

論文 / 著書情報  
Article / Book Information

題目(和文)	
Title(English)	Searching for New Interfacial Phenomena of 4He Crystal under Microgravity
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出典(和文)	学位:博士(理学), 学位授与機関:東京工業大学, 報告番号:甲第9253号, 授与年月日:2013年9月25日, 学位の種別:課程博士, 審査員:奥田 雄一,吉野 淳二,田中 秀数,斎藤 晋,大熊 哲
Citation(English)	Degree:Doctor (Science), Conferring organization: Tokyo Institute of Technology, Report number:甲第9253号, Conferred date:2013/9/25, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)  
Doctoral Program

## 論文要旨

THESIS SUMMARY

専攻 : Department of	物性物理学	専攻	申請学位 (専攻分野) : Academic Degree Requested	博士 (理学) Doctor of (理学)
学籍番号 : Student ID Number			指導教員 (主) : Academic Advisor(main)	奥田 雄一
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The purpose of our investigation is to search for interfacial phenomena of a  $^4\text{He}$  crystal which are masked by the gravity.  $^4\text{He}$  quantum crystals grow in superfluid very quickly at sufficiently low temperatures and therefore can relax fast to the equilibrium in accordance with the surrounding condition. The fast relaxation can be achieved even for a macroscopic crystal by the swift superflow of mass transport and by the negligibly small release of latent heat. Moreover, the very pure system which includes no impurities but  $^3\text{He}$  also allows the crystal to relax easily. Studies of  $^4\text{He}$  crystals provide us with deep understanding of fundamental physics, such as verification of roughening transition, temperature dependence of step free energy below the roughening transition, dependence of step-step interaction on interval between steps, and facet growth mechanism due to two dimensional nucleation or spiral growth. On the other hand,  $^4\text{He}$  crystals are sensitive to the gravity and the gravity masks fundamental phenomena on the crystal. For example, as long as the crystal size is much larger than the capillary length of 1 mm, the crystal is deformed by the gravity to minimize the gravitational energy and we are not able to observe the equilibrium shape of the crystal.

We are interested in the equilibrium shape of the crystal at low temperatures determined by the interfacial free energy. Therefore, we have got started to carry out experiments under microgravity produced by a parabolic flight of a jet plane. First, we had to develop a refrigerator for the microgravity experiments on the jet plane. The jet plane was so small that the cryostat had to clear some restrictions such as experimental space, available electric power and total weight of the experimental system including refrigerators, vacuum pumps, measuring instruments and so on. We succeeded in developing a  $^3\text{He}$  evaporation refrigerator and then a dilution refrigerator for experiments on the jet plane. Dilution refrigerators, a common device to get ultra-low temperatures, require the gravity to stabilize the  $^3\text{He}/^4\text{He}$  interface for the continuous operation and so special care has to be paid for the use in zero gravity. Although the refrigerator unit we constructed was an ordinary one, we found it keeps the lowest temperature of 150 mK during the period of 20 seconds by the parabolic flight. We expected this success by the experience of the  $^3\text{He}$  evaporation refrigerator which could keep its lowest temperature of 580 mK during the parabolic flight.

Using these refrigerators, we succeeded in observing macroscopic  $^4\text{He}$  crystals at around 600 mK and 150 mK under microgravity. After the gravity was reduced to zero by the parabolic flight, the crystals changed their shapes immediately to new equilibrium shapes from the ones in gravity. The crystal did not detach from the sample cell wall at any time under microgravity probably because the adhesive force manifested as partial wetting to the wall was sufficiently strong and we could not observe the equilibrium shape completely surrounded by the superfluid. However, we found  $s$ -facets to appear on some part of the crystal at around 200 mK under microgravity which was concealed at 150 mK by gravity. This is the very first observation of  $s$ -facet on an equilibrium shape of a  $^4\text{He}$  crystal. Moreover, equilibrium shapes we obtained under microgravity were found to depend on the initial shapes just before the relaxation, so we were able to observe different relaxation processes of the crystal by applying an acoustic wave pulse to the crystal to deform it.

In addition, we observed a clean Ostwald ripening of  $^4\text{He}$  crystals in superfluid  $^4\text{He}$ . Under gravity on the ground, the ripening was not apparent because it stops growing at the crystal size comparable with the capillary length. However, under microgravity, Ostwald ripening was observed up to the scale on the order of 10 mm due to the infinitely long capillary length, exhibiting a novel evolution of crystal shape driven solely by the interfacial free energy.

Thus, this work opened a new field of physics, the crystal shape of quantum solid under microgravity, which had not been studied so far.

備考 : 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 2 部提出してください。