" qh"vj g" u{uvgo "ku" mvy gtgf "ngcf kpi "vq" grgevtpu" vcpuhgt" hqto "O p⁵⁻ "vq" O p⁶⁻ 0Vj ku"v{r g"qh"eqw r kpi "ku" ceeqo r cpkgf "d {" qz {i gp" cvqo u" dgwy ggp" pgki j dqwtkpi "O p⁵⁻ "cpf "O p⁶⁻ "kvpu." dw"ku" f hgtgpv" hqto " vj g" uwr gtgzej cpi g"d {" vj g" kvxqkgo gpv'qh"vj g"ecttkgtu"] \ gpgt" *3; 73e+0"

Bound Magnetic Polarons (BMP)

Kp"vj g"DO R"o qf gn"qz {i gp" xcecpkvgu"cev"cu" grgevtpu" f qpqtu"cu"y gm'cu" vcr u" grgevtpu" vj cv'ecp" j qrf "vj g" grgevtpu" cpf "o ckpvckp" kvuwrkpi "dgj cxkqwt0 Gxgt {" vcr r gf "grgevtpu" eqw ngu" vj g" mcecn' o qo gpwu"qh"vj g" j quv' kvwkg" vj cv' rkg" y kj kp"ku" qtdk' hgttqo ci pgvecm{. "hqto kpi "c" dqwvf "r qmctqp" y kj "c" pgv'o ci pgve" o qo gpv0 Kp" ecug" qh" y q" pgki j dqwtkpi " r qmctqpu" f qp v' eqw ng" utqpi n{. " c"

r ctco ci pgve" kpuwrcvpi " r j cug" hqto u0' Vj qwi j ." hqt" egtvckp" r qmctqp/r qmctqp"
 f kuvpegu" cpf " eqo dlvckvapu" qh" grgevtpq/grgevtpq" cpf " grgevtpq/mqecn" o qo gpv'
 gzej cpi g"eqpuwcpvu."vj g"r qmctqpu"o c { "kpvgtcev"kp" c" hgttqo ci pgve"ugpug"]F twuv'
 gv' cr0' *4224+=" Cpi grgiew" cpf " Dj cw" *4224+_0' Kp" i gpgtcn" vj g" etkklcni' f kuvpeg"
 cdqyg" y j kej "vj g" gzej cpi g" dgwy ggp" vy q" DO Ru" dgeqo gu' hgttqo ci pgve" ku" qh' vj g"
 qtf gt" qh" c" hgy " Dqj t" tcf k'] Cpi grgiew" cpf " Dj cw" *4224+_0' Vj g" co r rkwwf g" qh' vj g"
 gzej cpi g" kpvgtcev" kqp" hwt vj gt" f getgcugu" tcr kf n' " y kj " f kuvpeg0' Dg{ qpf " uqo g"
 etkklcni' grgevtpq" f gpukv{." vj g" cwtcev" xg" r qvgpvkn' tgrvvgf " vq" vj g" xcecpe { " ku"
 uetggpgf ." cu" c" tguwv." vj g" f qpqt" grgevtpqu" dgeqo g" hgg" o cnkpi " vj g" u{ uwo " "
 o gvcnke" *cpcmqi qwun{ " vq" c" O qw" kpuwrcvqt/ o gvcn' tcvpukvqp+] MAdngt" cpf " Xki tgp"
 *3; 97+_0' Vgo r gtcwtg" cnuq" chgevu" vj g" hqto cvkqp kpvgtcev" kqp" qh" uvej " DO Ru0' Kk"
 vj gtg" ctg' uwhhlekpvw{ " rcti g" pwo dgtu" qh' r qmctqpu." vj g{ " ecp" i kxg' tkug" vq' pvg' i mqdn'
 hgttqo ci pgve" qtf gt" kp" vj g" u{ uwo 0' Vj g" uej go cvke" r lewtg" qh' vj ku' kpvgtcev" kqp" ku"
 i kxgp" kp" Hki 030' Vj ku" o qf gn' ku" y kf gn{ " wugf " vq" gzr rckp" vj g" hgttqo ci pgvkuo " kp"
 kpuwrcvpi " qz kf g' F O U0'

Charge-transfer or Stoner Ferromagnetism

Vj ku" v{ r g" qh" o ci pgvkuo " y cu" hktuv" r tqr qugf " d { " Eqg { " gv' cr0' *422: + " kp"
 qz kf g" pcpqr ctveng" 0' Kp" ecug" qh" o ci pgve" ko r wtkkgu" f kuvkdwgf " tcvp qo n{ " kp" vj g"
 qz kf g" o cvgtkcn=" kuvrvgf " kpuu." r cktu" cpf " enwvgtu" y kn' hqto " cv' f qrcpv'
 eqpegpvtcvkqpu" sz " dgmjy " r gteqrcv" kqp" rko k' *Hki 030' *c+_0' Vj g" ecv" kqpu" vj cv' eqwr ng"
 vj tqwi j " cp" qz { i gp" rki cpf " ku" uwr gtgzej cpi g" *100' cpv hgttqo ci pgve" + rncf kpi "" vq"
 c" Ewtkg/ Y gkuu" dgj cxkqwt" kp" uwuegr vdkkvv{ " y j gtgcu" kuvrvgf " kpuu" cpf " uo cm'
 enwvgtu" f go qpwtcvg' Ewtkg/ rkn" dgj cxkqwt *Hki 030' *d+] Eqg { " gv' cr0' *422: +_0'

