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Development of technology for fabrication of lithium CPS on basis of CNT-reinforced carboxylic fabric

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HIGHLIGHTS

- Preliminary study of carboxylic fabric wettability with liquid lithium is presented.
- Preliminary studies of carboxylic fabric wettability with liquid lithium consist in carrying out of experiments at temperatures 673,773 and 873 K in vacuum during long time.
- A scheme of experimental device for manufacturing of lithium CPS and matrix filling procedure with liquid lithium are presented.
- The concept of lithium limiter with CPS on basis of CNT-reinforced carboxylic fabric is proposed.

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ABSTRACT

The paper describes the analysis of liquid lithium interaction with materials based on carbon, the manufacture technology of capillary-porous system (CPS) matrix on basis of CNT-reinforced carboxylic fabric. Preliminary study of carboxylic fabric wettability with liquid lithium is presented. The development of technology includes: microstructural studies of carboxylic fabric before its CNT-reinforcing; validation of CNT-reinforcing technology; mode validation of CVD-method for CNT synthesize; study of synthesized carbon structures. Preliminary studies of carboxylic fabric wettability with liquid lithium consist in carrying out of experiments at temperatures 673, 773 and 873 K in vacuum during long time. The scheme of experimental device for manufacturing of lithium CPS and matrix filling procedure with liquid lithium are presented. The concept of lithium limiter with CPS on basis of CNT-reinforced carboxylic fabric is proposed.

1. Introduction

Ongoing studies of the materials for ITER and DEMO fusion reactors have shown that the existing structural materials and traditional technical approaches don't allow to solve the problems in creation of the divertor receiving plates and other plasma facing elements. The recent researches have shown that liquid lithium and lithium-based compounds are the best materials for use as a plasma facing materials (PFM) in fusion facilities [1–7]. The results obtained in 2013 on the EAST tokamak (China, Hefei) [8] confirmed that one of the main factors influencing the increase of plasma confinement time (about 30 s) is lithium use as a PFM.

The high prospects for future fusion devices have lithium stabilized in so-called capillary-porous system (CPS). Lithium CPS is a new composite material where liquid lithium is stabilized in the porous metallic matrix. (Stabilization means compensation the effect of natural forces J × B (MHD-effects) by surface tension forces). The main advantages of CPS are degradation stability and surface self-regeneration under normal plasma discharge, ELM, and plasma disruption conditions. The determinative factor in the concept of lithium CPS is capillary forces. They provide a stability of

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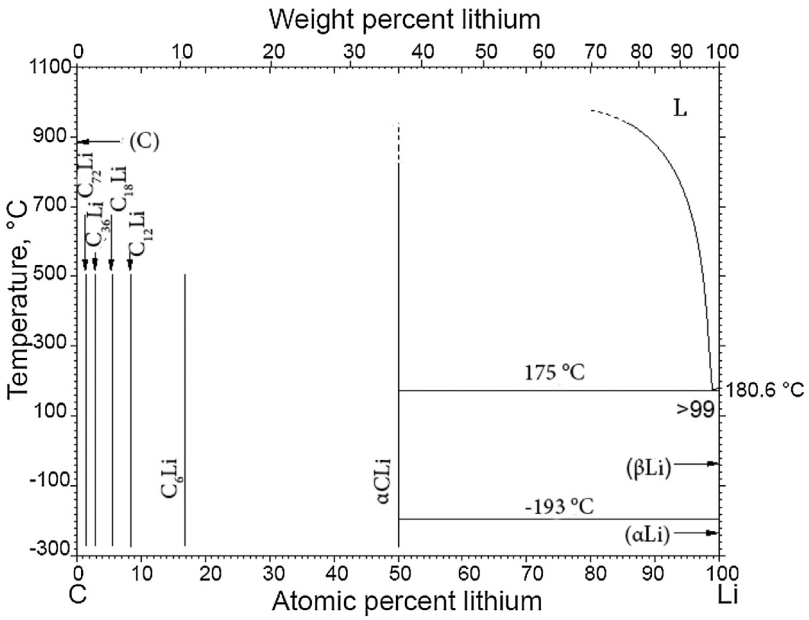

Fig. 1. Li-C phase diagram [11].

liquid metal under MHD-effects, prevent from lithium splashing, feed and fill the CPS with molten metal.

