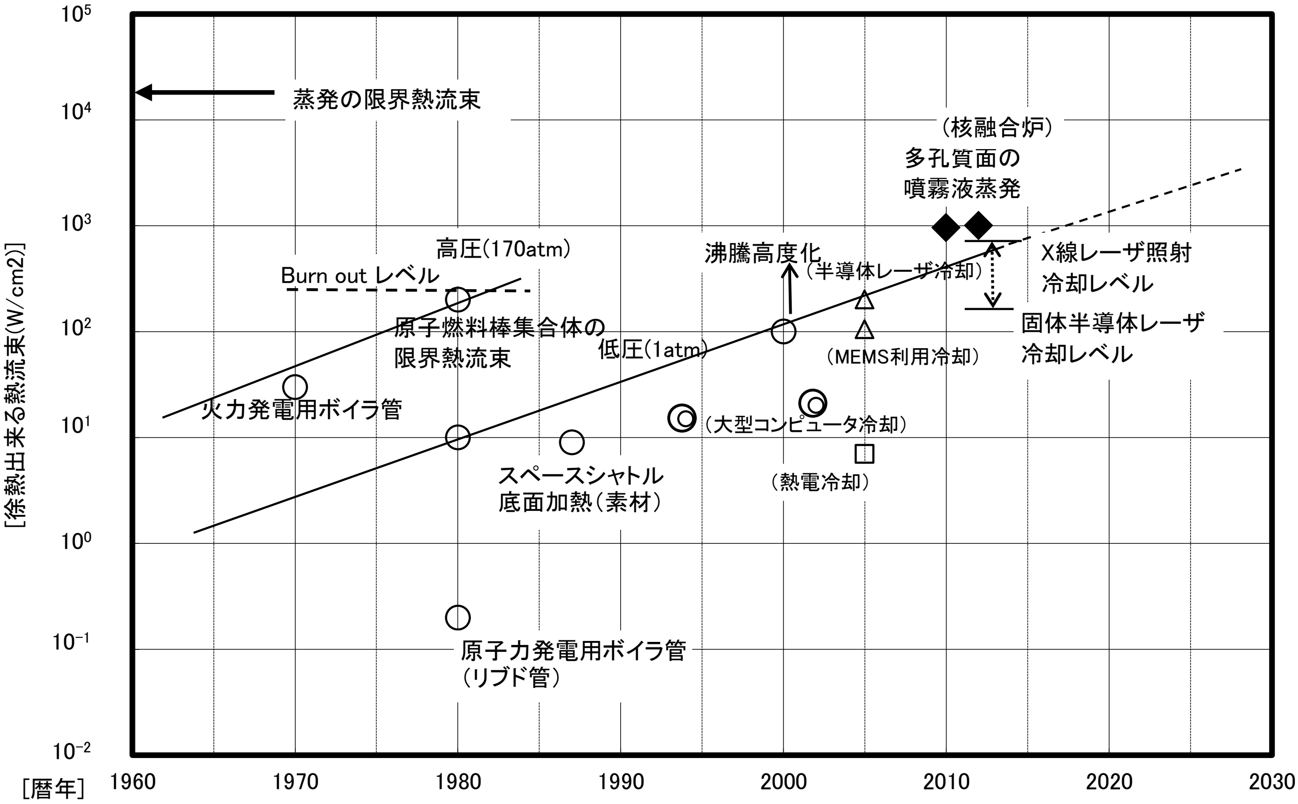
高熱流束除熱技術



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High-Temperature Heat Flux Heat Reduction Technology

(1) Aims

Selecting the heat removal limit heat flux that may serve as the general-purpose parameter showing the forefront and limit of temperature control, heat transfer enhancement, heat removal, and heat exchanging technologies, which are the key technologies in the heat engineering field, and clarifying the needs and consistent changes in numeric values, possibility of increases in the future, mechanical limits, and the form of society if these parameters increase in the future in order to provide engineers with social and academic meaning and quantitative targets and contribute to further progress of mechanical engineering.