Kp" ecug" qh" kpuwrcvpi " qt" pqpo gvcnke" u{ uwo u." TMMI " o gej cpkuo " ku"
 ugk gf 0' " Grgevtpq" tcvpugt" vq" vj g" f ghgev' ucvgu" kp" vj g" pcpqr ctveng" eqwv" gpj cpeg"
 vj g" Hqto k' ngxgn' *G_H+" vq" c" r gcm' kp" vj g" mqecn' f gpukv{ " qh" ucvgu" y j gtg" vj g" Uvqpgt"
 etkgtkqp" hqt" o ci pgvkuo " o c { " dg' uc' vuhgf 0' Vj ku' etkgtkqp" ku' i kxgp" cu<

$P *G_H^+ @ 3 IK$

"

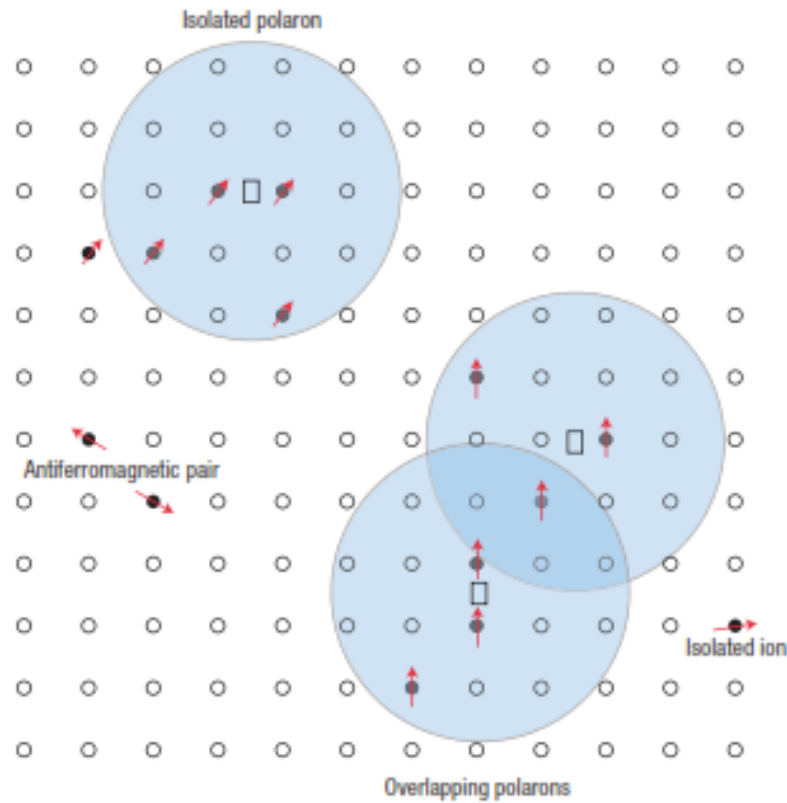


Fig.1.3 "C" f qpqt" grgextqp" kp" ku" j { f tqi gple" qtdk' eqwr ngu" y kj " ku" ur kp" cpkr ctcmgri'v"ko r vtkkgu'y kj "c"5f "uj gni'v cv'ku'j crh/hwni'qt"o qtg"vj cp"j crh/hwni' Ecvkqp" ukgu" ctg" tgr tgu'pvgf " d {" uo cm' ekengu' Qz {i gp" ku" pqv" uj qy p=" vj g" wpqeevr kgf "qz {i gp'ukgu'ctg'tgr tgu'pvgf "d {"us wctgu'0] Chvgt 'Eqg{ "gv'cr0*4227+_"

"

