Short scientific report

on usage of 2nd Eurominsci Conference Travel grant

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ESF Unit: LESC
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I used the 2nd Eurominsci Conference Travel grant to cover expenses on participation in AGU Fall Meeting 2008. The conference was held in San Francisco, California, USA, on 15-19 December, 2008.

This annual conference is known to be one of the most important geophysical meetings of a year. I am very thankful to ESF EuroMinSci program for giving me the opportunity to take part in this meeting, to present my work there and to get the very useful feedback from outstanding scientists from all over the world.

At the conference I presented the poster with my recent experimental results on investigation of Fe-Ni-C system at elevated pressures and temperatures. This work was done in the frame of EUROCORES project "Mineralogy and Chemistry of Earth's core". The abstract of my presentation is presented below as well as the copy of poster.

Abstract of the poster presentation at AGU Fall meeting 2008
Section: Study of Earth's Deep Interior
Special Session: The Ins and Outs of the Earth's Core

Fe-Ni-C system at high pressure

Olga Narygina[1], Leonid Dubrovinsky[1], Catherine McCammon[1], Dan Frost[1], Nobuyoshi Miyajima[1], Vitaly Prakapenka[2].

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Apart from being technologically important, FeNi alloys introduce particularly interest to the material sciences as well as to the geosciences. It is generally accepted that the Earth's core is predominantly composed by FeNi alloy with 10-15 wt% Ni. The certain amount of the light element(s) is also known to be presented in the Core. A number of candidates for the light component have been proposed, including sulphur, oxygen, hydrogen and carbon. In favor of the last one the following arguments can be listed (i) high cosmic abundance, (ii) chemical affinity to iron even at low pressures and (iii) capability of lowering the density of molten iron. Although there is quite a bit of experimental and theoretical results on high pressure high temperature behavior of the system Fe-C, there is still lack of information about the phase relations in Fe-Ni-C system at elevated pressures and temperatures.

Therefore we provided a series of compression experiments on the system Fe-Ni-C at pressures up to 53 GPa in temperature range 300 - 2600 K (combining diamond anvil cell and large volume press techniques) in order to investigate phase diagram of Fe-Ni system and the influence of carbon on the phase relations in the system at elevated pressures and temperatures.

We observed that dissolution of even 1 wt% carbon in FeNi alloys with 10, 15 and 22 wt% Ni leads to dramatic changes in the system: presence of carbon stabilizes *fcc*-structured FeNi through the redistribution of nickel. Combining Mössbauer spectroscopy, XRD, TEM and chemical analyses by microprobe and SEM techniques we detected the formation of Ni-poor and Ni-enriched phases, with different elastic and structural properties.

Acknowledgments

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Fe-Ni-C system at high pressure

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The Earth's core is believed to composed by FeNi alloy with a certain amount of the light element(s). A number of candidates for the light components has been proposed, but the most plausible are sulphur, oxygen, hydrogen and carbon. In favor of carbon the following arguments can be listed (i) high cosmic abundance, (ii) chemical affinity to iron even at low pressures and (iii) capability of lowering the density of molten iron.

Although there is quite a bit of experimental and theoretical results on the behavior of FeNi alloys at elevated pressures and temperatures, there is still lack of information about the influence of carbon on the phase relations in this system under extreme conditions.

In order to investigate effect of carbon on Fe-Ni phase diagram we provided a number of compression experiments on the Fe-Ni and F-Ni-C systems at pressures up to 53 GPa in temperature range 300 - 2600 K (combining diamond anvil cell (DAC) and large volume press (LVP) techniques).

Fe-Ni system

Providing *in situ* high pressure high temperature XRD experiments on $Fe_{0.78}Ni_{0.22}$ alloy (APS, GSCARS) we observed appearence of the second *fcc*-structured phase with slightly different lattice parameters at 24-37 GPa and 1450–2100K (Fig. 1.)

