

**PRODUCING ULTRADISPERSED MATERIAL CU-SI SYSTEM IN ELECTRODISCHARGE
PLASMA**

K.N. Shatrova, A.Ya. Pak

Scientific Supervisor: Prof., Dr. A.A. Sivkov

Tomsk Polytechnic University, Russia, Tomsk, Lenin str., 30, 634050

E-mail: ayapak@tpu.ru

**ПОЛУЧЕНИЕ УЛЬТРАДИСПЕРСНЫХ МАТЕРИАЛОВ СИСТЕМЫ CU-SI В
ЭЛЕКТРОРАЗРЯДНОЙ ПЛАЗМЕ**

К.Н. Шатрова, А.Я. Пак

Научный руководитель: профессор, д.т.н. А.А. Сивков

Национальный исследовательский Томский политехнический университет,

Россия, г.Томск, пр. Ленина, 30, 634050

E-mail: ayapak@tpu.ru

***Аннотация.** В работе показана возможность получения ультрадисперсных материалов системы Cu-Si в электроразрядной плазме дугового разряда. Получены кубические модификации ультрадисперсной меди, кремния, а также фаза силицида меди η "-Cu₃Si. Установлено, что в зависимости от места сбора порошкового продукта в экспериментальной установке (в реакторе, на электродах) соотношение перечисленных выше компонентов продукта различно.*

INTRODUCTION

Copper silicide may be produced by various methods such as magnetron sputtering [1], self-propagating high-temperature synthesis [2], crystal growing from the melt [3], mechanical activation of initial components in a ball mill [4], vacuum sintering [5], copper ion implantation into silicon substrate [6]. These materials can be used in microelectronics technology, the silicon production, the electric energy storage device production [7-9]. According to the silicon-copper system's phase diagram, three crystal modifications are stable under normal conditions: η "-Cu₃Si, ε -Cu₁₅Si₄, γ -Cu₅Si [10-12].

In this paper, the possibility of ultrafine material production in silicon-copper system are shown, particularly copper silicides are obtained. Moreover, control method of product phase composition are suggested by separately product collecting from different parts of the experimental facility.

EXPERIMENTAL

The experiment for powder product obtainment in the silicon-copper system was carried out using a pulsed plasma accelerator with copper electrodes [13, 14]. The micro silicon powder was placed into the plasma formation zone. During the working cycle the electric discharge generates the plasma. After it the synthesized product was separately collected from the reactor walls and the plasma accelerator's electrode system.

The crystalline phases of the synthesis product were determined by X-ray diffractometry (XRD) using Shimadzu XRD 7000 (CuK α -radiation) diffractometer with the counter monochromator Shimadzu CM-3121. Qualitative X-ray analysis was made using a database PDF2+.

Transmission electron microscopy (TEM) was carried out using the Philips CM12 microscope.

RESULTS AND DISCUSSION

According to X-ray diffraction (Fig. 1a, b), three main crystalline phases such as copper silicide η "-Cu₃Si (ICDD № 00-059-0263), cubic silicon (c-Si), cubic copper (c-Cu) can be identified in the product. Quantitative analysis of the X-ray diffraction patterns revealed that the powder, collected from the reactor walls, contains about 65% c-Si, about 1% c-Cu and up to 34% η "-Cu₃Si (Fig. 1a), while the powder, collected from the accelerator electrodes, contains up to 80% η "-Cu₃Si, about 14% c-Si and 6% c-Cu (by volume, estimation was carried out by known method using integrated intensity of X-ray diffraction pattern). Thus, the obtained crystalline phase ratio depends on the place of powder product collection.