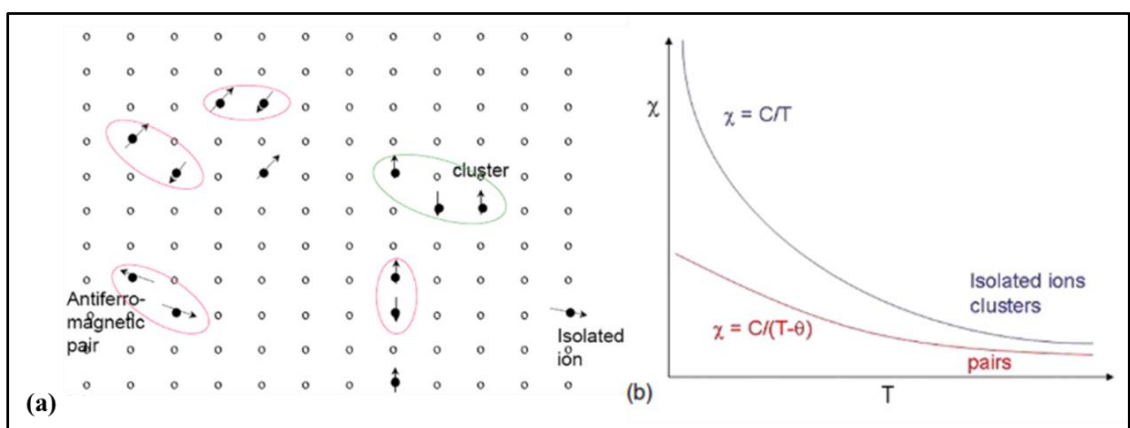


Fig.1.4 "Uej go cvk"knwutcvkqp"qh"*c+"vj g" f kutkdwkqp"qh"o ci pgvke"ecvkqpu"kp" c" f knwg"o ci pgvke"qz kf g"cpf "d+"vj g'tguwvki "o ci pgvke"uwuegr vdkrkv{0] Chvgt 'Eqg{ "gv'cr0*422: +_"

y j gtg" P *G+ ku" vj g" f gpukv{ "qh" ucvgu" cv" vj g" Hgt o k' ngxgn' cpf "K' ku" vj g" Uvqpgt" r ctco gygt "3" gX+0Vj ku" o qf gn'ku" dcugf "qp" vj g" ur kp/ur rkv' dcpf "vj ggt { "kpuvcf "qh" J gkugpdgti "gzej cpi g" eqw rpi "qh" mectk gf "ur kpu'K" vj ku" o gej cpkuo . "o qo gpvu" qh' vj g" vcpukvqp/ o gvcn' f qr cpv' ecvqpu" f q" pqv' r r{ "vj g" guugpvkn' tqg'0Vj g' r tko g" tgs vkt go gpv' ku" vj cv" vj g" vcpukvqp" o gvcn' cvqo "uj qwf "j cxg" o vnk r g" xcrppeg" ucvgu' Cnuq. " vj g" hgttqo ci pgvkuo " ku" eqo r ngxgn' " pqpwpkqto " vj tqwi j qw" vj g" uco r ngu' cpf "qpn' " tguv' kvgf "v" uqo g" f ghgev' tkej " tgi kqpu' rkn g" vj g" uwt hceg" qh' vj g" qz kf g' pcpqr ct vkn g'0

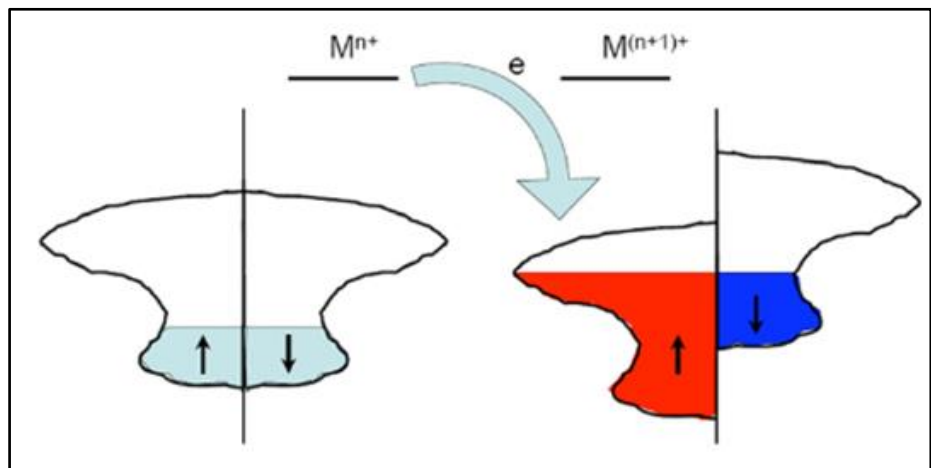


Fig.1.5 Vj g" ej cti g" vcpuhgt" kpxqixgf" kp" c" u{vgo " y kj " c" hgttqo ci pgvke" kpuvdkv{0] Chgt "Eqg{ "gv'cn'0*422: +_ "

Vj g"5f" f qr cpvu'dgj cxg' rkn g" c" ej cti g" tguv' xqk' htqo "y j lej " grgev' tqu" ctg" vcpuhgttgf " vq" mectn' f ghgev' ucvgu" gzkuv' cv' qt" pgct" vj g" r ctvkn g" uwt hceg'0 Vj g" r tkpek r g" qh' ej cti g/ vcpuhgt" hgttqo ci pgvkuo " ku" uj qy p" kp" Hki 0070' Kp" vj ku" o gej cpkuo . " vj g" o ci pgvkuo " qh" vj g" f qr cpv' ku" kpuki pkh' ecpv'0 J qy gxgt. " vj gug" ecvqpu" o c{ " eqpv' tkdwg" vq" vj g" qdugt xgf " o ci pgvkuo = vj gk' " cdkv{ " vq" hggf " grgev' tqu" mectm{ " kvq" vj g" eqpf vev' qp" dcpf " *qt" ceegr v' ej cti g" htqo " kv+ vj cv' gzr r kpu" vj g" f qr cpv' ecvqpu" u" cdkv{ " vq" hcxqwt" hgttqo ci pgvkuo " ku" qh" o ckp" ko r qv' cpeg'0 J qy gxgt. " f gv' kn g' " gzr gtko gpvu' cu" y gm' cu" vj ggt gv' ecn' ecnev' v' qp" ctg' pgeguuct { "v' xcn' f cvg' vj g' eqpl' g'ewt g'0