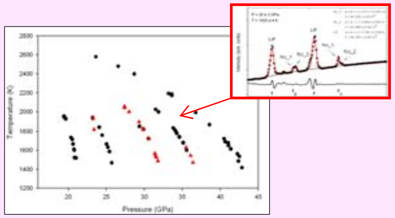


Fig. 1. P-T conditions at which XRD patterns were collected. Two *fcc* phases were observed to coexist at 24-37 GPa and 1450-2100 K (red triangles).

FeNi alloy samples (with 10, 15 and 22 wt% nickel) recovered after laser heating under pressure in DAC show presence of *fcc* and *bcc* FeNi (Fig. 2).

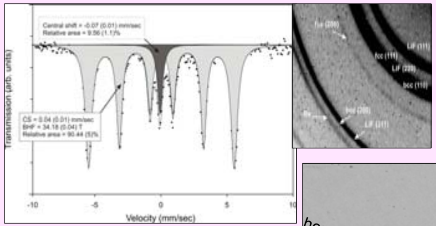


Fig. 2. Conventional Moessbauer and XRD spectra of $Fe_{0.9}Ni_{0.1}$ recovered after laser heating in DAC at 20 GPa and 2000 K.

However only homogeneous *bcc* FeNi (with a small amount of FeNi oxide) was detected in FeNi alloy samples of the same composition treated in multianvil press at the same P-T conditions (Fig. 3).

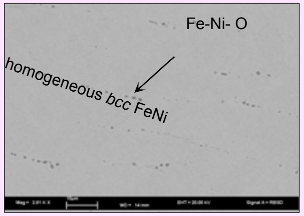


Fig. 3. SEM image of $Fe_{0.78}Ni_{0.22}$ heated at 20 GPa up to 2000 K.

This discrepancy between DAC and LVP experiments could be explained by some contamination in the case of DAC, that we can avoid in the case of multianvil. The only contamination which one cannot absolutely excluden in DAC experiment is carbon, that might come from diamond anvils. Therefore we repeated our multianvil runs with the same samples under the same P-T conditions in the presence of carbon.

Fe-Ni-C system

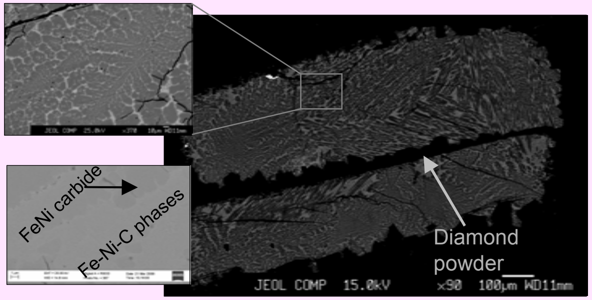


Fig. 4. SEM and microprobe images of $Fe_{0.78}Ni_{0.22}$ heated at 20 GPa at 2100 K in the presence of 10 wt% carbon.

XRD analyses of $Fe_{0.78}Ni_{0.22}$ sample recovered after heating at 20 GPa up to 2100 K showed Fe carbide phase that was indexed by electron diffration as Fe_3C with a small amount of Ni (Fig. 4, 5). Also XRD detected presence of *fcc* and *bcc* FeNi phases (Fig. 4)

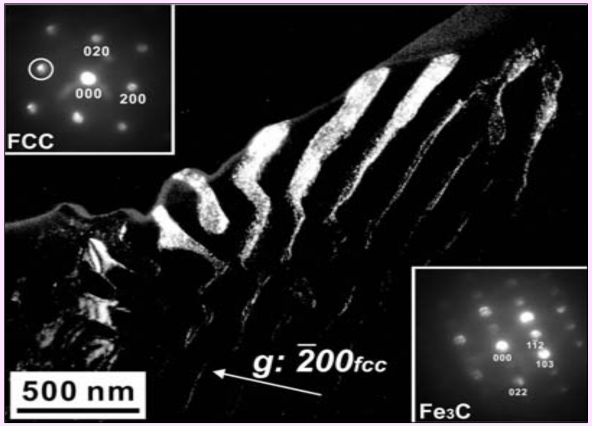
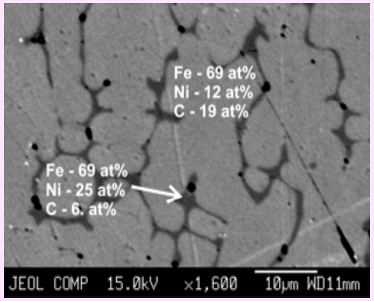


