Effect of heat treatment on the morphology and composition of Silicon-Germanium nanocomposite

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Introduction

Film structures based on Si_xGe_{1-x} are widely used in high-temperature thermoelectric converters, which have high stability and high efficiency in the temperature range 800-1100 °C, which provides a wide range of their application. For example, such materials are used to utilize heat removed during various high-temperature processes. Also, Si_xGe_{1-x} films are used in optoelectronic devices.
However, given the high cost of crystalline Ge and its gaseous precursors, compounds with a low Ge concentration, which do not have a combination of electrophysical and physicochemical parameters that are optimal for thermoelectric conversion, are usually used to obtain Si_xGe_{1-x} alloys.
In [1], a new approach is proposed to the formation of $Si_{1-x}Ge_x$ films. This approach includes electrochemical processes of the formation of porous silicon (por-Si), electrochemical deposition of low-melting metals, and Ge. When pores are filled with germanium at a given porosity, por-Si allows to control of the ratio of Ge and Si in the initial Si/Ge nanocomposite and, as a consequence, the Ge concentration in the final $Si_{1-x}Ge_x$ alloy after heat treatment at 950°C.
This paper presents the effect of heat treatment on the morphology and composition of Silicon-Germanium nanocomposite.

[1] I. Gavrilin, N. Grevtsov, A. Pavlikov, A. Dronov, E. Chubenko, V. Bondarenko, S. Gavrilov. Materials Letters. 13(2022)1.