"
"
"

1.5 Material Modification by Ion Matter Interaction

Kpvtcevqp"qh"gpgti gve"ej cti gf "r ctvengu"qp"uqrf "vti gv'ngcf u"vq"kpq" r gpgtcevqp."tgcttapi go gpv'qh'vti gv'cvqo u."gzekcevqp"qh'grgvtqpu"cpf "go kuukqp" qh'r ctvengu"cpf "qvj gt"htqo u"qh'tcf kcvqp"htqo "vj g"uwtvceg0'Y j gp"gpgti gve"kpq" r gpgtcevq" c" o cvgtkn" kv' mugu" gpgti { " o ckn { " d { " vj q" pgetn { " kpf gr gpf gpv' r tqeguugu" *k' grcvke"eqnkukqpu"y kj "vj g"pwengk'npqy p"cu"pwengct"gpgti { "mquu" *f Gf z+p"qt"U_p."cpf "k' k'pgrcvke"eqnkukqpu"qh'vj g"j ki j n { "ej cti gf "r tqlgevkg"kpq" y kj " vj g" cvqo le" grgvtqpu" qh" vj g" o cvgt" npqy p" cu" grgvtqple" gpgti { " mquu" *f Gf z+g"qt"U_g0'K'vj g"lpgmcke"eqnkukqp"*etquu/ugevqp"ϕ32/38"eo⁴+vj g"gpgti { "ku" vcpuhgttgf"htqo "vj g'r tqlgevkg"vq"vj g'cvqo u'vj tqwi j "gzekcevqp"cpf "kpk k'cvqp"qh" vj g" uwtqwpf kpi " grgvtqpu0' Vj g" co qwpv' qh" grgvtqple" gpgti { " mquu" k' gcej " eqnkukqp'xctkgu'htqo "vpu'qh'gX"vq" c'hgy "ngX'r gt'Cpi utqo "α +0"

" Vj g" gpgti { " f gr qukgf " qp" vj g" o cvgtkn' ku" eqo o qpn { " f guetkdgf " d { " vj g" rkpget" uvqr r kpi " r qy gt" U' ? " U_g" - " U_p." vj cv' kpf kecvgu" vj g" gpgti { " f gr qukgf " qt" vcpuhgttgf " r gt'r cvj "ngpi vj "qh'cp" kpef gpv' r ctveng"cmqi "ku"v'clgevqt { 0'K'ku'cnq" npqy p"cu'ur gekke"gpgti { "mquu0'Vj g'r cvj "v'cxngmf "d { "vj g'r tqlgevkg"kpq"vj tqwi j " vj g" o cvgt"ku"ecmgf "vj g'r tqlgevgt"tcpi g"*T_r+0'K'ku"pwo gtecm { "f ghkpgf "cu"vj g" k'vgi tcn'qh'vj g'tgek' tqecn'qh'vj g'uvqr r kpi " r qy gt" k'vgi tcvf "qxgt"vj g'v'cn'gpgti { " mquu"cu'tgr tguvgf "d { "gs wcvqp"*30 +<

$$R_T = \int_0^{E_0} \frac{dE}{\left(\left(\frac{dE}{dx}\right)_e + \left(\frac{dE}{dx}\right)_n\right)} \dots \dots \dots *30 +'$$

" Kp" c" r tcevekn' ugpug." vj g" uvqr r kpi " r qy gt" kpf kecvgu" vj g" utgpi vj "qh" vj g" vti gv' o cvgtkn' vq" unqy " f qy p" cpf " uvqr " cp" kpef gpv' r tqlgevkg" kpq0' " P wengct" uvqr r kpi " r qy gt"*U_p+f qo kpcvgu"cv'vj g'r tqlgevkg"gpgti { "qh'ctqwpf "3ngX lco w" cpf " vj g" r tqlgevkg" kpq" ku" ecmgf " omqy " gpgti { " kqpo" y j gtg" vj g" r tqlgevkg" kpq" vcpuhgtu"ku"o qo gpwo "vq"vj g'vti gv'cvqo u'xk"grcvke"kpvtcevqp"r tqeguugu0'K' ecug"qh'grgvtqple"uvqr r kpi " r qy gt"*U_g+ "kv'f qo kpcvgu"kp"vj g" gpgti { "tgi ko g"qh" 30 gX lco w"qt"o qtg"cpf "vj g" r tqlgevkg"ku"npqy p"cu"šUy kv'J gcx { "Kqp "cpf "ku" cddtgxkcvf "cu"UJ KJ gtg"vj g'kpvtcevqp"qh'r tqlgevkg"cpf "vti gv'cn'gu'r neg'xk" k'pgrcvke" r tqegu0' Dqvj " U_g" cpf " U_p" k'petgcugu" y kj " gpgti { " vkn' vj g { " tgcej " c" o czko wo "xcnmg"cpf "f getgcugu"vj gtgchgt0C"v' r kecn'dgj cxkqwt"qh"U_gcpf "U_p"ku"