(2) Social and technical needs

The following show the social and technical needs aroused by the increase in heat reduction fluxes:

- Heat fluxes of boilers (for preventing overheat of boiler piping)
- Cooling of spaceships when entering earth's atmosphere (for guaranteeing the thermal durability of spaceships)
- Cooling of nuclear reactors in case of accidents (for preventing breakage of fuel rods)
- Cooling of electronics, size reduction in cooling electronic devices, and higher-density heat generation (for reducing computer sizes)
- Hundreds of W/cm^2 are required for stable emission of cooled semiconductor lasers. However, the total heat generation amount is several watts or so. (For actualizing small solid semiconductor lasers for machining)
- Cooling in laser emission and X-ray emission is also a problem in the future. (High-power X-ray emission is needed.)

(3) Future directions for determining key mechanisms and parameters

The following show the possibilities for increasing heat removal heat fluxes:

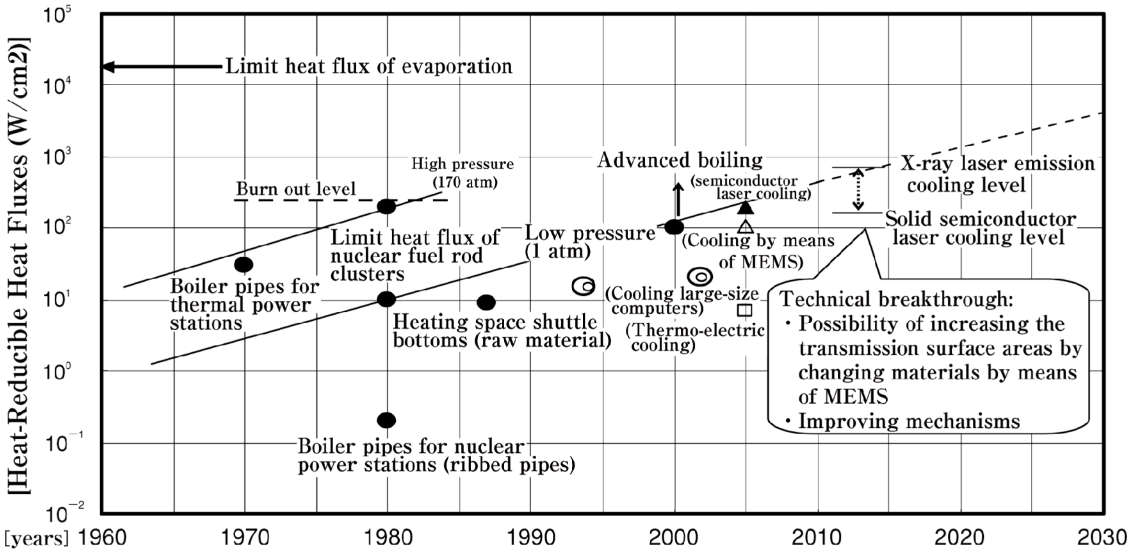
- The limit heat fluxes for pool boiling at the atmospheric pressure are up to 100 to 200 W/cm^2. A maximum of 400 W/cm^2 is approximately the limit heat flux for pool boiling at 80 atm, approximately one-third the critical pressure.
- The limit heat flux for forced convection sub-cool boiling may be increased up to 2 x 10^4 W/cm^2. The limit heat flux of evaporation is also 2 x 10^4 W/cm^2, showing promising utilization of the evaporation limit.
- In single-phase collision jet heat transmission of the normal convection heat transmission, the temperature difference is 150 K, flow velocity is 35 m/s, nozzle diameter is 1 mm, and heat flux using the property value of fluid water is 5000 W/cm^2.
- The area of the heat transmission surface is increased by means of MEMS. However, restrictions may be in place after increasing the area.
- The thermo-electric cooling value is approximately 10 W/cm^2 at present. How can we increase it? What is the technical breakthrough?

(4) Contributions to society

- Developing wearable lightweight computers. (Pocket-size computers and watches equipped with computer functions. However, such computers generate heat like pocket heaters and may break down due to overheating.)
- Further size reduction in computers will improve computer functions significantly. (Mobile computers will have the same performance as desktop computers. Besides, electric and electronic appliances and car-mounted microcomputers will have enhanced performance.)
- Developing portable high-power laser machine tools. Small machine tools may be carried and installed near materials to be machined. (This is the micro-factory concept. Lenses of glasses may be processed in convenience stores, for example. Small high-power lasers may also serve as weapons.

