Sensor Coating Systems Ltd

Thermal History Coatings

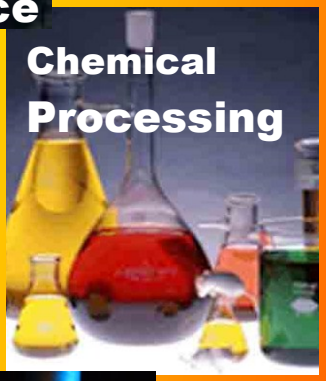
A technology proposal outline for
machinery manufacturers,
the chemical & processing industry,
automotive & gas turbine OEMs,
Formula One,
airlines and power generators,
marine propulsion,
rocket propulsion,
and nuclear engineering applications.

Date: 23/10/2012/Conference

Launched August 2012

A Generic Technology that will

replace Thermal Paints



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Purpose of this document

The aim is to invite original equipment manufacturers (OEMs) across different sectors to join a consortium – launched in August 2012 – to develop a novel and innovative temperature sensing technology which will replace thermal paints. This most innovative technology will be based on luminescent materials and is a derivative technology to the thermal barrier sensor coatings developed by Sensor Coating Systems. The replacement of thermal paints by a superior technology will be highly beneficial to different industrial sectors where temperature information is required from difficult to access locations and from rotating machinery. This truly enabling technology will be generically developed in the consortium over a period of two-to-three years to achieve a technology readiness level (TRL) of 5. Member specific developments would be developed on a one-to-one basis at a later stage bringing this to TRL 6. A tool for low temperature applications will be available after 12 months.

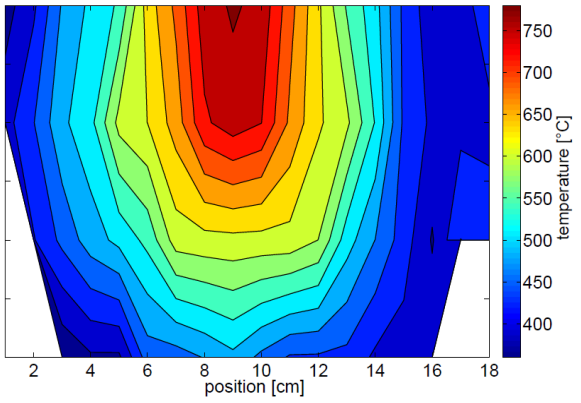
The members will gain multiple technical and commercial benefits from participating in a consortium.

The user group will obtain a new generation temperature profiling method and apply this throughout their engine and machinery development and monitoring programmes with all the associated cost benefits and first mover advantages.

Thermal History Coating: Technical Advantages & Background

Sensor Coating Systems (SCS) proposes the final development of its *Thermal History Coating* (THC) which has been successfully tested in laboratory conditions and applied under production line conditions.

SCS's technology works by exciting with light a particular class of ceramic materials which then start to luminesce. The luminescence can change when the material experiences changes such as temperature variations or structural changes inside the coating triggered by heat impact. The Thermal History Coating technology and associated read out technology is being protected through patent filings by SCS after having successfully proven it as a concept.



The pulsed excitation light stimulates an oxide based material which is doped with optically active ions and releases an exponential decay type luminescence. This luminescence can be detected and acquired electronically and then read using a look-up table which, in turn, will deliver the indication of the temperature to which this material has been exposed.

Advantages of the Thermal History Coating include:

- **Large temperature range covered with few coatings/paints**

  The active components of these SCS Coatings/Paints allow the continuous measurement of temperatures between 300 and 1400°C, and potentially up to 1700°C.

- **Temperature accuracy about ± 5-10°C**

  The SCS Thermal History Coatings/Paints have shown temperature accuracy between 5 and 10°C over the whole dynamic temperature range. This is better than thermal paints.

- **Can be applied as a paint or coating**

  The SCS Thermal History Paints are easy to apply and remove after use. When applied as paint, they do not alter the thermal behaviour of the component during testing. The SCS Thermal History Coatings are applied as a robust coating by thermal spraying, resulting in robust structures which could withstand harsh environments for much longer than thermal paints.

- **Automated and objective temperature reading**

  The surfaces are interrogated at room temperature after exposure. The readout is done using specialised electronic and optical instrumentation, developed by SCS. This readout is objective and can be automated, in contrast to a subjective readout as in the case of thermal paints. Further the electronic system will provide a reduced readout-time enabling, in turn, the personnel to check more components in the same period of time.