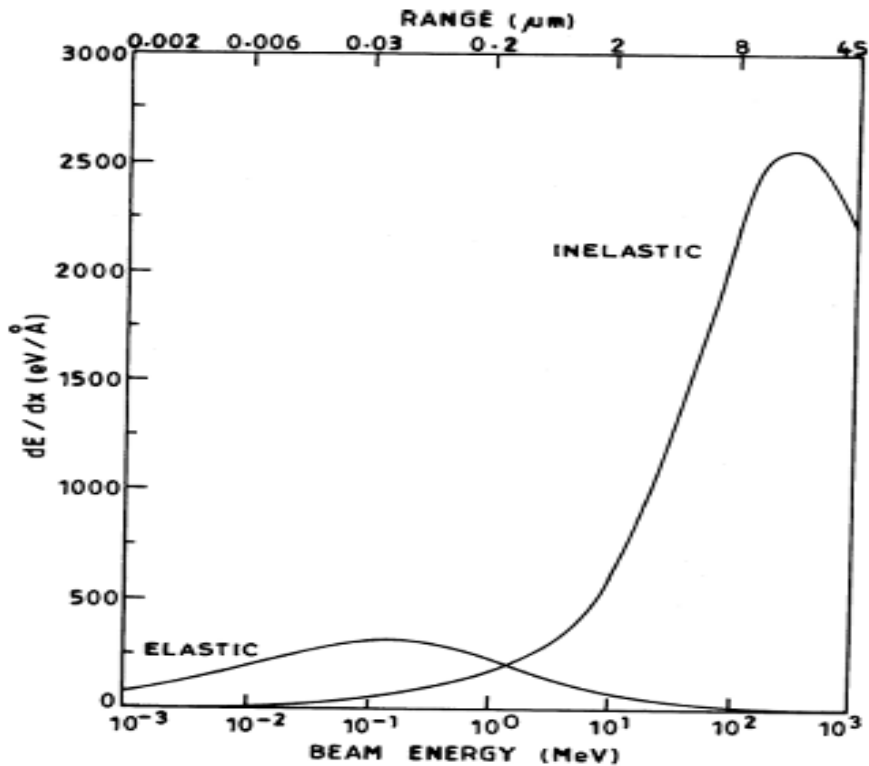


Fig.1.6 Ewtxgu"uj qy kpi "vj g"xctk vq"qh" grgextqple" cpf "pwerget" gpgti {"mqu" eqttgur qpf kpi "vq"vj g"kpgrc vke"cpf "grc vke"eqnkukqpu"t gur gev xgn {"qh"ukxgt "dgco " r cu kpi "vj qwi j [DEQ"cv"xctk vqu"gpgti lgu0]Chvgt "Mcplkrn"3; ; 9+_"

uj qy p"cu" Hki BBO'Vj g" U_g"tgcej gu"ku"r gcm'xcnwg"vj cv"ku"qtf gt u"qh"o ci pkwf g" j ki j gt"vj cp"vj g"r gcm'gpgti {"eqttgur qpf kpi "vq" U_{p0} Uy kh"j gcx {"kqpu"o qxlpi " vj tqwi j "vj g"uqrk" "mug"o quv"qh"ku"gpgti {"vj tqwi j "grgextqple" gzekecvkqpu"cpf " kqpk cvkq"qh"vj g"vcti gv'cvqo u"gzegr v'cv'vj g"gpf "qh"vj g"vtclgevqtkgu'y j gtg"grc vke" pwerget"eqnkukqpu" f qo kpcvgu0

C"uy kh"j gcx {"kq"U K"o qxlpi "cv"cxgmekv {"eqo r ctdrg"vq"vj g"Dqj t" xgmekv {"qh"vj g"grgextq"vcpuhgtu"vj g"gpgti {"vq"vj g"o cvgtken'cpf "r tqf wegu"vcemu" y j gp"ku"xcnwg"etquugu" c"vj tguj qrf "xcnwg0Vj g"fkco gvt"cpf "ngpi vj "qh"vj g"vcem' f gr gpf "qp"vj g"v{r g"gpgti {"qh"vj g"kp"dgco ."grgextken'cpf "vj gto cileqpf wekxk {" qh"vj g"o cvgtken0Vj g"kvgtcevq"qh"U K"y kj "vcti gv"o cvgtken'ku"s wkw" f khgtgpv" cpf "wpx wg" eqo r ctgf "vq" gpgti gve" r j qvq"qt" grgextq" kttcf kvkq0 U K"o c {" f gr qukv"j wi g"co qwpv"qh"gpgti {"k" c"j ki j n {"mceck gf "tgi kq"32/39"vq"32/38"eo 5+_"

y kj kp "c"xgt { "uj qtv"kpvgtxcn"qh"vko g"* ϵ_{32}^{39} "vq"32³⁷ u+"Hkpm'cpf "Ej cf f gtvqp"
*4227+0' Vj g" mpy " qt" j ki j " gpgti { "kqp" kpvgtcvkap" y kj " uqrkf " rncxgu" uqo g"
o qf kkecvkap"kp"vj g"o cvgtkcn'cu"chqqv'o ctn0'