Social & Technical Needs

1960～1970	・Cooling boilers in thermal power stations
1970～1980	・Cooling electronic devices
1980～1990	・Cooling boilers in nuclear power stations ・Development of higher-density electronic devices
1990～2000	・Development of higher-density electronic devices ・Reduction of super computer sizes
2000～2010	
2010～2020	・Size reduction (of handy laser machine tools, etc.) & development of wearable computers
2020～2030	



Technical Breakthrough

1960～1970	・Pipes with internal grooves (ribbed pipes) and circling flow of boiler water
1970～1980	
1980～1990	・Vertical rising pipe structure (rifle pipes) ・[Heat insulating materials for space shuttles (withstand temperature, strength and attaching method)]
1990～2000	
2000～2010	
2010～2020	・Possibility of increasing the transmission surface areas by changing materials by means of MEMS (area increasing process technology)
2020～2030	

Changes in Society and Markets

1960～1970	・Large-size computers were released first in Japan (by NEC). ・Transistor TV sets were released first in the world (by Sony). ・Space shuttle landed on the moon.
1970～1980	・LCD LSI portable calculators were released (by Sharp). ・Word processors were released (by Toshiba and Sharp). ・NEC PC computers were released.
1980～1990	・Laser machining products were developed. ・Static weather satellite Himawari No. 2 and broadcast satellite BS-2 were launched. ・PC communication services [ASCII-NET] started. ・Notebook PCs were released (by Toshiba and Fujitsu).
1990～2000	・Test broadcasting of BS high-visions started. ・Commercial providers were founded and Internet expanded.
2000～2010	・Scale of wearable computers in the U.S. market reached 600 million dollars even in 2003. ・Japanese experimental booth (Kibo) of international space station was launched. ・Mass production of notebook PCs with fuel batteries ・Changing the Internet device standard into IPV6 (next-generation communication standard) was started mainly by Government.
2010～2020	・Individual-customized electronic magazines and newspaper were propagated. ・Portable PCs with solar and fuel batteries were put into practical use. ・One-chip ubiquitous computers were put into practical use. ・Nanometer-scale 3D IC processing technology ・About 50% of notebook PCs were changed into PCs with semiconductor drive (SSD) units.
2020～2030	・Super high-vision broadcasting was put to practical use. ・Wearable automatic voice translators were put to practical use. ・Quantum information optical transmission system was put to practical use. ・Tele-work population doubled. ・Desktop PCs had supercomputer-level performance.

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高熱流束除熱 技術ロードマップ

熱工学部門　産業技術総合研究所　矢部　彰，　神戸大学　平澤茂樹

1. 趣旨

熱工学分野でのキー技術である温度制御，伝熱促進，除熱，熱交換技術の最先端と限界を示す汎用的なパラメータとして，実現できる除熱限界熱流束を取り上げる．

2. 社会的・技術的ニーズ

高熱流束除熱に関して，熱工学分野における学問的な研究動向を図1に示す[(1)]．すなわち，小型化・低コスト化のための熱交換器のコンパクト化＝伝熱促進の研究開発＝限界熱流束の促進．

除熱熱流束の増大が実現してきている社会的・技術的ニーズを以下に示す．

- ・ボイラの熱流束（ボイラ配管の過熱防止のため）
- ・宇宙船の大気圏再突入時の冷却（宇宙船の熱的な耐久性確保のため）
- ・原子炉事故時の冷却（燃料棒の破損防止のため）
- ・エレクトロニクス冷却，電子デバイスの冷却における小型化，高発熱密度化（コンピューターの小型化のため）
- ・半導体レーザー冷却で，安定な発信を実現するためには，数百 W/cm^2 が必要になっている．（加工用固体小型半導体レーザー）
- ・レーザー照射冷却，X線照射時の冷却も今後の課題（強力なX線照射を実現したい）

