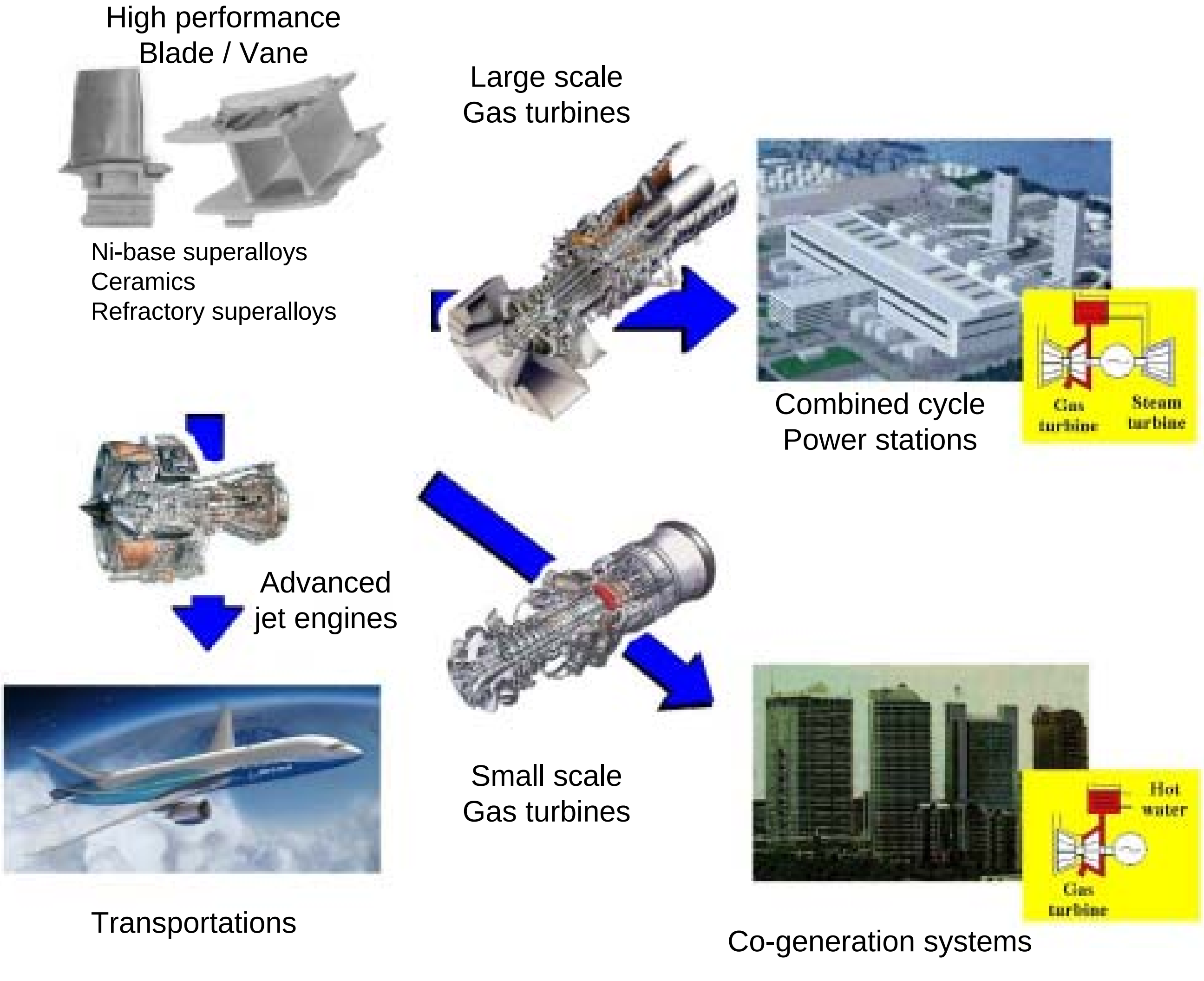
High Temperature Materials 21 Project

National Institute for Materials Science(NIMS), Japan

In this project, we are developing advanced **Ni-base superalloys, Si_3N_4 ceramics** and **refractory superalloys** whose creep temperature capabilities under 137 MPa / 1000 hours are **1100℃**, **1500℃**, and **1800℃**, respectively. Also, a **virtual turbine** computer program is being constructed and used for evaluation of the developed materials. In addition, turbine tests of our materials are being conducted using actual gas turbines and jet engines to demonstrate the benefits given by our materials on the effective CO_2 reduction and prevention of global warming. A wide range of collaborations are being done especially with gas turbine/jet engine manufacturers including those overseas. (1.7-4.2 million US$/year, F.Y.1999-2007)

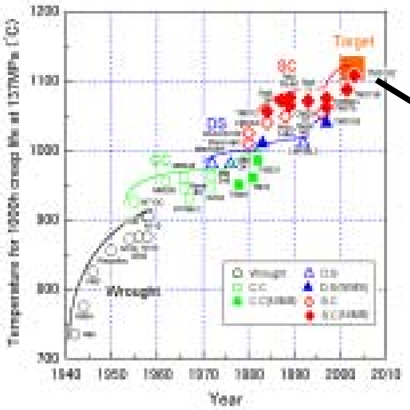
Advanced high temperature materials for effective use of fossil fuels to cut CO_2 emissions



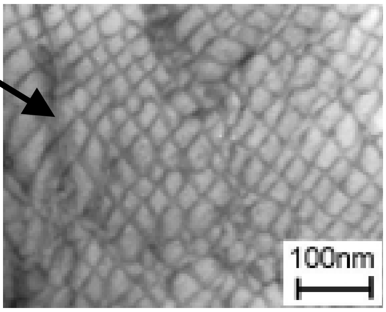
High Temperature Materials 21 Project