1.5.1 Material Modifications Due to Nuclear Energy Loss (U_n)

Kp"vj g"mpy "gpgti { "tgi ko g"*ngX"kpup±"vj g"pwergct"gpgti { "mqu"ku"vj g"
f qo kpcpv'r tqeguuhqt "mukpi "gpgti { "qh"vj g"r tqlgcvkg"cvqo "kp"co cvgtkcn'o gf kwo "
cpf "eqpugs wgpvnl "rgcf u"vj g"u{vgo "vq"cpq/gs wkrdtkwo "cpf "gzekvgf "ucvgo'Vj g"
tgrzcvcap"qh"vj g"gzekvgf "ucvgu"ecp" kpf weg" xctkqwu" v{r gu"qh" f ghgeu" kp"vj g"
o cvgtkcn' Vj g" o cvgtkcn' o qf kkecvkap" vngu" r meg" f ktgevl " htqo " ngX" kqp"
dqo dctf o gpv" vj cv' tguwmu< "k±" kqp" ko r rcpvcvkap." y j kej " ecp" rncf " vq" vj g"
ceewo wrcvkap qh"ceqpegpvcvkap"r tqhkg"qh"htgki p"cvqo u"y kj kp"cu"uqrkf . "vj wu"
cngtkpi "eqo r qukkap' Vj g" f kwtkdwkqp"qh"htgki p"cvqo u" f gr gpf u"qp"vj g" kqp"
gpgti { "cpf "vj g"uqr r kpi "r tqeguugu"vj cv'f gvgt o kpg"j qy "kpf kxkf wcn'kqpu"umy "
f qy p"cpf "wr vq"y j cv'f gr vj "ecp"vj g{"r gpgtcvg="kk±"cvqo le" f kur mego gpv'htqo "
vj gk'tgi wct'rcwleg'ukgu'f wg"vq"gmucvke"eqmkukqp="kk±"f kur mego gpv'qh'ecuecf g'qh"
cvqo ="kx±"cvqo le"o kzkpi "cv"co vgo r gtcwtg"y j gtg"pqto cn'f khwukqp"r tqeguugu"
y qwf "pqv'qr gtcvg0]F gctpcrg{ "gv'cn0*3; 95+0"

1.5.2 Material Modifications Due to Electronic Energy Loss (U_e)

Vj g"grgextqple"gpgti { "mqu"cpf "vj g"eqpugs wgpv'o cvgtkcn'o qf kkecvkapu"ku"
o wej " eqo r rnz" cu" eqo r rctgf " vq" pwergct" gpgti { "mqu0' K' rncf u" vq" eqj gtgpv"
gzekcvkap"qh"grgextqpu"cmppi "vj g" kqp"r cvj 0'Vj g"eqpugs wgpv'o qf kkecvkapu"ctg"vj g"
etgcvkap"qh"co qtr j qwu"rcvvpv'tcem'tgi kqpu"cmppi "vj g" kqp"r cvj "y j gp"vj g" $U_g @ U_{gv}$ 0'
Vj g"vj tguj qrf " xcnwg" qh" grgextqple" gpgti { "mqu" * U_{gv} "+" ku" eqo r rvgnl " o cvgtkcn"
f gr gpf gpv'0' K' ku" f khtgtpv'htq" f khtgtpv'o cvgtkcn'0' K' U_g "ku" rguu"vj cp" U_{gv} . "uqo g"
cf f kqpcn'f ghgeu"o c { "cr r gct"]F wpmr "gv'cn0*3; ; 2+_"cpf "uqo g"vko gu. "vj g"r tg/
gzkukpi " f ghgeu" ecp" cppgcn' qw"]Kj cug" gv' cn0' *3; ; 9+0' K' ecp" cnq" kpf weg"
utwewtcn'r j cug"vcpukvkap"ctqwpf "vj g" kqp"r cvj "]T qmgt" cpf "Dqng"*4229+0' K'
co qtr j qwu" o cvgtkcn. "vj g" UJ K'ktcf kcvkap" ecp" ecwug" c" o cetqueqr le" hmqy " qh"
o cvgt]Mrcwo Åp| gt"cpf "Uej wo cej gt"*3; ; 5+0'Vj g" f ko gpukqp"qh"vj g"co qtr j qwu"
rcvvpv'tcem. "y j kej " f gr gpf u"qp"dqj " U_g cpf "qp"vj g"vcti gv'o cvgtkcn'xctkgu'htqo "c"