- **Full 2D profiling of components**

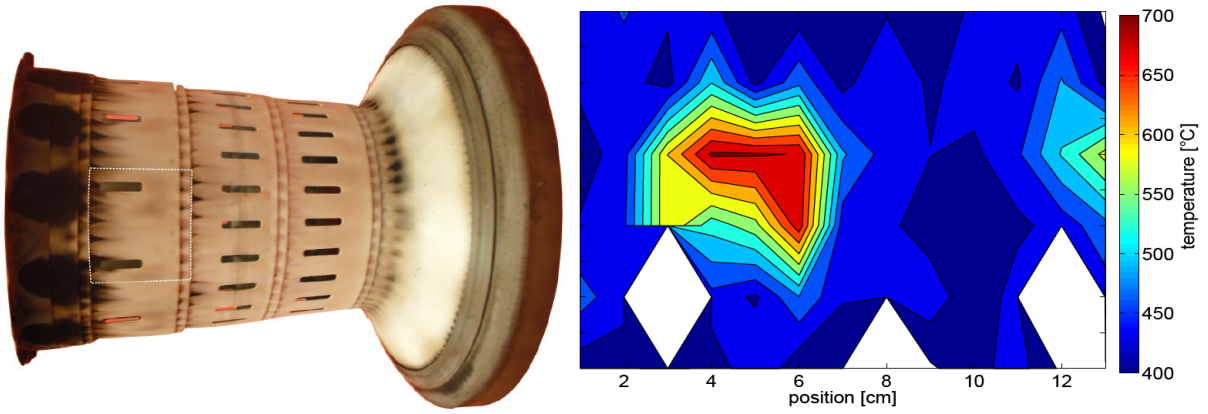
  Full 2D temperature profiling of complete, complex individual components or assemblies can be obtained as the probing light-source can move across the surface of a component and read the historic highest temperature experienced at any location on the component

- **In-situ measurements**

  The SCS Thermal History Coatings/Paints can be interrogated in-situ, without the need for dismantling of the components or assemblies. Furthermore, the interrogation does not require a controlled lighting environment, and could thus be performed as a borescope-type inspection.

The technology is based on thermal barrier coating systems as applied in the gas turbine industry and SCS's intense development work over the past six years. Today, SCS can advise on the production of highly durable sensor coatings by using industrial standard techniques (such as EBPVD[1] and APS[2]). SCS also has reliable suppliers providing the relevant powders and coatings. It is on the basis of these results that SCS bases its confidence that the ceramic powders can be mixed also into paints.

Combustion liner Thermal History Coating interrogated after operation



Beating REACH[3] - Registration, Evaluation, Authorisation & restriction of CHemicals

REACH is a European Union regulation concerning the **R**egistration, **E**valuation, **A**uthorisation & restriction of **CH**emicals. It came into force on the 1st of June 2007 and replaces a number of European Directives and Regulations with a single system. Under this EC regulation the use of hazardous materials for industrial purposes is restricted. The regulation requires industry to manage the risks from chemicals and to provide safety information on their substances for consumers/users. Manufacturers and importers are required to gather information on the properties of their chemical substances, which will ensure their safe handling, and to register this information in a central database run by the European Chemicals Agency (ECHA). The use of thermal paints falls under the restrictions of REACH namely under the risk label R50/R53[4] which indicates very toxic properties for the aquatic environment. Users of such paints must analyse if safer alternatives exist.

SCS's proposed technology is based on oxide ceramics and thermal barrier coating architecture hence this technology is non critical under REACH. The introduction of the thermal history coating technology will benefit the user as the requirements under REACH will be fully complied with.

