Progress in Materials Science 70 (2015) 50–154

Contents lists available at ScienceDirect

Progress in Materials Science

journal homepage: www.elsevier.com/locate/pmatsci

Synthesis, electron transport properties of transition metal nitrides and applications

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ARTICLE INFO

Article history:
Received 10 February 2014
Accepted 24 November 2014
Available online 4 December 2014

Keywords:
Transition metal nitrides
Electron transport
Nanocrystalline
Layered compounds
Superconductor

ABSTRACT

To understand the electron transport properties of transition metal nitrides (MN), electronic structure relationship between metal and corresponding nitrides is important. In binary nitrides, when nitrogen atoms occupy interstitial sites of metal lattice, volume expansion started initially without changing structure of metal lattice. Above certain concentration of nitrogen into interstitial sites of lattice, the system starts stabilizing its energy to minimum that in turn changes to another crystal structure. The chemical bonding in MN is due to the mixing of *d*-orbitals of M and *p*-orbitals of N. This is confirmed theoretically and experimentally such as X-ray photoelectron spectroscopy. The Fermi energy is generally lowered by the introduction of vacancies. However, reports on the particle size effect in the electrical resistivity of nitrides are scanty. One reason is that the role of the particle size in resistivity is difficult to determine because there is a need to understand N concentration. It poses a challenge to the synthesis of nanostructured transition metal nitrides. The transition metal binary nitrides show unusual electron transport, optical and magnetic properties as compared to their metal counterparts. Electronic properties of all transition metal nitrides known till date are discussed. Different ways of synthesis of nitrides and their applications are mentioned.

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http://dx.doi.org/10.1016/j.pmatsci.2014.11.004
0079-6425/

Nomenclature

A	atom
AFM	atomic force microscopy
A_i	interfacial surface area
A_p	pre-exponential function (resistivity)
A_w	atomic or molecular weight
α	temperature co-efficient (e–e)
α_1	a characteristic length
bcc	body centered cubic
bct	body centered tetragonal structure
β	temperature co-efficient (e–ph)
BCS	Bardeen–Cooper–Schrieffer
C	Curie constant
C_s	specific heat capacity
CDW	charge density wave
C_{nn}	pre-exponential function (conductivity)
C_{vr}	temperature independent constant
cp	cubic phase
$\chi = M/H$	susceptibility
χ_0	Pauli-susceptibility constant
D	dimension
d	nearest-neighbor atomic distance
D_1	diffusion constant.
d_{ij}	distance between grains via grain boundary
Δ	magnetic interaction parameter
Δ_g	band gap
ΔT_c	superconducting transition width
E	activation energy of electrons at the Fermi level
e	electrons
e–e	electron–electron
e–m	electron–magnon
e–ph	electron–phonon
EDAX	energy dispersive analysis of X-ray
ε	spin-valve coefficient
F'	a screening constant for coulombic interaction
fcc	face center cubic
ΔG	free energy change
γ	the surface energy
H	applied magnetic field
h	Plank's constant
$\hbar$	$h/2\pi$
hp	hexagonal phase
H_c	coercivity
H_{cr}	critical field
hcp	hexagonal closed packing
I	current
I_F	a generalized Stoner parameter
J'	current density
J'_c	critical current density
J_{ij}	exchange interactions
$JCPDS$	joint committee on powder diffraction standards
K	a constant
k	a wave vector