Progress in Ni-base Superalloy Developments

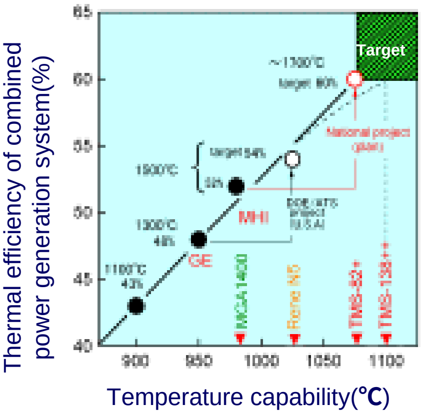
- ✧ Fourth and fifth generation single crystal superalloys, such as TMS-162, were developed by dislocation network control on the γ/γ' coherent interface with help of materials design computer program provided by the Design and Analysis Team. We achieved our target creep temperature capability set for Ni-base superalloy, 1100℃, with TMS-162 (the world highest).
- ✧ High temperature property databases for developed SC superalloys were generated under a wide range of collaborations with various Japanese and overseas companies, such as IHI and Rolls-Royce.
- ✧ Turbine blade manufacturing trials were made in private companies. SC castings for supersonic engine blade were successfully demonstrated with a fourth generation SC superalloy TMS-138 and tested in ESPR engine.



Improvement in temperature capability of Ni-base superalloys.

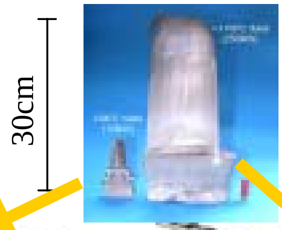


γ/γ' interfacial dislocation network in TMS-162 which have the world's highest temperature capability, 1100℃.