SCS: Location, facilities & team

Southside Thermal Sciences (STS) was founded in 2002 to develop sensor coating technology primarily for online temperature measurements. **In 2012 Sensor Coating Systems (SCS) spun-out of STS** to focus on the development of luminescent sensor materials and associated instrumentation for alternative applications in harsh environments. SCS has established its own luminescence laboratory with highly skilled personnel (e.g. an optical engineer and an instrumentation specialist). The laboratories include a mobile high-power class-4 laser, a high temperature furnace (up to 1700°C) and a photo-multiplier-based measurement system. Further, SCS has a unique thermal

[1] Electron beam physical vapour deposition.
[2] Atmospheric plasma spraying.
[3] Regulation (EC) No 1907/2006; Journal ref: L396, 30 12.2006,pp.1-849.
[4] Nigel Marsh, RR, Company Head of Environmental Management. Nov/Dec 2007, www.hse.gov.uk/reach/events/nigelmarsh.pdf

gradient burner test rig for 24/7 testing of advanced coating designs under realistic conditions. Most importantly SCS owns two Rolls-Royce Viper 201 engines located in a dedicated testing facility at Cranfield University. One of these engines is operational and is equipped with six optical access ports while one engine acts as spare parts. These engines are employed to perform instrumentation testing and can be used as a test vehicle for the development of Thermal History Coatings and other test activities.

The SCS team has a proven track record of successfully managing multi-partner projects on national level but with international participation such as The Carbon Trust project *SATURN* and the TSB project *SeCSy* with a combined value of around £1.2m. Further, the SCS team has contributed successfully to European projects namely TOPPCOAT and ASTERIXE. In each project the necessary milestones were delivered on time and budget.

The highly committed international technical team consists of Messrs Sollazzo, Berthier, Pilgrim and Dr Feist. Together they combine the necessary skills in optics, electronics, software development and luminescence materials to advance the Thermal History Coating. Further the team is technically advised through its board of non-executive directors namely Professor John R. Nicholls, FREng. (Cranfield University) and Dr Andrew Heyes (Imperial College). Project progress is monitored at board level on a monthly basis.

The consortium approach

After approaching several OEMs in the field of gas turbines SCS formed the view and was encouraged to form a user group for the development of the Thermal History Coating technology as a generic tool for the industry. This approach would have a plurality of advantages for the consortium members:

- Limited financial exposure for each consortium partner during the development process.
- A broad generic specification accepted and endorsed by all end users (industrial standard).
- Limited technical risk as all end users will review technical progress and will provide feedback.
- '*First mover'* advantage for all participants.
- Data exchange between partners which will assist in building-up confidence levels.

Although primary applications are believed to be in the power generation and aerospace industry, through the consortium the membership is sought to include users from:

- the chemical and processing industry
- machinery suppliers
- automotive & Formula One
- marine and nuclear
- end users such as airlines and power generators
- rocket propulsion
- and the insurance industry

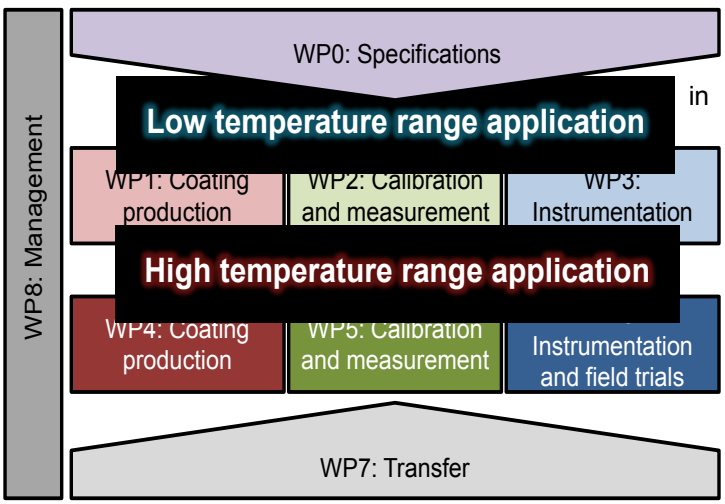
The consortium is intended to include several partners with an immediate interest in the technology.

Project status & outline

A consortium of OEMs and SCS has been established in August 2012 with several participating OEMs and has the ability quickly and independently to evaluate the technology and integrate it the R&D processes. Furthermore, the project is supported by both UK and US governmental funding bodies.

The programme is divided into six technical work packages and one management work package. Milestones are introduced after 12 months and after 30 months. This will assist in 'de-risking' the project. WP1 and WP2 will run in parallel to enable the simultaneous development of the instrumentation and coating application.

Development programme outline



First year

WP0 Specifications: In this initial work package pre-existing results will be reviewed by all members and specifications will be worked out for different application scenarios to bring the technology to TRL5. The end users will help determine the application needs.

WP1 Coating manufacturing for low temperature range: The objective of this work package is to produce a durable coating which can be used in conjunction with the calibrated instrumentation to make an accurate temperature measurement across the temperature range 300-900°C.