3. キーパラメータの高度化を実現するメカニズムの可能性

除熱熱流束の増大を実現する可能性としては以下の事項があげられる[(2)(3)]．

- ・熱伝達は，大気圧のプール沸騰限界熱流束は，100～200W/cm^2 の程度まで．臨界圧力の1／3程度の80気圧で最大約400W/cm^2 がプール沸騰の限界熱流束になる．
- ・強制対流サブクール沸騰の限界熱流束は，$2\times10^4 W/cm^2$ のオーダーまで可能．蒸発の限界熱流束も $2\times10^4 W/cm^2$ のオーダーで，蒸発の極限利用は大きな可能性を有している．
- ・通常の対流熱伝達では，温度差150K，流速35m/s，ノズル直径1mm，液体に水の物性値を使った熱流束は，5000W/cm^2 になる．
- ・MEMSによる伝熱面積拡大で対応しているが，面積拡大には限界があるのではないか．
- ・熱電冷却は現状では10W/cm^2 程度，どのようにして増加させるか，技術的なブレークスルーは何か．

4. 将来の社会に関する展望

- ・身につけられる軽量のコンピューターの実現（ポケットに入る大きさのコンピューターや時計にモバイルコンピューター機能が搭載される．ただし，暖房用カイロのような発熱体であり，過熱による故障の心配がある）
- ・コンピューター製品の小型化の一層の推進により，身近なコンピューターの機能が飛躍的に増大する（モバイルでデスクトップと同等の性能を発揮する．また，電気・電子機器や車のマイコン制御の機能が増大する）
- ・持ち運びの出来る強力レーザー加工機械の実現．これにより，加工される材料のそばに小さな加工機械を持っていき，設置して使用することが出来る（マイクロ・ファクトリーの概念で，コンビニでめがねレンズの加工が出来る．また，強力な小型レーザーは凶器としても使用される心配がある）

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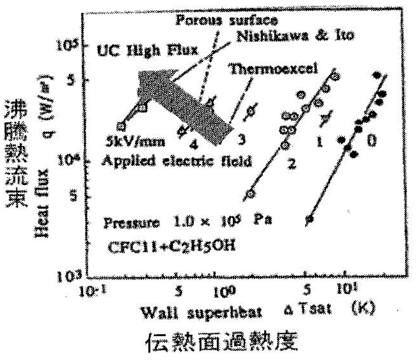

沸騰熱伝達の伝熱促進
＝ 高性能沸騰面
（伝熱面過熱度をより小さく）
or
＝ 限界熱流束の促進
（より大きな高熱流束除熱）

図1　学問的な研究動向

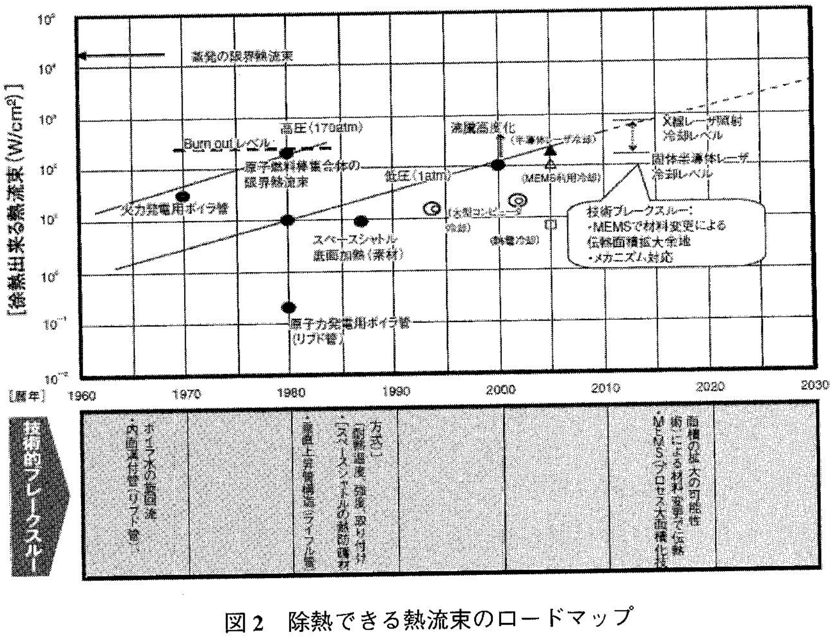

図2　除熱できる熱流束のロードマップ