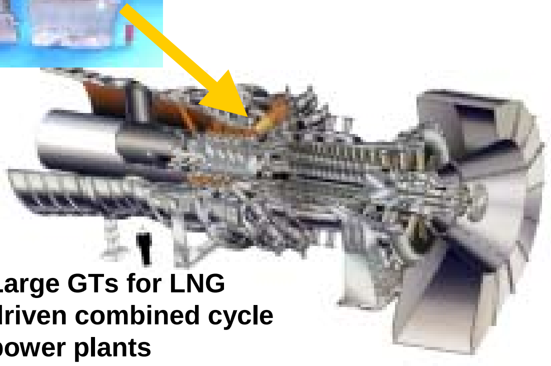


Toward to realize ultra-high efficiency gas turbine system.

New collaborative projects, MEXT/METI, F.Y. 2004-07.

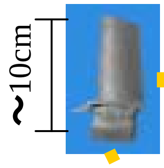


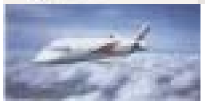
Small GTs for co-generation (Kawasaki H.I.)



Large GTs for LNG driven combined cycle power plants (METI/Mitsubishi H.I.)

Japanese Eco-engine (METI/IHI) Project





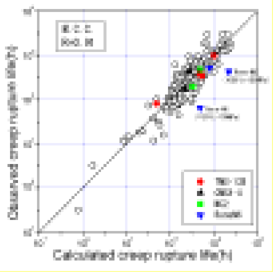
Advenced jet engines for A380, Boeing 7E7,etc.

High Temperature Materials 21 Project

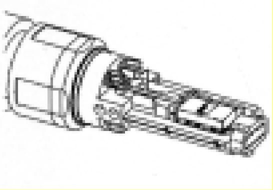
Progress in Materials Design and Virtual Turbine System

Design and Analysis Team : Microstructural analysis at high temperatures

- ✧ Various materials design techniques, e.g., statistical thermodynamics, phase field method, FEM, regression analysis, are employed to simulate the microstructure evolution and to predict high temperature properties of materials.
- ✧ The relationship between the creep resistance and the interfacial dislocation network generated on the γ/γ' interface was clearly shown by TEM observation of the creep interrupted specimens.
- ✧ In-situ observation of Ni-base SC superalloys under 'creep' conditions up to 1100℃-150MPa was made ready; a development of special 'creep holder' to be fitted into a 400kV TEM has been accomplished.



Prediction of creep rupture life by newly developed alloy design program.

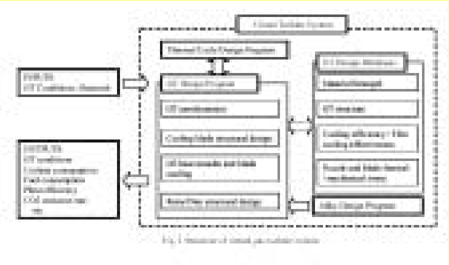


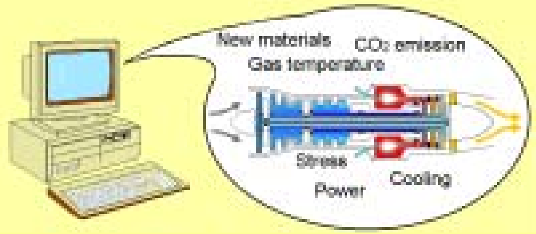
Creep holder for in-situ observation

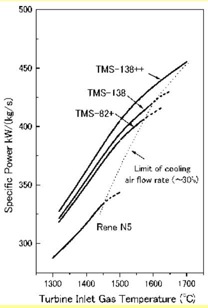
Specimen under creep test

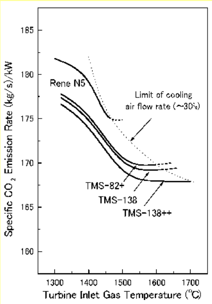
Virtual Turbine Team : Toward a combination of materials and GT system research

- ✧ 1700℃ class VT system has been improved so that a cooled blades made of Ni-base superalloys, and uncooled blades made of ceramics or refractory superalloys can be evaluated.
- ✧ Arbitrary chemical compositions of SC superalloys, as well as the turbine operating condition, can be input for calculation. The gas turbine efficiency, as well as creep rupture life of the blades and vanes, etc., can be calculated.