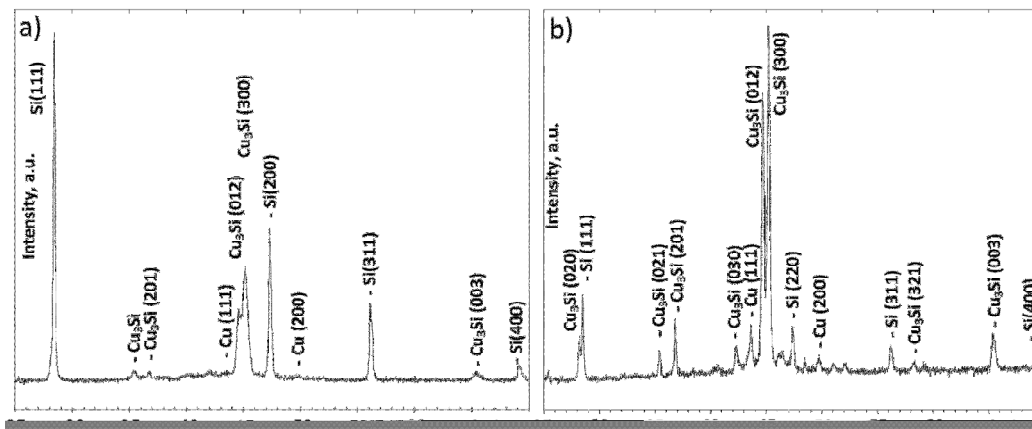


Fig. 1. X-ray diffraction patterns of the product: a) collected from the reactor, b) collected from the plasma accelerator electrodes

As a result of image analysis, obtained by transmission electron microscopy, including selected area electron diffraction (SAED), objects, identified by X-ray diffractometry, was visualized. Fig. 2a) shows the bright field image in which objects of the identified phases (c-Si, c-Cu, and η "-Cu₃Si) are marked. Fig. 2b) shows a typical pattern of SAED. As can be seen at Fig 2a the η "-Cu₃Si crystals have the form like a sharpened at the end of the nanorod. This form is typical for the monocrystals structure of silicon carbides Cu₃Si as have been shown before [15].

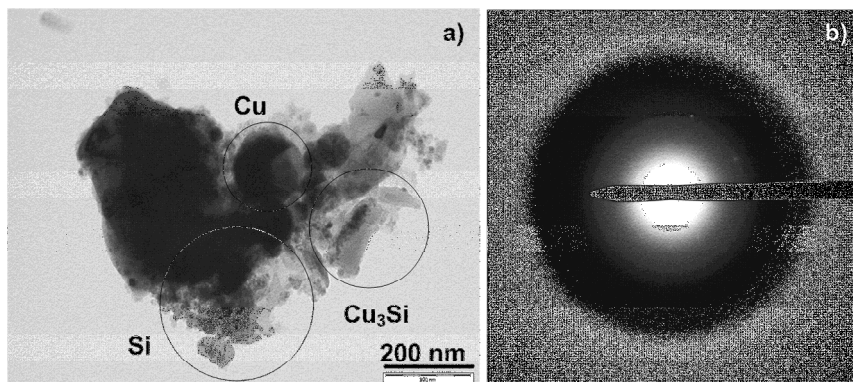


Fig. 2. The results of transmission electron microscopy: a) the bright field image b) SAED

Interpretation of TEM-data allows to calculate the crystal interplanar space sizes of the product objects: $d = 2,04 \text{ \AA}$, $d = 1,88 \text{ \AA}$, $d = 1,59 \text{ \AA}$, $d = 1,31 \text{ \AA}$, $d = 1,25 \text{ \AA}$, $d = 1,11 \text{ \AA}$. These data agree with the X-ray diffraction results, taking into consideration of possible errors in interplanar space determining.

CONCLUSION

In this paper, the possibility of ultrafine material production in silicon-copper system are shown using electropulsed facility generating electric discharge plasma, in particular, the cubic copper, cubic silicon and copper silicide η -Cu₃Si phases were obtained. In addition, the possible of product obtainment with different above-mentioned phase ratio by separate product collection in different parts of the experimental facility is found.

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