Fig. 5. TEM image of $Fe_{0.78}Ni_{0.22}$ alloy recoverd after heating along with 10wt% diamond powder at 20 GPa up to 2100 K in multianvil press.



FeNi alloys heated at 20 GPa up to 2100 K in the presence of only 1 wt% carbon decomposed to Ni-poor and Ni-enriched phases with different carbon content (Fig. 6).

Fig. 6. Microprobe image of $Fe_{0.78}Ni_{0.22}$ alloy recoverd after heating along with 1wt% diamond powder at 20 GPa up to 2100 K in multianvil press.

We performed the series of LVP runs with homogenious Fe-Ni-C powder mixtures of different stochiometry ($Fe_{0.90}Ni_{1-x}C_x$, 0.01 ≤ x ≥ 0.05) at pressures 0.5 - 20 GPa and temperatures 2010–2300 K.

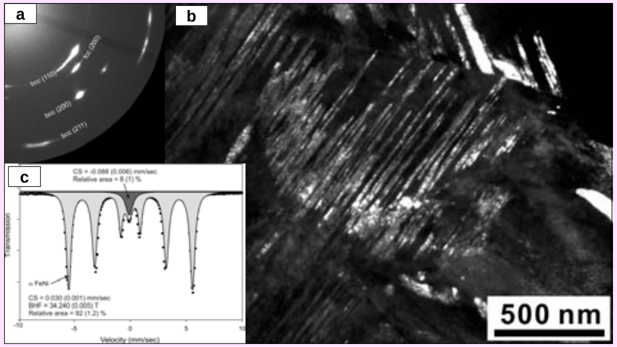


Fig. 7. XRD pattern (a), TEM image (b) and conventional Mössbauer spectrum (c) of $Fe_{0.90}Ni_{0.08}C_{0.02}$ alloy synthesized at 9 GPa and 2300 K.

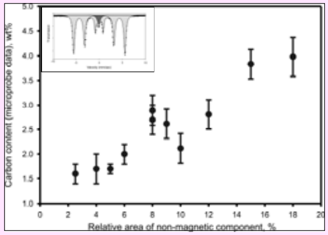


Fig. 8. Amount of carbon in the quenched samples (obtained by microprobe analyses) vs. relative area of non-magntec component (the area of shaded in dark gray Mössbauer singlet).

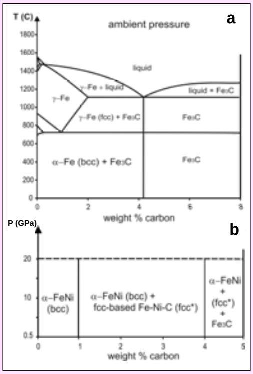


Fig. 6. Fe-C phase diagram at ambient pressure (a). Preliminary FeNi-C phase diagram at high pressures (0.5-20GPa), obtained as the result of LVP experiments, reported here.

Conclusions:

- ☐ The solubility of carbon in FeNi alloy increases with pressure and can reach value of 4 wt% (at 20 GPa) without formation of Fe_3C carbide ;
- ☐ Carbon has a significant effect on the phase relations in Fe-Ni system:
  1. It decreases melting temperature of FeNi alloys for several hundreds degrees;
  2. At high pressure presence of even 1 wt% carbon in Fe-Ni system leads to formation of non-magnetic *fcc*-based phase (*fcc**);
  3. Amount of these *fcc** phase is proportional to the amount of dissolved carbon.