Influence of annealing temperature on the morphology

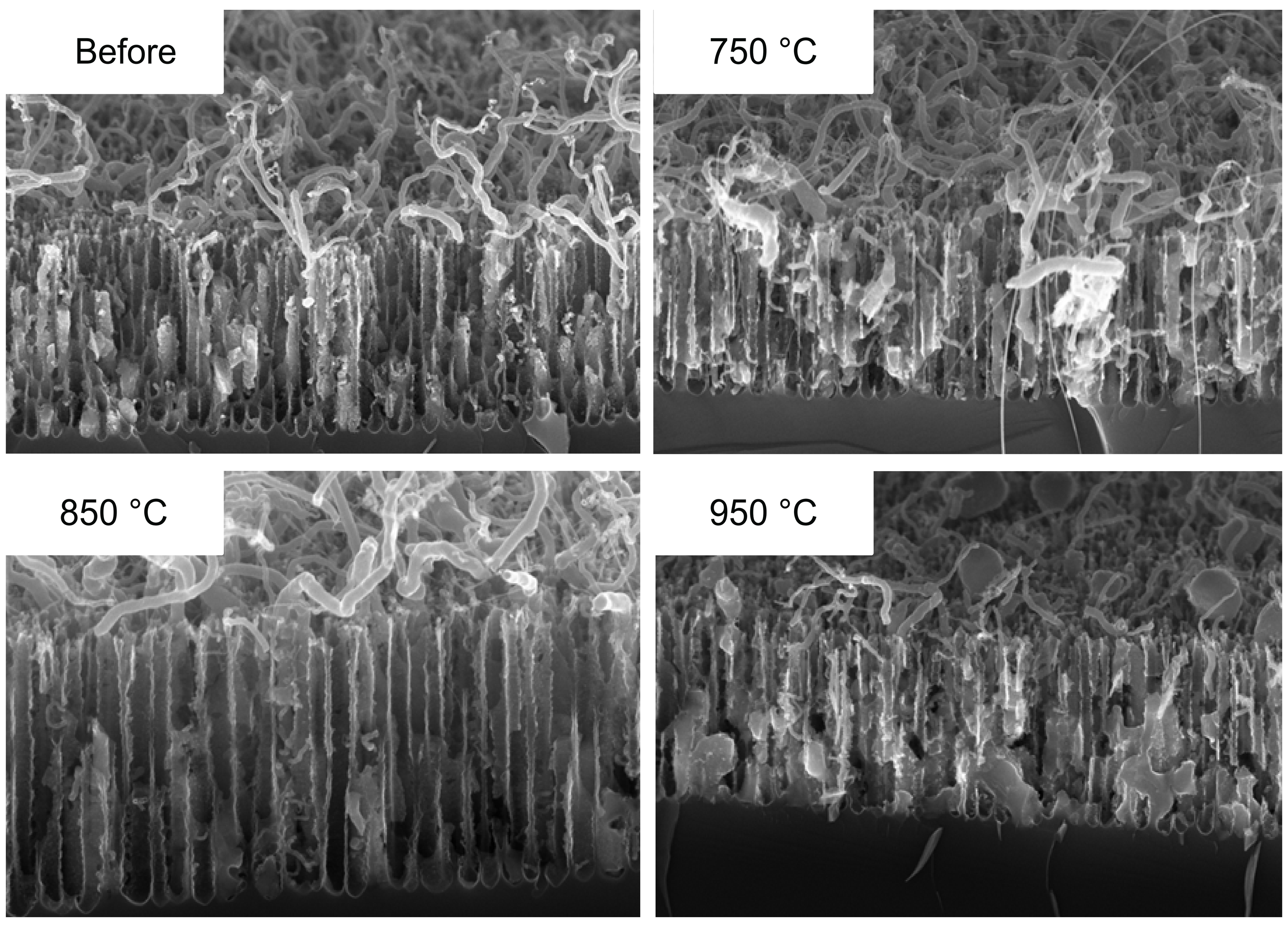

Fig. 2. Scanning electron microscope (SEM) images of silicon-germanium nanocomposite before and after thermal annealing at different temperatures for 10 min in argon.

Fabrication of Silicon-Germanium nanocomposite

A schematically proposed approach for obtaining Silicon-Germanium nanocomposite is shown in Fig.1. This approach consists of the following stages: 1) anodic etching of a single-crystal plate to obtain porous silicon, 2) electrochemical deposition of In nanoparticles (which are germanium crystallization centers) into a porous Si matrix, 3) electrochemical deposition of Ge from an aqueous solution of GeO_2 into porous Si.