At the moment, the manufacture technology of lithium CPS requires further development in terms of optimizing the matrix material. The material of CPS's base should have good compatibility with liquid lithium: high corrosion resistance, insensitivity to liquid metal embrittlement, resistance to radiation damage, good wettability with liquid metal, good thermal conductivity, high bulk and surface void ratio. Currently, Mo, W or stainless steel in a mesh or felt are used as the materials for CPS's base. New materials may be more processible, have lower activation in a neutron field, and have a higher level of liquid metal confinement due to dramatic reduction of the effective pore radius of the capillary system, which cannot be reached with the materials being used before. An important step in investigations at this stage is to determine the basic technological procedures for the production of lithium CPS with new material—CNT-reinforced carboxylic fabric.

The aim of this work was to develop a technology for manufacturing of CPS matrix on the basis of CNT-reinforced carboxylic fabric, and to carry out the preliminary studies of carboxylic fabric wettability with liquid lithium.

2. Liquid lithium interaction with carbon-based materials

In the lithium-carbon system a stable carbide Li_2C_2 is formed, which has a number of allotropic transformations (Fig. 1). Lithium and Li_2C_2 form a eutectic with a melting temperature of 438–448 K, which contains about 2.8% of lithium carbide [9,10]. Carbon solubility in liquid lithium (C, %) according to the diagram in reference [3] is determined by:

$$lnC = 5.772 - 3885 \cdot T^{-1} \quad (1)$$

Such high solubility is close to the solubility of nitrogen in lithium and it is not confirmed by the later data (Fig. 2), which is recommended for use (Table 1).

Carbon is the least soluble element in the lithium liquid phase comparing with other non-metallic elements (see Table 2).

It gives a reason to expect an acceptable level of CNT corrosion compatibility with liquid lithium in a fusion reactor. A necessary condition for design of lithium CPS on the basis of CNT-reinforced carboxylic fabric is a good wettability of this carbon material with liquid metal, which usually depends on temperature. Lithium as a material of alkaline group forms ionic bonds with carbon-based materials. There are quantitative data on the graphite wettability

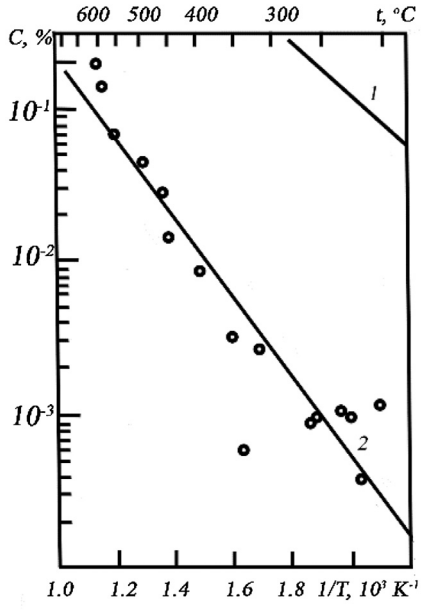

Fig. 2. Carbon solubility in lithium: 1—[9]; 2—[12].

Table 1
Recommended parameters of solubility temperature dependence $lnC = A - BT^{-1}$ for non-metals in lithium [13].

	Temperature range	Parameter	
Impurity	K	*A*	B
Hydrogen	523–775	8.112	5314
Deuterium	472–771	7.706	5082
Carbon	**477–908**	**3.505**	**5750**
Nitrogen	468–723	7.581	4832
Oxygen	530–715	6.033	6659