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Advances in the Development and Testing of Micro-Pocket Fission Detectors

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Miniaturized sensors capable of real-time neutron flux measurements are needed for in-core deployment in research nuclear reactors. Prototype Micro-Pocket Fission Detectors (MPFDs) have previously been tested in neutron beams up to 10ˆ8 n cmˆ-2 sˆ-1 [1] and in-core up to an estimated neutron flux of 8×10ˆ12 n cmˆ-2 sˆ-1 [2]. Although previous studies confirmed MPFDs can be used to track reactor power, improvements were needed regarding detector dead-time and neutron-reactive material deposition methods.

MPFDs hold several advantages over conventional neutron flux measurement techniques. Typical ionization and fission chambers are large and are often used externally to monitor neutrons which have escaped the reactor core [3]. Many fission chambers are composed of highly-enriched U-235 [4], and those designed for high-flux applications are typically operated in current-mode due to the high interaction rate [5]. Such devices are impractical for use in critical mock-ups, high performance material test reactors (MTRs), and transient test reactors because of their fragile construction and large flux perturbation when installed in-core or near-core. MPFDs, however, are constructed of radiation-resistant materials and do not significantly perturb the local neutron flux. MPFDs also provide continuous, real-time pulse-mode measurement capability for extended in-core operation.

Significant progress has been made to advance the development of MPFDs. A controlled electro-deposition process for neutron-conversion materials has been developed. Non-destructive measurement techniques have been utilized to measure the mass of neutron-conversion material deposited onto electrodes much smaller than 1.0 mmˆ2. Finally, optimization of neutron-conversion material compositions extends stable device operation for high-fluence applications [6]. MPFDs presently utilize small depositions (< 1 μg) of natural uranium yielding a very low interaction rates (˜10ˆ-8 fissions per neutron), enhancing operation in high-neutron-flux environments.
Advanced MPFDs have been built and deployed in the Kansas State University TRIGA Mk II research reactor (neutron flux up to 10ˆ12 n cmˆ-2 sˆ-1). Detector parameters such as ionization chamber volume, neutron-reactive material mass, and electrode size can be varied based on application. The most recent development in MPFD research has produced small neutron detectors capable of pulse-mode operation in the high-neutron and high-gamma-ray flux of the reactor core [7]. These advanced MPFDs are inherently gamma-ray insensitive due to their small size and have operated in pulse-mode up to a reactor power of 200kW (˜10ˆ12 n cmˆ-2 sˆ-1).
Research is ongoing to develop MPFD arrays capable of simultaneous, real-time measurement of the neutron flux in multiple locations throughout a reactor core. Detector chambers which are sensitive only to fast neutrons are also being developed. Electronics packages are also in development which will standardize device readout and eliminate the need for numerous NIM components. Ultimately, the compact, accurate, high-fluence neutron detectors will be deployable for critical mock-ups of existing and advanced nuclear reactors designs, high-performance materials test reactors, and transient test reactors.

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