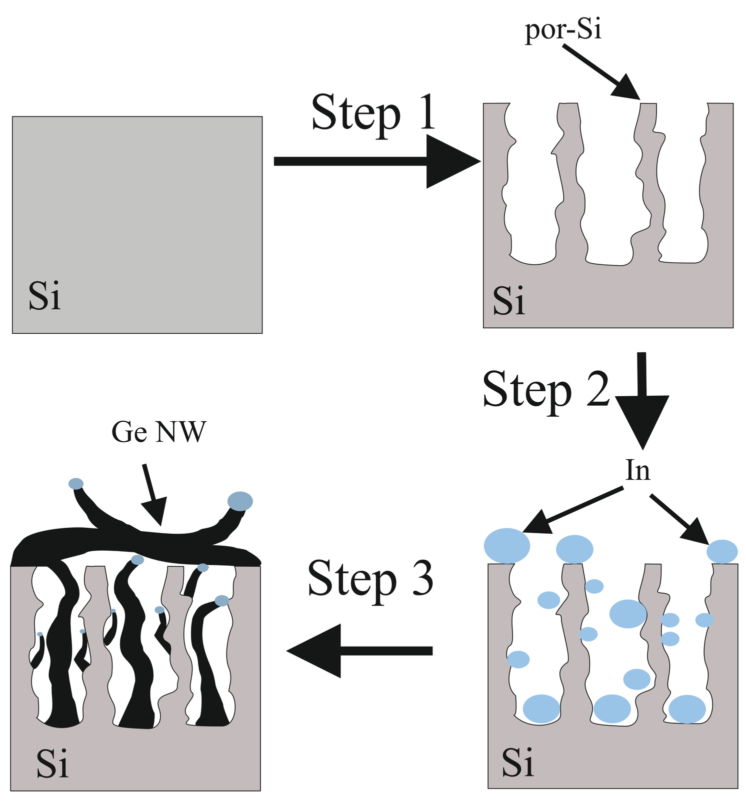

Fig.1 Schematic illustration of Silicon-Germanium nanocomposite fabrication

Raman spectra for sample

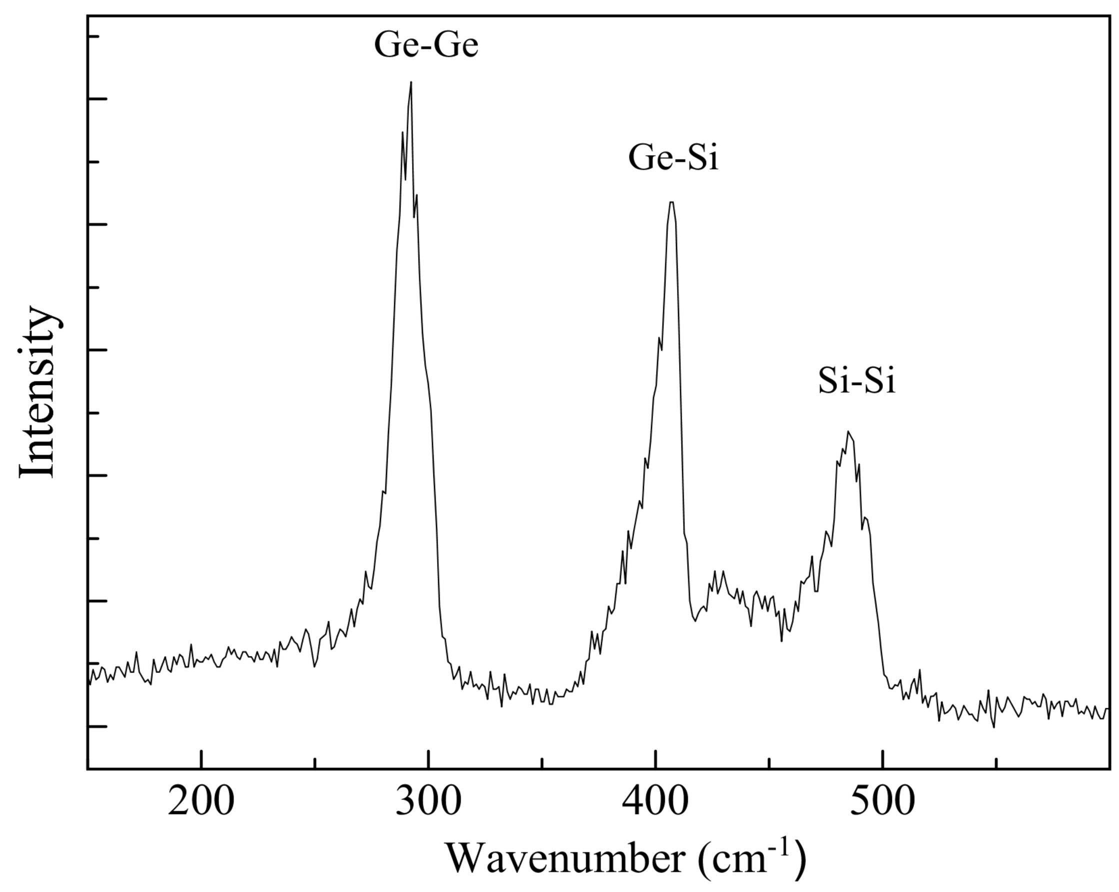

Fig. 3. Raman spectra for sample after thermal annealing for 120 min at 950°C.
The Raman spectrum shows peaks at ~ 291 cm^{-1}, 403 cm^{-1}, 489 cm^{-1}. These peaks correspond to the vibration modes of the Ge-Ge, Si-Ge, and Si-Si bonds in the $Si_{1-x}Ge_x$ film, respectively. The ratio of Si and Ge in the obtained $Si_{1-x}Ge_x$ alloy has been determined from the obtained Raman spectra. The Ge fraction of the analyzed sample in Fig. 3 has been found about 0,6. As a result, an alloy of the composition ~ $Si_{0.4}Ge_{0.6}$ has been obtained Raman spectra for $Si_{1-x}Ge_x$ film.

Influence of annealing time on the morphology

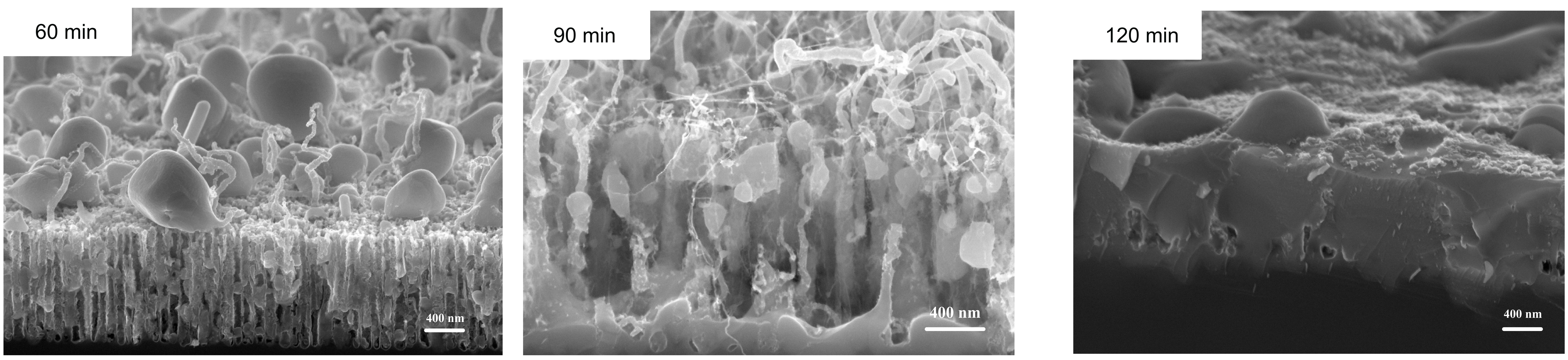

Fig. 4. SEM images of silicon-germanium nanocomposite after thermal annealing for diferent time at 950°C in argon.

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