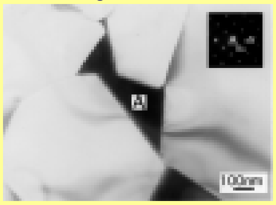
Estimations of specific power and CO_2 emission rate of 200MW class C/C power plant with the comparison of Rene-N5, TMS-82+,TMS-138 and TMS-138++ use.

High Temperature Materials 21 Project

Progress in New Materials and Coating Developments

Ceramics Team: Development of new ceramics by grain boundary structure control

- ✧ Temperature capability of Lu_2O_3-doped Si_3N_4 ceramics increased up to 1500℃ and achieved the target.
- ✧ A new process to decrease the sintering additive for Si_3N_4 less than 0.3 mol% (conventional amount 5%) was developed with the addition of HfN. The decreasing the amount of grain boundary phase is effective for improving the high-temperature properties of Si_3N_4 ceramics.

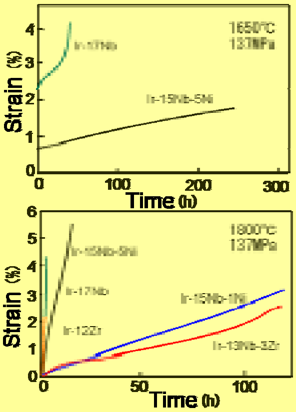


Crystallized grain boundary of Lu_2O_3 -doped Si_3N_4 ceramics

Creep srength of Si_3N_4 at high temperature

Refractory Superalloys Team: Development of new alloys based on platinum group metals

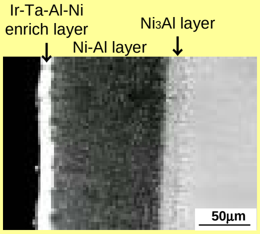
- ✧ The temperature capability reached 1750℃ with the Ir-base ternary alloys (target: 1800℃).
- ✧ The creep resistances of Ir-base ternary alloys such as Ir-Nb-Zr, were higher than those of Ir-base binary alloys at 1800C. Ir-Nb-Pt-Al quaternary system has a wide fcc+L12 two-phase region from Ir to Pt sides.



Compressive creep property of Ir-base refractory superalloys.

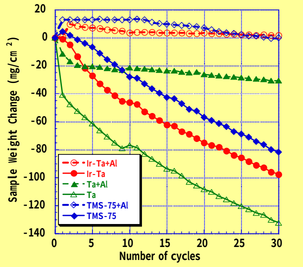
Coating Team: Development of new coating systems for Ni-base SC superalloys

- ✧ Ir-Ta and Ir-Hf coating systems have been developed and evaluated with using TMS-75, etc. These coating systems showed good oxidation resistance and therefore promising for novel bond-coat systems on the newly developed Ni-base SC superalloys capable of being exposed at 1100 ℃ level metal temperature.
- ✧ Electrolytic deposition of an Ir-Pt alloy system was developed. The composition of the Ir-Pt coatings can easily be controlled with constant deposition rate.



SEM image of Ir-Ta coating system.