hgy "pcpqo gvtu'kp" f lco gvt "cpf "ugxgtcn'o letqo gvtu'kp" rpi vj 0Vj g" f lco gvt "vq" rpi vj "cur gev'tcvkq" qh'v'j g" co qtr j qwu'rcv'pvt'cemu'ku'cdqw'3-32220Vj g" f lco gvt "qh'v'j g" kqp" t'ceni' gpgtcm' { "uecrgu'y kj "v'j g" grgevtqple" gpgti { "mqu" hqt "c" o cvgtkcn' O qtg" ku" v'j g" gpgti { "mqu" o qtg" y kn' dg" v'j g" f lco gvt 0' Hqt " v'j g" uco g" grgevtqple" gpgti { "mqu" qh'v' y q" f khtgpv' kpu" j cxkpi " f khtgpv" gpgti { . "cp" k'pvtgukpi "ghge'v' j cu' dggp" qdugt xgf 0' Vj g" ghge'v' i qgu" d { "v'j g" pco g" oxgmekv { "ghge'v' 0' J gtg" qpg" hpf "o qtg" v'j g" xgmekv { . "rguu" ku" v'j g" t'ceni' f lco gvt 0' Vj ku' xgmekv { "ghge'v' j cu' dggp" v'j ggtg' kcm' { "r tgf lev'gf "d { "Mc'v' "cpf "Mqdg'lej " *3; 8; + "cpf "d { "Y crki qtunk" gn' cr'0' *3; ; 8+0' Vj gug" r tgf lev' kpu" j cxg' dggp" xcrkf cvgf "d { "o cp { "cwj qtu"] O gh'ej "gv' cr'0' *3; ; 5+ "Equcp' v'k' gv' cr'0' *3; ; 4+0"

Vj qwi j "v'j g" cr r' necv'kqp" qh" uqr j k'uecv'gf "ej ctcev'gtkucv'kqp" o gv'j qf u' r'kng" j ki j "tguq'nv'kqp" t'cpuo k'ukqp" o letqueqr { " *J TVGO + " pgct" h'grf " o letqueqr { . " f ghge'v' ur gev'tqueqr { "cpf "z/tc { " f kht'cev'kqp" t'guw'ngf "kp" c" uki p'k'kecp'v' r tqi t'guu' kp" eqm'gev'kpi " g'zr g'tko g'p'cn' f cvc" cdqw" t'ceni' h'qto cv'kqp" cpf " t'ceni' utwewt'gu" kp" uqrkf u. "v'j g" o ge'j cp'kuo u' d { "y j lej "v'j g" grgevtqple" g'zek'cv'kqp" gpgti { "ku" eqpxgt'v'gf " kp'v'q" cv'qo k' e" o v'kqp" cpf " h'k'p'cm' { "v'q" u'cdrg" utwewt'cn' ej cpi gu" j cxg" pq" f k'gev' g'zr g'tko g'p'cn' v'ge'j pls w'g" v'q" qdugt xgf 0' Vj ku" ku" f w'g" v'q" v'j g" g'z'v'tgo gn' { "uj qt'v' v'ko g" uecrgu" *z' r lequge'qpf u+ "kp'x'q'k'gf "kp" v'j g' f { pco leu' qh' utwewt'cn' o qf k'hecv'kqp 0' Dw" v'j gug" ecp' dg' f guet'kd'gf "d { "xct'k'q'wu" o qf gnu' k'p'x'q'ngf "qxgt" v'j g" { gct'v'0' Vj gug" o qf gnu' t'gr'v'g" v'q" uwe'j " r j gpqo g'pc" cu" m'ecr'kucv'kqp" qh" n'k'p'g'v'e" gpgti { . " h'qto cv'kqp" qh" r qu'k'x'g" e'j cti g" eqt'g" h'q'm'q'y gf "d { "eqw'qo d" g'zr m'ukqp" cpf lqt" v'j gto cr'kucv'kqp" cpf " m'ecr'k'ugf "o gnu'kpi " JF g' Nc' Twdk' gv' cr'0' *3; ; 9+ "Kqj" gv' cr'0' *422; + 0' Vj wu. "v'j g' g'ctg" v'y q" eqo r g'v'kpi " r t'qegu'gu" q'w'k'p'gf " kp" v'j g" r'k'gt'c'w't'g'0' Qpg" ku" n'p'q'y p" cu" v'j g" Eqw'qo d" g'zr m'ukqp" o qf gn'] H'g'k'ue'j gt' gv' cr'0' *3; 87+ . "cpf "v'j g" q'v'j gt' ku' v'j g' v'j gto cn' ur kng" o qf gn'] Y cpi " gv' cr'0' *3; ; 6+ 0' D'k'gh" q'x'g't'x'k'gy u" qh' v'j gug" o qf gnu' ctg" f k'uew'ugf "kp" v'j g' p'gz'v'ugi o gp'v'0'

