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SOLID STATE TRACK RECORDER APPLICATIONS IN  
UNITED STATES NUCLEAR REACTOR ENERGY PROGRAMS

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UNITED STATES NUCLEAR REACTOR ENERGY PROGRAMS<sup>†</sup>

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The domain of Solid State Track Recorder (SSTR) applications in United States nuclear reactor energy programs extends from the harsh high temperature environments found in high power reactor cores to very low flux environments arising in out-of-core locations, critical assemblies, or away from reactors (AFR) experiments. The neutron energy region arising in these applications is very broad, covering more than eight orders of magnitude from thermal up to fusion energies. The range of neutron flux/fluence intensity is even greater, extending over more than thirteen orders of magnitude. As a consequence, use of a variety of SSTR is entailed in U.S. nuclear reactor energy programs.

Applications of SSTR in reactors arise in three broad power ranges: (1) Very Low Power (VLP), which is typical of critical assembly work; (2) High Power (HP), which is representative of the in-core region of power reactors; (3) Low Power (LP), which is an intermediate power range between critical assembly and high power reactor environments. The HP needs of reactor energy programs are the most urgent. In HP environments, where high fluence (HF) irradiations arise, the limitations of SSTR must necessarily be defined. To this end, emphasis has been placed on mica and natural quartz crystals, which are outstanding SSTR candidates for accurate HF applications. Three major effects which can limit SSTR-HF applicability are: (1) thermal annealing, (2) radiation damage, and (3) background track production. Investigations<sup>1-3</sup> of these three major effects will be summarized with the goal of defining the domain of applicability of SSTR for

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HP reactor environments. It must also be noted that the existence of track pile-up produces accuracy limitations at higher track densities.

Each of these effects can play a significant role in defining the high fluence limit of applicability of a given SSTR. It must be stressed that these different effects act in consort rather than independently to produce a high fluence limit. For example, radiation damage of the crystal lattice produced by a high fluence of fast neutrons in a given SSTR can alter SSTR annealing characteristics dramatically. Hence, track fading due to annealing can be considerably enhanced due to the damage of the SSTR crystal lattice that is produced at high fluence.

Although these HF effects are not actually separable, our work to date suggests that radiation damage of the crystal lattice is the most serious HP limitation of SSTR. However, the existence of this specific limitation for HF-SSTR fission rate observations is not a complete deficit. Indeed, it is on this very basis that the concept of the SSTR radiation damage monitor has been advanced.<sup>4</sup> In HF applications, a number of SSTR attributes have exhibited significant fluence dependence. For minerals, SSTR characteristics depend intimately upon crystal lattice structure. Hence, for sufficiently high neutron fluence, radiation damage of the lattice alters SSTR properties. In particular, track registration as well as bulk and track etch rates undergo substantial change. Consequently, for HF irradiations, any of these SSTR observables afford a unique measure of radiation damage.

Beyond these three major effects, track pile-up represents an intrinsic limitation for HF reactor applications. To this end, the status of recent work to extend quantitative track scanning into the high track density pile-up regime will be outlined.<sup>5</sup>

A summary status of SSTR experiments undertaken in U.S. nuclear reactor energy programs will be presented. The diversity of these SSTR nuclear reactor applications can be surmised by consulting Tables I-III, which outline efforts in the Fast Breeder Reactor (FBR), Light Water Reactor (LWR), and Magnetic Fusion Energy Reactor (MFER) programs, respectively. Recent experimental results from these efforts will be highlighted.

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Table I

SSTR Experiments in the U. S. Fast Breeder Reactor (FBR) Program

<u>Application</u>	<u>Status</u>	<u>Power Range</u>	<u>SSTR<sup>a</sup></u>	<u>Reference</u>
1. Fast Test Reactor (FTR) Characterization				6
• Neutron Dosimetry	In Progress	VLP,LP,HP	E,M,Q	
• Absolute Fission Rates	In Progress	VLP,LP,HP	M,Q	
• Fission Product Yields	In Progress	VLP,LP,HP	M	7
• Out-of-Core Measurements	In Progress	LP,HP	M,Q,CR-39	
2. Criticality Safety Studies	Complete	VLP	M	8
3. Fuel Storage Safety Measurements	Complete	AFR	M	9

<sup>a</sup>E=Emulsions, M=Mica, Q=Quartz Crystal

Table II

SSTR Experiments in the U. S. Light Water Reactor (LWR) Program

<u>Application</u>	<u>Status</u>	<u>Power Range</u>	<u>SSTR<sup>a</sup></u>	<u>Reference</u>
1. Pressure Vessel Surveillance				
• Critical Assembly Irradiations	In Progress	VLP	E,M	10
• Accelerated Metallurgical Tests	In Progress	HP	M,Q	
• Operating LWR	In Progress	HP	M	
2. Non-Destructive Spent Fuel Assay	Complete	AFR	M,CR-39	11,12
3. Spent Fuel Repository Measurements	In Progress	AFR	M	13
4. Photo-Fission Studies	Planned	VLP,LP,HP	M,Q	1

<sup>a</sup>E=Emulsions, M=Mica, Q=Quartz Crystal

Table III

SSTR Experiments in the U. S. Magnetic Fusion Energy Reactor (MFER) Program

<u>Application</u>	<u>Status</u>	<u>Power Range</u>	<u>SSTR<sup>b</sup></u>	<u>Reference</u>
1. Neutron Dosimetry for FMIT <sup>a</sup>	In Progress	VLP,LP,HP	E,M,Q,CR-39	14,15
2. Neutron Radiography for FMIT <sup>a</sup>	In Progress	LP,HP	M,CR-39	14,15,16
3. Deuteron Straggling in Lithium (for FMIT <sup>a</sup> )	In Progress	VLP	CR-39	15
4. Damage Monitors at High Neutron Energy	Planned	HP	M,Q	4
5. Primary Knock-on Atom (PKA) Spectral Measurements at High Neutron Energy	Planned	VLP,LP,HP	CR-39,CN,Glass	1,17

<sup>a</sup>Fusion Materials Irradiation Test Facility

<sup>b</sup>E=Emulsions, M=Mica, Q=Quartz Crystal, CN=Cellulose Nitrate