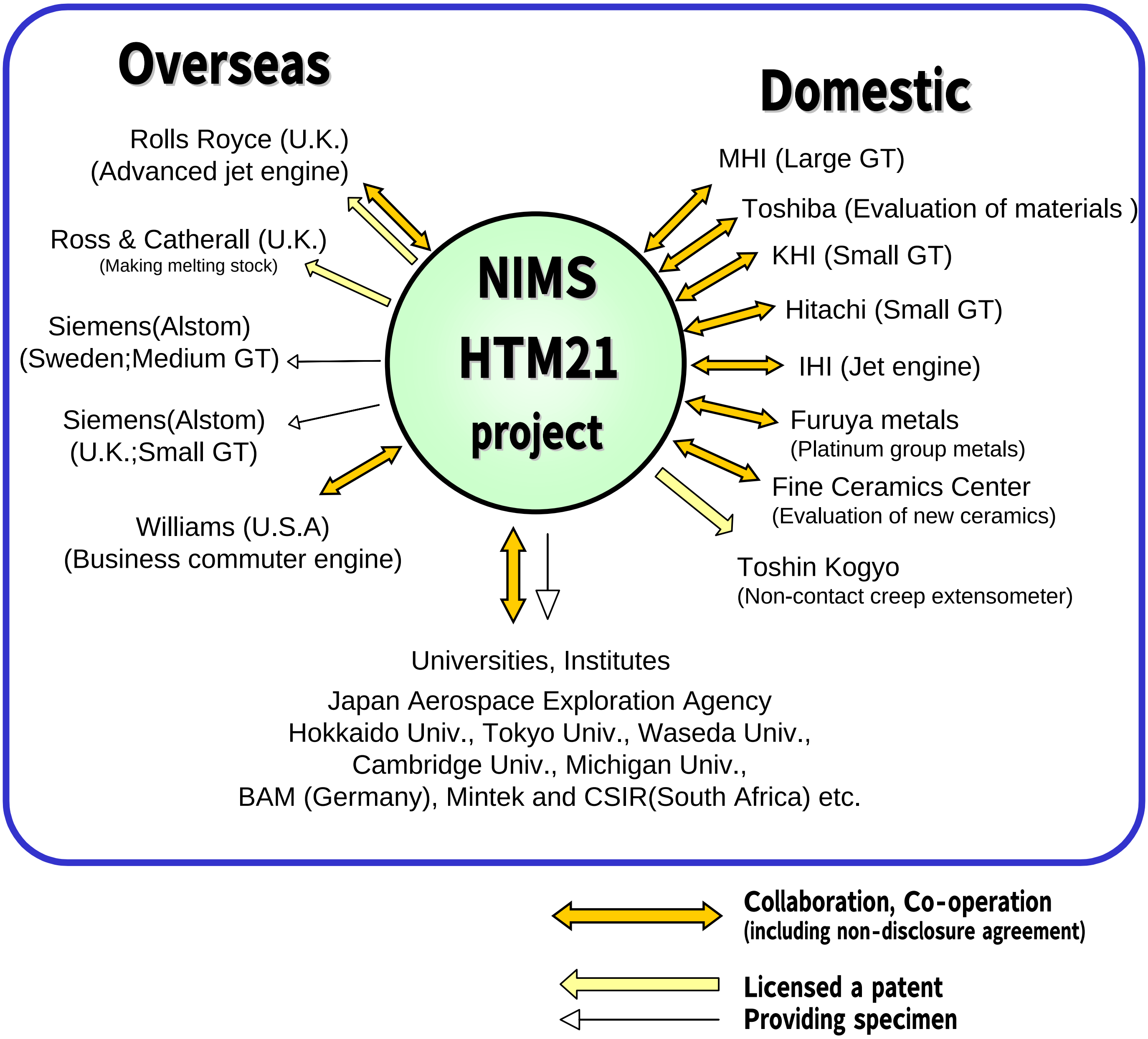
(EB-PVD+Al-pack cemented process)



'Ir-Ta+Al-1237K', which Al-pack cemented process was carried out at1237K, have the best oxidation resistance.

High Temperature Materials 21 Project

Collaborations & Technology Transfer



Patent License

Alloy Design Program	: Rolls - Royce (U.K.)	
3rd gen. Superalloy TMS-75	: Ross & Catherall (U.K.)	1,400kg
2nd gen. Superalloy TMS-82+	: Ross & Catherall (U.K.)	400kg
Non-contact creep extensometer	: Toshin Kogyo	