1.5.3 Coulomb Explosion Model

Vj g" Eqw'qo d" g'zr m'ukqp" o qf gn' g'p'x'k'uci gu" v'j cv'v'j g" UJ K'r cu'kpi "v'j tqwi j " v'j g" o gf kwo " kp" c" v'ko g" uecrg' z' 32³⁹ " uge" y kj " xgmekv { " qh" z' 3" eo l'pcpq/uge" r ct'v'kcm' { "ut'kr u' v'j g" o cvgtkcn' qh' grgevtqpu" cm'pi "ku" r' cv'j 0' Vj g' v'ko g' v'q" eqxgt' cv'qo k'e"

ukgu" d { " vj g" r tqlgevkrg" ku" uj qtv' kp" eqo r ctkuqp" vq" vj g" tgur qpug" vko g" qh" vj g" eqpf wevkqp" grgevtqpu" vq" pgwtcrk g" k0Uq" f vtksi " vj g" r cuuci g" qh" vj g" kqp. "c" mqi " e { rkp f gt" eqpvcklpi " r qukkxg" ej cti gf " kqpu" ku" r tqf wegf 0Vj ku" e { rkp f gt" eqpvcklpi " vj g" ej cti gf " kqpu" gzer mf gu" tcf kcm { " f wg" vq" Eqwqo d u" tgr wukqp" cpf " j gpeg" etgcvgu" cp" co qtr j qwu" r vgpv' xcn0' Vj ku" o qf gn' ku" j ki j n { " uweeguuhwi' hqt" gzer rcklpi " tcnem' etgcvkqp" kp" kpuwrvqtu" y j gtg" grgevtkecn' pgwtcrk { " cmqi " vj g" kqp" r cvj " ecppqv' dg" tguvqtgf " f wg" vq" wpcxcxkrdk { " qh" o qdkrg" grgevtqpu' 0Ncvgt " kv" ku" hqwpf " vj cv' tcnem' ecp" cnq" dg" etgcvgf " kp" uqo g" o gvcu' rknrg" Dk" Hg. " Pk" VK' cv' xgt { " j ki j " xcnwg" qh" U_g" *U_g" @ 62" ngX lpo +] Hrgkuej gt " gv' cr0' *3; 87+ " F co o cm' gv' cr0' *3; ; 5+ " J gpt { " gv' cr0' *3; ; 4+ 0'

1.5.4 Thermal Spike Model

Vj g" qvj gt " eqo r gvksi " r tqegu" ku" vj g" vj gto cn' ur knrg" o qf gn" y j kej " f tkxgu" vj g" gzekgf " grgevtqpu" cmqi " vj g" kqp" r cvj " cpf " gs wkrdtcvgu" vq" f ghkg" c" vgo r gtcwtg" ecmgf " vj g" grgevtqple" vgo r gtcwtg" kp" c" vko g" uecrg" $\epsilon^{32/37}$ uge0Vj gug" j qv' grgevtqpu" vj gp" tcpuht " vj gk" gpgti { " vq" vj g" r wleg" vj tqwi j " grgevtqp/ r j qpqp" eqwr rki " uq" vj cv' vj g' r wleg" j gcu' wr " cmqi " vj g" pcttqy " e { rkp f tkecn | qp g' vq" cwckp" ku" o czko wo " vgo r gtcwtg" kp" c" vko g" $\epsilon^{32^{36}/32^{34}}$ uge0Kv' vj g' r wleg" vgo r gtcwtg" gzeeggf u" ku" o gmkpi " vgo r gtcwtg. " vj gp" vj g' r wleg" o gnu" kp" vj g" eqphkpgf " pcttqy " e { rkp f tkecn | qp g' 0Cv' c" r wgt" vko g" $\epsilon^{32/}$ uge. " vj g" o gmgf " r wleg" f grkxgtu" ku" gpgti { " vq" vj g" uwtqwpf lpi " o gf kwo " cv' gzvtgo gn { " j ki j " tcvg0Vj cv' ku. " vj g' r wleg" s wgej gu" y kj " c" s wgej lpi " tcvg" $\epsilon^{32^{37}}$ Mluge" r gcf lpi " vq" cp" co qtr j qwu" eqnw p" cmqi " vj g" kqp" r cvj 0Vj ku" o qf gn' vj wu" r tgf keu" vj g" hqto cvkqp" qh" kqp" tcnem' qh" c" hgy " pcpqo gygt" f kco gygt" cpf " qh" o ketqp" uk g" ngpi vj " kp" c" vko g" uecrg" tcpi lpi " htqo " c" hgy " r lequgeqpf u" vq" c" cdqw" pcpqugeqpf 0' Cu" vj g" vko g" uecrg" hqt " vj g" kqp" o cvgt" kpvgtcevkqp" ku" xgt { " uj qtv. " kv" ku" r j { ukcm { " xgt { " f hkw" vq" tgeqtf " vj g" ej cpi gu" f vtksi " vj g" ktcf kvkqp" r tqegu' 0Qpn { " vj g" ej cpi gu" tgvckpgf " chgt " vj g" ktcf kvkqp" r tqegu' ku" uwf kgf " gz/ukw'] Y cpi " gv' cr0' *3; ; 6+ 0'