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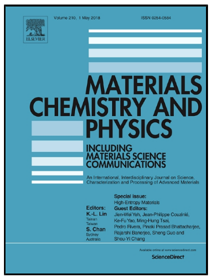

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PII:	S0254-0584(18)30296-7
DOI:	10.1016/j.matchemphys.2018.04.034
Reference:	MAC 20529
To appear in:	*Materials Chemistry and Physics*
Received Date:	25 July 2017
Revised Date:	29 January 2018
Accepted Date:	07 April 2018

Please cite this article as: Vera P. Val'chuk, Dmitry S. Zmienko, Vladimir V. Kolesov, Sofya N. Bokova-Sirosh, Tatyana S. Dolotova, Igor A. Mikhaylov, Dmitry Golberg, Leonid A. Chernozatonskii, Novel Ni-Cr-C alloys with chromium carbide whiskers, *Materials Chemistry and Physics* (2018), doi: 10.1016/j.matchemphys.2018.04.034

Novel Ni-Cr-C alloys with chromium carbide whiskers

Vera P. Val'chuk,[a] Dmitry S. Zmienko,[b] Vladimir V. Kolesov,[c] Sofya N. Bokova-Sirosh,[d] Tatyana S. Dolotova,[a] Igor A. Mikhaylov,[e] Dmitry Golberg,[f] and Leonid A. Chernozatonskii[a,e] *

[a]*Emanuel Institute of Biochemical Physics of RAS, 4 Kosygin St., Moscow, 119334, Russia*
[b]*Rosatom State Nuclear Energy Corporation, 24 BolshayaOrdynka St., Moscow, 119017, Russia*
[c]*Kotel'nikov Institute of Radio Engineering and Electronics of RAS, 11-7 Mokhovaya St., Moscow, 125009, Russia*
[d]*Prokhorov Institute of Physics, 38 Vavilov St., Moscow, 117312, Russia*
[e] *Science school chemistry and technology of materials, Plekhanov RUE, 36 Stremyanny per., Moscow, 117997, Russia*
[f]*National Institute for Materials Science, Namiki 1-1, Tsukuba, Ibaraki 3050044, Japan*

*Corresponding author: E-mail: cherno@sky.chph.ras.ru

ABSTRACT

We study the phases forming in the Ni–Cr–C three-component system appearing during powder mixture baking at 1200-1300 °C followed by fast cooling under increasing the concentration of a graphitic component (up to 5 wt.%). The resulting multiphase new alloys show distinctive crystalline Cr_3C_2 rods with 1–10 micrometer diameters. The whisker regions in alloys have an extremely high hardness from 2200 up to 3200 HV (comparable to the highest hardness of nano whiskers and coatings with the presence of chromium carbide nanoinclusions). We formulate a sol–gel chemistry mechanism of rod formation via carbon diffusion into Cr and Cr_xC_y through a softened Ni-C particle on the Cr particle and the top of growing whisker. It explains discovered correlation between whisker diameters and Ni-particle sizes.

Keywords: Chromium carbide, Ni–Cr–C alloys, Scanning electron microscopy, X-ray microanalysis, Hardness

1. Introduction

Hard materials as reinforcements in alloys and composites attract prime attention of both researchers and engineers due to their useful properties [1]. Among these, carbides are becoming most attractive and promising candidates in modern scientific and technological applications. Chromium carbide exhibits an extremely high strength, hardness, anti-erosion and corrosion properties, good surface characteristics, etc. Commonly used alloys are based on chromium carbide with a nickel binder matrix. Owing to the high hardness of over 1000 HV [2], and wear resistance such materials are among the only few materials that can perfectly work under synergetic influences of friction, abrasion, corrosive environment, and elevated temperatures.

An additional advantage of hard alloys based on chromium carbide is their wide availability and relatively low cost of raw components. Therefore, the search for new solid modifications of a chromium carbide phase once it is shaped as nanowires or crystal micro-whiskers is a very important fundamental and technological direction [3-5].

Chromium carbide is the compound of chromium metal and carbon with the formula Cr_3C_2, having 13.3 wt.% of carbon. This well-ordered phase has a narrow homogeneity region with a melting point of 1895 °C. Cr_3C_2 formation starts at 1150–1200 °C through appearance of lower chromium carbides ($Cr_{23}C_6$, Cr_7C_3) [1-5]. An increase of temperature up to 1500–1600 °C in a hydrogen environment leads to the formation of Cr_3C_2 single phase with very marginal free carbon content [2].

In technological applications, chromium carbide is most commonly used in a powder form with micro- and nanoscale grains [2-5]. Methods of Cr_3C_2 synthesis differ with respect to the raw materials used, equipments utilized, and product variety (powders, coatings, alloys, porous ceramic [6]), obtained via diverse techniques, e.g. carbo-thermal method [5], sol-gel chemistry[7], thermal spraying [8] or high velocity oxy-fuel spraying