WP2 Calibration & measurement for low temperature range: This work package will cover the necessary measurement and calibration of the coatings using the instrumentation in order to provide information for the refinement of the complete system. The accurate working range of the system will be determined to ensure measurement reliability.

WP3 Instrumentation for low temperature range: The objective is to deliver a instrumentation prototype after 12 months which can be used to acquire a reliable signal and relate this to temperature information, between 300 and 900 °C, with an accuracy of ±10ºC.

MILESTONE 1 after 12 months: Low temperature coating applied and working on a complex shape. Delivery of a system for the temperature regime up to 900°C.

Second & third year (12 to 30 months)

WP4 Coating manufacturing for high temperature range: Similar to WP1, a coating will be developed for the high temperature range above 900°C

WP5 Calibration and measurement for high temperature range: The coatings developed in WP4 will be calibration using the instrumentation developed from the prototype delivered in Milestone 1.

WP6 Field trial and high temperature measurements: The instrumentation developed in the first 12 months will be used to conduct a field trial on example operational components in order to test the system in the low temperature application range. The field trial will be followed by further developments to the instrumentation for the high temperature range application. This will lead to the construction of the final instrumentation package for the detection of temperatures in both the low and high range to the specified accuracy, ±10ºC.

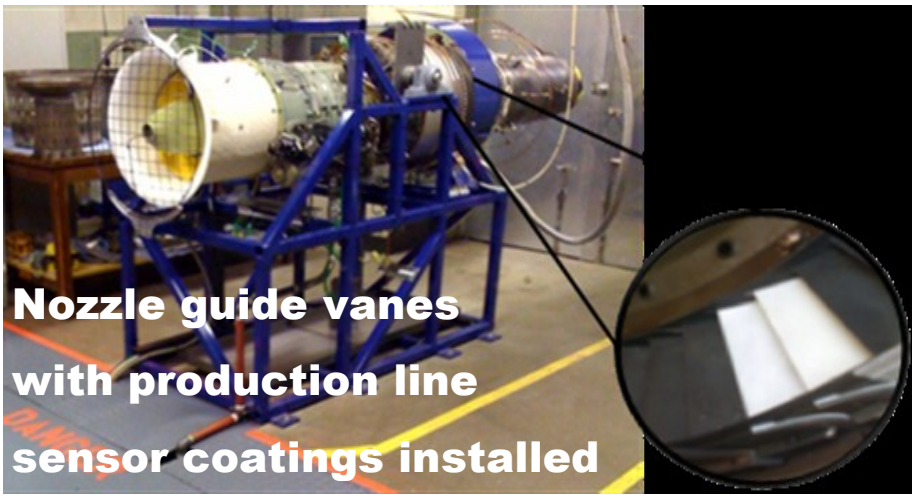
WP7 Transfer: The objective of this work package is to assist the transfer of the technology to industrial applications by directing the development towards the needs of the members.

MILESTONE 2 after 30 months: temperature profiling system will have been specified for complex components.

Commercial Policy & Funding

SCS regards funding from inside the consortium as the most efficient and fastest way to progress the technology to TRL 5. The total programme cost is estimated to be between £450K to £550K over 30 months in direct financial contributions. In-kind contributions, in the form of components, materials and testing time, will be considered by the Consortium members, to align the programme with customer requirements.

A direct financial contribution per annum is sought from each member over a period of 30 months. For further details please get in touch with SCS.



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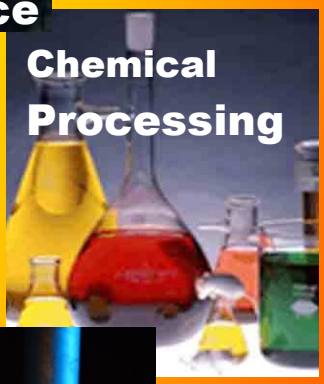

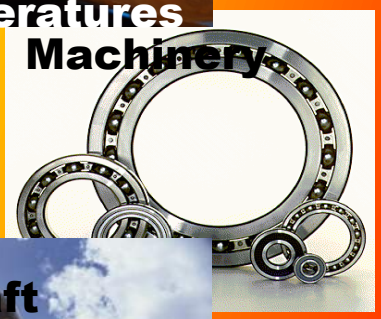

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